Clothed wax effigies: construction materials, challenges and suggestions for preventive conservation

Efígies de cera vestidas: materiais de produção, desafios e sugestões para a conservação preventiva

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Abstract

Wax effigies, fully dressed life-size models of human figures, have been constructed since the medieval times. The construction materials of historical effigies differ to the contemporary ones, yet the construction process of the wax parts has more or less remained unchanged over the centuries. This paper starts with the history, construction materials and manufacture techniques of wax effigies. The inseparable relation of the wax effigies and their costumes is explained, and the characteristics and deterioration agents of their most important construction materials are presented in order to understand their needs for preservation, with emphasis on wax and fabrics. The aim of this paper is to suggest preventive conservation guidelines for wax effigies, with proposals for appropriate environmental conditions during display and storage, and suggestions for proper handling, storage and transportation. Advice for disaster preparedness and actions in cases of emergency situations is also provided.

KEYWORDS
Wax
Wax deterioration
Textile
Garments
Wax museums
Conservation

Resumo

As efígies de cera, modelos de figuras humanas completamente vestidas em tamanho real, foram criadas desde os tempos medievais. Os materiais de produção de efígies históricas diferem dos contemporâneos, mas o processo de produção dos componentes de cera manteve-se mais ou menos inalterado ao longo dos séculos. Este artigo começa com a história, materiais e técnicas de produção de efígies de cera. Explica-se a relação inseparável das efígies de cera e os seus trajes, apresentam-se as características e os agentes de deterioração de seus materiais de produção mais importantes, de modo a compreender as suas necessidades de preservação, com ênfase na cera e nos tecidos. O objetivo deste artigo é sugerir procedimentos de conservação preventiva para efígies de cera, com propostas de condições ambientais adequadas durante a exposição e armazenamento, e sugestões para manuseamento, armazenamento e transporte adequados. São também fornecidos conselhos para a preparação para desastres e ações em casos de situações de emergência.

PALAVRAS-CHAVE
Cera
Deterioração da cera
Têxtil
Vestuário
Museus de cera
Conservação

Introduction

The use of wax dates back to ancient Egypt, Greece, Rome [1-4] and possibly in prehistoric times [5]. Children in ancient Greece and Rome played with wax dolls, and knowing the model casting skills of ancient Greeks who employed the lost-wax technique [6], and after noting findings of small moulds exhibited in several museums, it could be assumed that a great deal of ancient Greek votive offerings were made of wax. During the medieval times, statues of saints, miniature portraits, dolls, and other items were made of wax [7]. From the sixteenth century onwards, framed relief wax portraits, busts, life sized effigies, and smaller artefacts such as statuettes were made. Eighteenth century Italian wax portraiture heads and busts of capuchin monks are dressed in Franciscan cowls and bear coloured glass eyes and real beards and hair [1]. Waxen botanical models appeared in the sixteenth century and became widespread as a hobby in the eighteenth-nineteenth centuries [8]. In the end of the seventeenth century, Italian abbot Gaetano Giulio Zummo or Zumbo (1656-1701) collaborated with surgeon and anatomy professor Guillaume Desnoues (1650-1735) to create anatomical wax models [9]. By the eighteenth century, scientific and medical modelling had become popular [4], and in the nineteenth and twentieth centuries, thousands of wax moulages -three-dimensional wax models of pathological conditions- were made for educational purposes [10-11]. Natural history museums soon became interested in wax. The Natural History Museum in Florence hosts over 2000 models of anatomy, zoology and botany made of wax mixed with resins and colourants, created by Gaetano Zumbo, Clemente Susini (1754-1814), Francesco Calenzuoli (1796-1829), Luigi Calamai (1800-1851) and Egisto Tortori (1829-1893), who worked under supervision of anatomists [12-14]. In Paris and Turin, wax display stands were used to display clothes at international exhibitions in 1900 and 1911 respectively [15]. Biographies of renowned wax modellers were published by Pyke in 1973 [16].

This paper focuses on a more complex category of wax objects, namely clothed wax effigies, historical and contemporary ones. In the field of invasive or preventive conservation, the knowledge and information on the suitable preservation of effigies is limited. The combination of their construction materials, including wax, textiles, metal, wood, glass, real human hair, plastic, paints, etc. is challenging for conservators and curators wishing to establish good preventive conservation practices for such collections on display, in storage, and during transportation.

History and construction technology of wax effigies: from ancient Greece to the twenty first century

The use of wax for human effigies is attributed to many reasons: wax is easy to find; it has a reasonable price; it has good workability; it can be modelled, cast, carved and sculpted; it permits corrections, changes and additions at any stage; it has a naturally convincing colour; it can be mixed with hardeners, plasticisers, solvents and pigments; it takes paint very well, can depict the human skin better than most materials that have been tested and used, and can be adorned with real hair and other organic materials to produce a realistic representation of the human body [1, 4, 17].

The technique of wax-casting a person's face has remained more or less the same since the antiquity. Our knowledge on the construction of historical effigies is mainly restricted to the observations of conservators who undressed historical effigies in order to restore them, and on historical sources. Direct modelling of soft wax, heating and fusing of separate wax parts, moulding and casting, and finishing by carving and scraping with ivory and heated metal tools have been reported [4].

Waxen face and head casts in ancient Greece and Rome

Pliny (23-79 CE), in his Natural History book XXXV, LXIV [18] attributes the method of the making of wax casts of people's faces to Greek sculptor Lysistratus of Sicyon (fourth century BCE), who created plaster moulds of a living person's face, poured wax into them and made final corrections to the wax cast.

In the end of the third century BCE, and until close to the time of Pliny [19], wax effigies of faces attached on boards were carried in funerals and exhibited in the halls of ancestors, as Pliny states in his book XXXV, II [18]. Mazzeri [19] claimed that these were rather three-dimensional wax heads, and presented the outcomes of her research through the study of Latin literature, publishing images of sculptures depicting such objects, the casts of ancestors' imagines, and the photograph of a second century CE wax head of a man, discovered in Cuma, Italy. This is the oldest known life-size wax head, hollow, impressively realistic, with open glass-paste eyes and traces of colours on its surface [19].

Votive wax effigies in the Renaissance

Models of parts of bodies were and are still offered in churches as ex-votos: gifts to a saint asking or thanking for a miracle. In Italy, the custom of making votives of parts of bodies out of wax led to the creation of full body wax votives [20]. From the thirteenth century and through the Renaissance, life-sized clothed wax mannequins were dedicated, with Cennino Cennini (1360-1472) detailing the stages of the cast production [21]. In the fifteenth century, life-size votive effigies were very popular at the church of Santissima Annunziata in Florence [20]. After a murder attempt against him in 1478, Lorenzo de Medici (1449-1492) ordered Orsino Benintendi (1440-1498) who was guided by Andrea del Verrocchio (1435-1488) to create three life sized wax votive effigies, with hollow wax heads, hands and feet, portrayed from life and painted with oil colours, attached on wooden skeletons interwoven with splint reeds covered with waxed cloths, and dressed with his own garments [21]. Over the following centuries, churches became packed with waxen votive effigies, cast in life or death, fully dressed in clothes or armour, and positioned closer or farther from the altar, depending on the status of the portrayed personality [21].

Seventeenth-eighteenth-centuries funerary wax effigies

In the seventeenth century, a new wax item category appears: wax funeral effigies. Funeral effigies had been constructed since the fourteenth century [22-23] to be displayed in funeral convoys, palatial or church settings in England, France, Italy and Prussia until the eighteenth century [24]. This follows the ancient – and still surviving – funeral practice of placing the deceased in common view for the last farewell; yet, when royal funeral ceremonies lasted for weeks, the disintegration of the body did not allow for its long-term public exhibition [25], resulting in the construction of mannequins to be used instead. The first reported use of a waxen effigy dates in 1612: Italian doge Leonardo Donà was buried privately the night of his death and a wax effigy was employed for the funeral rituals [1]. Although complete Italian funeral effigies have not survived to this date, funeral heads or wax death masks have survived. Such items, kept in gilt wooden cases or standing on bases, are modelled with cloth soaked in wax according to the Venetian carnival mask-making technique, and bear human hairs or present several small holes on the eyebrows, indicating the use of real hairs to enhance resemblance to the deceased [1].

Westminster abbey has a respected collection of wax funeral effigies. The oldest ones were made of wood or plaster, but after 1660 effigies with waxen heads and hands – and occasionally waxen legs – were made [26]. Most effigies were particularly constructed for the portrayed person, yet in some cases older figures were reused with additions and extensions to fit the new role and new head and hands were added [27]. The fully dressed effigies, with their multiple layers of clothing, accessories, jewellery, weapons, wigs, colouration of the face so that they consisted of vivid representations of the deceased once they were alive, render them unique artefacts that portray not only the person, but also their social status and personality. The clothes on the effigies are in most cases the ones that the portrayed person wore on a special occasion, such as their coronation day, providing further information of a historical value. In some cases, parts of clothing or accessories were particularly made just to be used on the effigy. Regarding jewellery, fake stones were used instead of the original jewels. The construction of the figure varies from one wax modeller to another. The effigies are therefore not just mannequins for the display of flamboyant costumes, neither just artworks of wax sculpture vividly representing known historical personalities. All of the features of these complex objects comprise an inseparable entity providing valuable information on the depicted person, their costume, status, but also information of the development of the effigy manufacture techniques. The habits of the deceased are also represented, as effigies often bear favourite items, or they are presented in the wax cast figures. One example is the bitten nails of the 1735 effigy Prince Edmund Duke of Buckingham, which also presents sunken cheeks, indicative of his health condition before his death [1, 27].

The waxen parts were based on death masks, cast from the corpse, or modelled from the corpse or the living person, and overpainted to imitate human skin [27]. Often the effigies were constructed while the portrayed people were alive, enabling them to oversee the procedure and approve the final outcome. For example, the 1775 effigy of William Pitt, Earl of Chatham was publicly presented as soon as it was finished, three years before the Earl's death [27].

The heads, fixed on wooden posts or cardboard strips, bore glass eyes and painted or real eye-lashes and eyebrows [27]. An interesting case is the wax effigy of Queen Elisabeth I: the original 1603 effigy was wooden, yet in 1760 the head and hands were replaced by thin wax casts set on plaster bases [27]. Wax was also used on features requiring more detailed work, such as ankles and calves of otherwise wooden limbs [25]. The torsos were made of wood or canvas or other cloths stuffed with straw, hey, tow and sacking, and stiffened with wooden posts or/and wire; or built up by card and nailed on the effigy [25, 27-28]. The limbs were wooden and attached to the wooden base with wires, string, or handmade screws; or padded about iron wires and glued on the central skeleton; or made of canvas, plaster and glue and bound with woollen cloth; or made of wax resin reinforced with cloth and covered with silk [27]. When legs or feet were not meant to be viewed, they were simply not constructed, such as in the case of the 1740 seated Queen Anne effigy [27].

Several layers of original clothing dressed the figures, including armour, human hair wigs, leather shoes, jewellery, weapons, undergarments and accessories [27-29] made of various materials such as silk, velvet, wool, cotton, linen, canvas, lace, kid, goatskin, fur, ostrich feathers, glass, silver, iron, gilt copper, pastes, artificial pearls and gems, and even the oldest known stuffed bird surviving today [27]. Interestingly, the 1702 effigy of Duchess Frances of Richmond wears woollen inner stockings, claimed to have been put to prevent the wax of the legs from staining the silk stockings [27], rendering it an interesting example of early preventive conservation attempts.

Wax modellers known to have created funeral effigies are Mrs. Goldsmith (active 1695-1703), American Patience Lovell Wright (1725-1786), Catherine Andras (1775-1860), and possibly Mrs Salmon (1650-1740) and her employee Thomas Bennier [27].

In the end of the eighteenth century, the Westminster Abbey funerary effigies were used as attractions [22]. In the early nineteenth century visitors paid to see them [22, 28], and collection keepers started paying for their conservation [29-30].

It is worth mentioning that one more funeral effigy, belongs to non-royalty Sarah Hare (1689-1744), permanently exhibited in Stow Bardolph church, Norfolk, UK [27, 31], as the sole testimonial of "the spread of the tradition for effigial representation" [27].

Wax effigies as portraits: sixteenth-nineteenth centuries

French aristocracy commissioned the creation of wax portraits and busts in the sixteenth century [15]. French court artist Antoine Benoist (1632–1717), commissioned by King Louis XIV (1638-1715), produced forty three wax effigies, known as *Le Cercle Royal*, exhibited for a fee throughout France since 1668 [32-33]. King James II (1633-1791), triggered by his work, invited him to England in 1684, to create effigies of the British aristocracy [33]. In London, Mary Salmon (1650-1740) created at least 140 wax figures, exhibited for a fee in fairs and in her *Mrs. Salmon's Waxworks*, from 1710 up until her death [34]. Some were able of moving, thanks to inbuilt clockwork mechanisms [15, 34]. In 1721, Italian sculptor Bartolomeo Carlo Rastrelli (1675-1744) created the wax effigy of Russian Tsar Peter the Great (1672-1725), using wood, wax, metal and enamel [35], and 19 years later, Danish court painter Johann Salomon Wahl (1689-1765) created wax figures of the Danish Royal couple [15]. Wax modelling was not restricted in the European continent. In 1771 Patience Wright and her sister Rachel Wells held a successful life-sized wax figures exhibition in New York [27].

Curtius, the French Revolution and Madame Tussaud

Swiss physician Philippe Mathé Curtius (1737-1794) initially created anatomical wax models, yet in 1765 abandoned medicine to practice wax modelling as an artist, establishing his *Cabinet de Cire* in 1776, soon flooded with visitors [36]. Curtius taught Madame Tussaud (1761-1850) who in 1793 was forced to create wax death masks of the nobles executed during the French Revolution [37]. In 1794 she inherited Curtius's wax exhibition, moved the best exhibits to Britain in 1802 [7] and established her own exhibition in London in 1835.

The procedures followed by Curtius and Madame Tussaud started by applying oils and ointments on the face of the subject, and straws in the nostrils of living individuals for breathing purposes. A mask was then created by applying fine plaster of Paris. Clay was squeezed in it to produce a model, and a clay mould in two pieces was made out of it. Hot wax was poured into the mould, creating the final hollow product which was coloured and finished with human hair, human teeth and glass eyes [7].

Modern wax effigies

In the nineteenth century the popularity of wax effigies was such that an exhibition was on permanent display in nearly every major European city [15].

Mid-twentieth century recipes known for casting from the skin include paraffin, bayberry wax, carnauba and stearic acid. For the separation of the plaster negative, yellow beeswax and carbon tetrachloride, or paraffin in benzene were used. Known recipes for the waxen parts are the Douglas formula (white wax, paraffin, talcum, cornstarch and yellow beeswax); the Ziskin formula (refined paraffin, pale and dark carnauba wax, and beeswax); and resin-wax formulas. To strengthen the casts, cotton, wood, jute, hemp, cheesecloth and burlap were used [38].

Today, the use of wax continues for hyper-realistic human sculptures exhibited in modern museums worldwide. Wax effigies represent important historical, political or artistic personalities and replicate activities and historical moments for educational or commercial reasons. Historical, Natural History and other types of museums use wax mannequins in dioramas as exhibition tools to spur the feelings of the museum visitors and enhance the museum experience, motivating them to become part of the depicted scene and take pictures among the free standing wax models [39]. At the Melody World Wax Museum in Mysuru, India, wax figures are used to display musical instruments, rather than the instruments being displayed in showcases, enabling visitors to see the cultural context within which the instruments were played. As it has been beautifully expressed by Varutti [39], body reproductions "facilitate the connection between the present and the past by endowing the past with physical features and by enabling the establishment of new, personal, and emotional relationships with a past no longer distant and authoritative, but approachable". Well-known wax museums operating today include Madame Tussaud in 23 cities; the Hollywood Wax Museum in 4 cities; the National Presidential Wax Museum in Keystone, South Sakota, USA; Dublin's National Wax Museum; the Pavlos Vrellis Wax Models Museum of Greek History, Ioannina, Greece; the Siddhagiri Gramjivan Museum, Kaneri, Kolhapur, India; and many more.

Creating an effigy does not always require a large amount of wax, since only the body parts visible to the audience are made of this material. The materials of the non-wax parts of the effigies vary. Wax artist Pavlos Vrellis for example, made skeletons of fine iron rods, and built up with "plaster and sackcloth, or matting, or flax, or wood shavings" [40].

Some wax artists work solely based on photographs or paintings depicting their subject, and on their sculpting skills and their osteology, myology and physiology knowledge [40]. For more lifelike effigies of living people, the wax artist meets with them to take numerous measurements. Over 200 face measurements have been reported, non-including those required for other body parts [41]. Along with drawings, photographs and additional research, the measurements are used to sculpt a clay body on a metal skeleton, to create a mould later [41].

The sculpting of the head, performed in several stages, requires about six weeks and employs careful comparison of the sculpture to the measurements taken during the previous stage. The plaster mould of the head is prepared

Figure 1. Contemporary hyper-realistic wax effigy by Madame Tussauds during painting of the skin. Note the custom-made glass eyes and the hair on the eyebrows. Source: Insider, 'How Madame Tussauds Creates its Realistic Wax Figures' (2018-08-03), video uploaded at https://www.youtube.com/watch?v=CQ9knHW6LIY (accessed 2019-11-25).

in sections – fourteen different sections have been reported – which are then assembled together. The mould is rinsed clean, and placed into a *wax bench*, a specially prepared table that keeps it stable while melted wax is poured into it. Beeswax is still used for the creation of wax effigies, following the tradition of centuries. Japanese beeswax has been reported as a material. The wax solidifies within an hour, forming a thick crust in the interior of the cast, the thickness of which measures only a few centimetres. The crust at the area of the neck is cut away, and the remaining liquid wax is poured out, leaving a hollow wax head, which is allowed to solidify for a further hour, after which the plaster mould is removed piece by piece. The production of hands and other wax parts follows different procedures, with hands often cast from the subject [41].

While creating wax figures, deformations may occur, that can be retouched by artists later. Molten wax flows in small niches of the mould and after its removal, distinguishing lines from the mould connections appear all over the figure. The sensitivity and brittleness of the wax can easily result to more deformations. Finally, the addition of powder pigments in the wax creates different colour and texture variations [42].

The skin tone of the casts is matched according to charts [41]. Oil colours are most often used due to their compatibility to the wax. The paint is not brushed straight onto the wax surface, but splattered against it, then blotted to blend in, creating a speckled look to imitate skin texture and pores [41] Figure 1. Knuckles, veins and other features are painted, nails are manicured, and after the insertion of eyes and hairs, extra paint is added on the face like makeup [41]. In total, over thirty five layers of colour are applied to achieve a vivid effect [7].

Ready to use glass eyes [40], acrylic [7] and custom-made eyes that imitate the uniqueness of the person's iris [41] are used. As a medical glass eye spins on a wheel, the artist blots on a white pupil. The surface is over-painted while the eye stays still, with colours of the portrayed person's iris. The eye is then placed back on the wheel, the black pupil is added, and the spinning of the wheel blends the liquid together. Red silk threads are adhered on the sclera to imitate blood vessels [41].

The eyes are placed on the head, and synthetic or actual human hair are added [40-41]. Hairs, eyebrows and eyelashes are inserted individually by piercing the wax with a hot needle, melting the wax, and enclosing the hairs, in a lengthy process that can last for four weeks [41].

Apart from sculpting and colouring, realistic quality is also achieved through the dressing with appropriate costumes. Clothing is a basic element of an individual's identity and an important feature of wax effigies. The garments are in many cases authentic clothes donated by the depicted person, replications of the originals, contemporary custom made, or modified old pieces [40].

The recipes of contemporary wax effigies and the rest of the materials are not widely available, apart perhaps in exhibition catalogues where the materials of the artworks are written down. For example the materials listed for Maurizio Cattelan's 2001 effigy of Hitler entitled *Him*, are wax, human hair, suit and polyester resin [43].

A whole setting may be created around the effigies, using various materials Figure 2. Vrellis lists real and artificial rocks "made of sackcloth, glues, colors and plaster", cement, wood, leaves, grass, canes, branches, original historic artefacts, and props made of plaster, fibres, flax, cloth, clay, tempera colours etc. [40].

The composition and nature of wax used for effigies

The wax employed in the making of wax effigies from ancient times until present is mainly European and Asian

Figure 2. *The slaughter of Ali Pasha* at Pavlos Vrellis Museum of Greek History. The building façade and props are not just a setting to highlight the wax effigies, but part of the wider personal artwork by artist Pavlos Vrellis, who wished to transform the museum interior so that the visitors themselves can immerse into it and live a unique experience by becoming part of the represented scene. Image courtesy Pavlos Vrellis Museum of Greek History.

beeswax. European wax producing bee species are *Apis mellifera*, and Asian ones are *Apis florae*, *Apis dorsata* and *Apis cerana* [44]. Different bee species produce wax with different compositions and melting points [44-45]. Asian beeswaxes have a shorter carbon chain length, lower melting point, higher ester/acid ratio, reduced free fatty acids, increased hydrocarbons, and are softer and more plastic than European waxes [44-45]. The colour of honeycomb beeswax varies from white when first produced, to yellow, brown and black, as the wax ages, due to the relative amounts of propolis and pollen colorants [44]. Different beeswax subtypes in the beehive serve as cues for bees to recognise bases, sexes and comb age [44]. The more larvae excrements, pupae skins and propolis rests accumulate over the years, the darker the wax [44, 46] and the higher the protein content [44].

Worker bees secrete wax from the abdominal wax glands, plasticize it by chewing, and then use it as a building material for combs and honeycombs [5]. Wax is traditionally extracted from the honeycombs through heat direct from the sun or from boiling [5, 44]. Heating in iron, zinc brass or copper containers results in the production of dark wax, therefore stainless steel and aluminium containers are contemporarily used [44, 46]. Traditionally wax is bleached by exposure to the sun [44]. Modern bleaching methods include the use of citric acid, oxalic acid, hydrogen peroxide and potassium permanganate [5, 44, 46].

Chemically, beeswax is an inert complex material of a crystalline structure, comprising of over 300 different substances: saturated and unsaturated hydrocarbons, saturated and unsaturated monoesters, diesters, triesters, hydroxyl monoesters, hydroxypolyesters, acid esters, acid polyesters, free fatty acids, free fatty alcohols, glycerols, palmitates, oleates, paraffins, alkanes, iso-paraffins and various other substances and volatile aroma components [5, 42, 44-45]. Beeswax becomes plastic at 30-35 °C, and begins to melt at 60-70 °C [44]. Heating at 120 °C for over 30 minutes removes water content and increases the wax hardness [44]. Long heating or higher temperatures lead to degradation and loss of esters influencing the physical characteristics of the wax, changing the wax structurally and altering the characteristics of many of its minor compounds [44]. After cooling down beeswax shrinks by about 10 % [44].

Chinese insect wax from *Ericerus pela*, and vegetable waxes carnauba from the Brazilian *Copernicia cerifera* palm and candelilla from American plants *Euphorbia* and *Pedilanthus*, were introduced in Europe in colonial times [5]. Vegetable waxes form as a layer on the leaves, limiting the diffusion of water and solutes, while controlling the release of volatile substances [47]. From the nineteenth century onwards, beeswax was often mixed with other waxes including candelilla, carnauba, ceresin produced since 1875 by refining fossil wax ozocerite [5], Japan wax, paraffin, spermaceti and stearin [48] to alter the wax properties or reduce the cost. In example, carnauba, one of the hardest and highest-melting natural waxes [5] increases the hardness and raises the melting point [42]. Paraffin, a mixture of alkanes obtained from crude petroleum distillation, and stearin, synthesized from animal fats saponification, were introduced in the mid nineteenth century as beeswax substitutes [17, 42, 49]. Fully synthetic waxes have been produced since 1935 [5].

The beeswax employed for historical wax effigies was probably bleached, with additions of pigments and inerts [4]. Various wax modellers used different recipes [8, 49]; in example, Anne Marie Carl-Nielsen (1863–1945) mixed potato flour, olive oil, Venetian turpentine, Burgundy pitch, butter and colour in her wax pastes [48]. Starch has been reported to assist removal from the mould [38]. Lead was added to colour the wax, and reduce its shrinkage and hardening to ease carving [4]. Lead white, zinc oxide and Spanish white were added to decrease transparency [48]. It should be noted that heavy pigments gravitate during the cooling of the wax, and thus the colour gradually darkens towards the higher parts of the relief, also creating textural variations [4, 42]. The addition of animal fat, castor oil, pitch, tallow, lard, Canadian balsam, linseed oil and olive oil, composed of triglycerides, esters of glycerol, saturated and unsaturated fatty acids, increased malleability at room temperature [4, 42, 48]. Natural resins such as Venice turpentine and rosin (composed of abietanes, pyrans and labdanes) were added to increase the hardness of wax and add colour [42, 49]. Starch (composed of amylose and amylopectin) and flour, were also added in the nineteenth century wax mixtures as fillers to reduce the cost of the model since beeswax was expensive [4, 42, 48-49]. Glycerol and talcum powder have also been reported [48].

Deterioration agents of clothed wax used for effigies

Wax effigies are constructed by a variety of organic and inorganic materials, in contact to one another: the wooden parts to the filling material, the metal skeleton and the wax; the wax to the fabrics, glass eyes, hair etc. In most cases, the construction details only become known during conservation treatments, during which the effigies are undressed and disassembled [25, 27, 50].

In general, damage to effigies may take many forms, as a result of poorly controlled ambient environment, inadequate maintenance, improper handling during exhibition, storage and transportation, inadequate packing for transportation or shipping; and insufficient measures for disaster preparedness. The agents that affect wax effigies the most are light, temperature (T), humidity, pollution and pests. Due to the mixed materials used in their making, and due to the factors listed above, effigies can present physical damage, chemical deterioration, weathering, mechanical and biological damage.

Wax effigies, their deterioration factors and conservation-related issues have not received adequate scientific attention, resulting in a lack of relevant publications. Reported damage on the wax components of effigies includes cracks, breakages and losses; white bloom due to the drying out of the wax; surface dirt; surface cracking and penetration of dirt in the wax; and loss of the colour that was originally applied on the wax [27, 51] Figure 3. Reported damage of other materials includes instability of effigies due to loosening of the joints of the torso and limbs; rotting and weakening of the armature and binding holding the arms in position; insect damage on hair, textiles and whalebone; hair losses including eye-lashes and moustache; oxidation and losses of metal parts; loss of gilding; holes and losses of fabric including loss of clothing elements such as tassels; fading of silk- in some cases due to washing; discolouration of threads of embroidery; weakening of threads resulting to loose pearls and stones; losses of smaller elements such as buttons; dirt on fabrics, fur, hairs and leather; rodent attack on the clothes and storage cabinet; rotting of fabrics due to moisture; and insect remains on clothing [27, 31, 51-52].

Wax ageing and wax bloom

Information on the deterioration of wax can be retrieved from papers on wax objects other than effigies, yet it should be stressed that different types of objects present different degradation problems [53]. Non-pigmented wax objects have been reported to exhibit flaking and delamination due to the impression and kneading methods involved in their making which led to the creation of a fine, layered microstructure [53]. Known problems with wax are its sensitivity to many solvents; susceptibility to damage by heat and pressure; shrinkage, hardness, brittleness and susceptibility to breakage due to ageing; and white surface bloom [4, 53]. Wax discolouration may occur in cases of waxes mixed with pigments, plasticisers or hardeners [4].

Wax bloom does not seem to affect beeswax mixed with inorganic pigments [54]. It is a layer or crystal aggregations that develops over weeks or months on newly created beeswax surfaces, considered as aesthetically unacceptable, and the compounds forming the efflorescence are sometimes regarded as beeswax plastifiers, and their depletion as an embrittlement cause [55]. Wax efflorescence is composed of aliphatic hydrocarbons and alkenes [54, 56] or palmitic, stearic and other fatty acids naturally occurring in beeswax [57-58], or beeswax sometimes combined with a small amount of water [59-60]. A study on beeswax seals [55] revealed that wax bloom composition was similar, regardless of origin, age and storage history and comprised of linear alkenes naturally occurring in recent Mid-European beeswax, while historical beeswaxes contained only traces of unsaturated hydrocarbons. Wax bloom is caused by a variety of factors, including the wax composition and manufacture procedure, and external environmental parameters. The first group of factors includes higher cooling rates during solidification [61], the presence of impurities in the

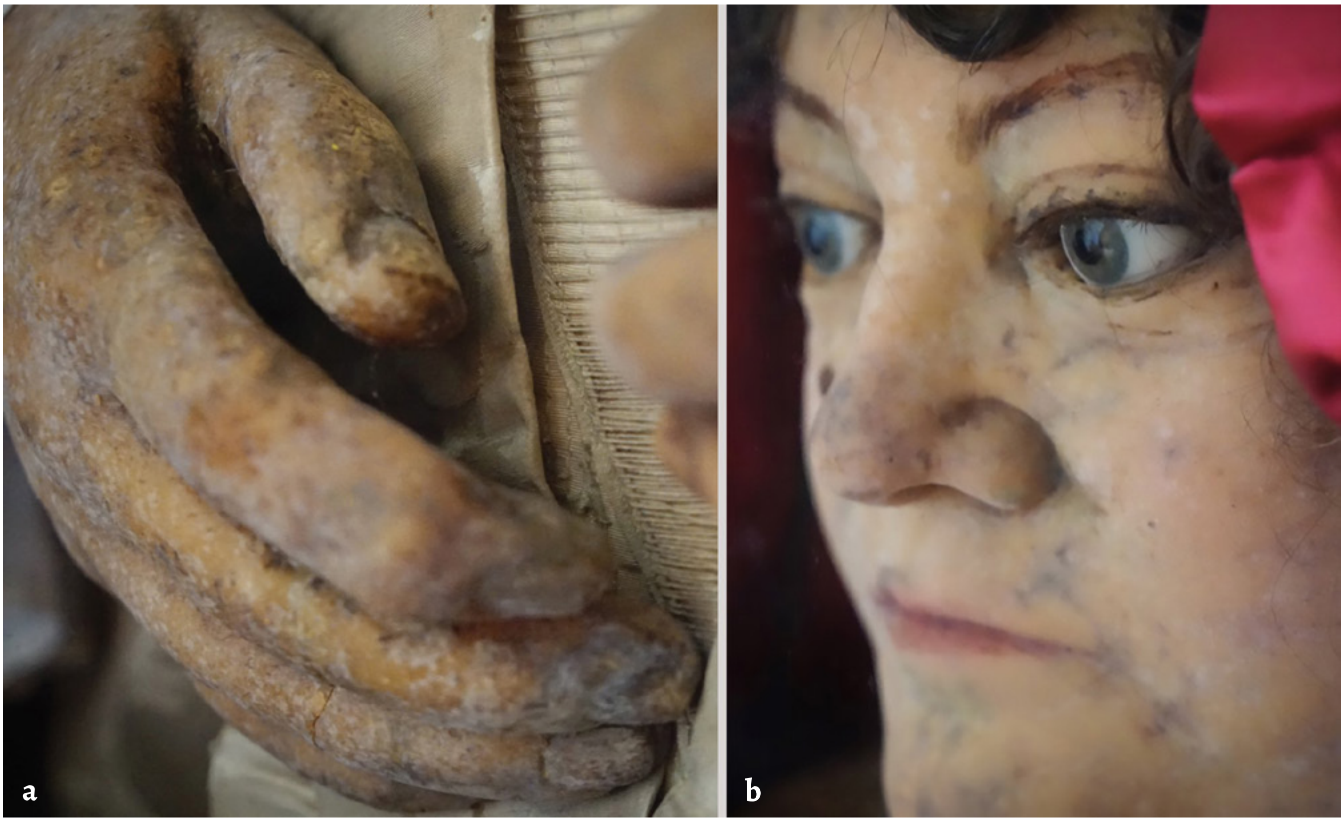

Figure 3. Damage on the waxen parts of the 1744 Sarah Hare's effigy: breakage on one finger *(a)*, wax discolouration and degradation *(a,b)*, mould *(a,b)*, loss of hairs *(b)* and surface colours *(a)*. Details from photographs uploaded on twitter by Brown, J. (2019-08-09) at https://twitter.com/dr_jrbrown/status/1159907535509446656 (accessed 2019-11-29).

beeswax [62], the presence of admixtures such as stearine or resins [56-57, 63], and wax degradation processes [58]. The migration of aliphatic hydrocarbons towards the surface is possibly promoted by the recrystallization of beeswax at temperatures below 12-16 °C [54], or as a result of an outflow of volatile unsaturated compounds at a 38 °C melting point [55]. The high fatty acid content is caused by the hydrolysis of esters due to ageing or the presence of stearine mixtures [56, 64]. Environmental factors causing wax bloom include extreme temperatures [54, 60] or temperature fluctuations – also possibly exposure to fire – [54, 56-57, 61], and lower or higher relative humidity (RH) [59].

High quantities of starch in the wax mixture lead to structural weaknesses [42]. The ageing of the wax alters its chemical composition. Esters hydrolise, flavonoids are chemically transformed, alkanes undergo changes affecting the lighter hydrocarbons, unsaturated hydrocarbons are reduced, and the hydrolysis of low molecular weight esters leads to an increase of acids and free alcohols [42]. The increase in acidity leads to an increase in polarity and hardening [42]. The ageing of the fatty acids in tallow and lard used as additives leads to partial hydrolysis of esters and the formation of palmitic and stearic acid, diglycerides and monoglycerides, and exudation of oils [42, 65]. The degradation of abietadienic acids results to the presence of dehydroabietic acids [42]. In turn, free acids in wax can cause corrosion on the copper elements [48] of wax effigies, which will lead to wax discolouration if the two materials are in contact with one another. In addition, Cu ions act as catalytic pro-oxidants and cause chain scission, hydrolysis, lipid oxidation, deterioration and liquidation of the wax mixture [48].

Problems caused by unstable environmental parameters

Organic materials share common characteristics such as complicated molecular structures, susceptibility to deterioration due to extremes and changes in RH and T, hygroscopicity, sensitivity to light and high risk of microbial and insect attack. The textiles employed in wax effigies as clothing or as sacking materials may be made from animal, vegetative materials or synthetic fibres, and their deterioration is accelerated by external factors which cause significant reduction in strength and elasticity [66]. Their main physical and chemical deterioration factors are light, humidity, temperature, air pollution and pests [67].

Climatic fluctuations result in the formation of cracks in the wax, leading to fragility [42]. Big temperature and humidity fluctuations increase the deterioration rate and promote pest activity.

Problems related to temperature (T)

Low, and abrupt falls in temperatures can be destructive, as materials, including wax, contract and harden, become brittle, more fragile, vulnerable to vibration and susceptible to breakages and losses due to mechanical stress and vibrations [42].

Temperatures above 20 °C result in sticky surfaces of the wax [48]. The softening of wax at temperatures over 30 °C [42] leads to the entrapment of dust, dirt and pollutants within the tacky surfaces and render it more sensitive to handling [57]. Depending on the type of wax mixture, temperatures over its glass transition temperature, can cause permanent wax deformations and oily stains on the textiles in contact to the wax.

High temperatures cause evaporation of the water molecules of hygroscopic materials, resulting to a dry and weak structure causing mechanical damage and formation of cracks, and create an environment suitable for the growth of insects and micro-organisms.

Problems related to relative humidity (RH)

RH plays a significant role in chemical and physical forms of deterioration. Organic materials in wax effigies, such as fabrics and wood, absorb and lose water and therefore swell and shrink respectively along different directions. Such dimensional alterations among the materials cause a continuous pushing and pulling against one another, resulting in structural cracks and gaps in joints.

Humidity can promote hydrolysis of the ester bonds in wax, and saponification in the case of alkaline humidity, which particularly affects aged materials [42]. High humidity levels cause metal objects to corrode faster [68] and biological activity to increase. Poor ventilation and RH > 65 % results in an increase of the humidity content of hygroscopic materials, attracting microorganisms, which generate metabolic water further increasing the water content [42]of textiles, leather, wood, and other hygroscopic materials present in wax effigies.

Low moisture levels can cause shrinkage, dryness and brittleness to materials. Dryness results to the loss of light hydrocarbons in wax as a result of sublimation reactions [42].

Continuous and large fluctuations of humidity can be destructive to wax effigies. Hygroscopicity results fabrics to readily take up and lose moisture directly connected with fluctuations of relative humidity and temperature. This can cause dimensional change and mechanical stress that can lead to breakage and structural damage as fibres gradually lose their elasticity and resilience.

Problems caused by light

Visible light, infrared (IR) and ultraviolet (UV) radiation triggers a series of photochemical, photolytic and thermochemical reactions resulting in the physical and/or chemical composition [42] of several of the materials present in a wax effigy. In addition, lamps and direct natural light may comprise a heat source. The photochemical effect of light is a process by which the absorption of photons from the surface of the object provides its molecules with energy triggering chemical reactions [42].

Light radiation in any form can cause the fading of textile dyes and brittleness of the fibres [69]. Damage from photochemical reactions is irreversible and can cause fading, bleaching, colour changes, change the crystal structure of wax [70-71] and can make organic materials dry and brittle [72]. Smaller wavelengths result in greater discolouration [42].

Damage induced by light on wax is often localized on the surface due to loss of tone in the organic dyes in the wax mixture, or due to the presence of plasticizers and hardeners [42].

Daylight can cause fading to the pigments on wax, paper and textiles, and the pigments or dyes that fade can disappear within as little as a few hours of direct sunshine [73]. UV causes yellowing, chalking, weakening, and/or disintegration of wax, leather, glass, plastic and other materials [73]. IR heats the surface of the wax surface, becoming a source of local exposition to high temperatures that may exceed the 30-35 °C in which beeswax becomes plastic, or even the 60-70 °C at which it begins to melt.

Problems caused by pollutants and surface deposits

Pollutants and surface deposits result not only in the degradation of the aesthetic quality of effigies, but their presence involves a series of alterations of the physical, mechanical and chemical properties [42] of the various materials they are composed of. Pollutants in wax museums derive from the external environment; the construction materials of the museum, exhibition or storage areas; and the materials of the wax effigies and their settings. Their concentration varies among the various museum areas depending on the climate and geographic location of the building [74], its vicinity to roads, industry and farms, the outdoor concentration levels and the air exchange rates, and fluctuates throughout the year and time of the day due to open doors and windows during visiting hours [75].

Pollutants deriving from outdoor sources include sulphur dioxide (SO_2), nitrogen dioxide (NO_2), nitrogen oxide (NO), ozone (O_3), hydrogen sulphide (H_2S), reduced sulphur gases [74-75], pollen and dust. Vehicles, industrial activity, sea, soil and biological organisms are some of their sources [76]. Visitors and museum staff transfer dust particles and fibres through their clothes and shoes. Indoor induced pollutants derive from various materials such as building materials, wood, wool, carpets, paints, composite boards, cleaning products etc. and include acetic acid (CH_3COOH), formic acid (CH_2O_2), acetaldehyde (C_2H_4O), formaldehyde (CH_2O), H_2S, carbonyl sulphide (COS) and O_3 [74].

Dirt particle accumulation due to inadequate exhibition and storage has been reported as a deterioration cause in wax objects, leading to darkening of the surface, from a grey colouring to a dark brown tone, exacerbated by the thickness and density of the dirt layer, and compromising the aesthetic, plastic and perceptive value of the objects [77]. Part of the dirt becomes embedded in the upper wax layers, due to the thermoplastic and electrostatic nature of wax [48, 77]. Surface deposits can trigger further reactions with the wax components, as pigments can react with the sulphur compounds of the atmosphere. Soft dirty surfaces can result to pest attraction and along with high humidity can increase the action of biological agents [42]. Abrasion of wax surfaces due to friction with solid particles on the surface has also been reported [42].

Deposited dirt and dust can embed into the textile fibres, causing discolouration, obscuring the appearance of the exhibits and damaging fibres by causing cuts and abrasions. Pollutants settle in the textile structure, causing disfigurations and affecting dyes, finishes and embellishments. The sharp edges of particles such as salts and pollutants that can be carried onto the museum exhibits through the air, including COS, SO_2, NO_2, etc., can cause mechanical damages to the textile fibres, cutting and abrading them, especially when the fibres expand and contract in response to changes in RH [78-79].

Pollutants are also harmful to effigy materials such as pigments, glass eyes, metal and leather accessories, paper labels etc. O_3 causes pigments to fade [74, 80-81], organic dyes to discolour or blacken [42] and double bonds between C atoms to break down [42]. SO_2 and nitrogen oxides cause degradation to vegetable-tanned leather [82], paper [83] and artists' colourants [84]. Organic carbonyl pollutants, mainly CH_3COOH, CH_2O_2, C_2H_4O, and CH_2O, have been accused for efflorescence on glass [85] and corrosion and degradation of copper [86], bronze [87] and paper [88]. Reduced sulphur compounds are related to silver tarnish [89].

Problems caused by biodeterioration and pests

The organic materials present in wax effigies such as wax, textiles, paper, wood, starch, binding media for pigments, soils, and stains are an excellent source of food for microbes and insects.

Wax containing starch is prone to mould and fungal attack, the latter causing flaking, whitening in appearance, and powdering, apart from wax pastes that include vermillion or verdigris in their composition [42]. Mould and bacterial spores can be airborne or carried along with other particulates [90]. The presence of carpets in the museum increases the concentration of micro-organisms. Bacteria are commonly brought into a collection area by contaminated floodwater or grow in standing water in buildings [90]. High RH increases the risk of bacterial and microorganism infection, with mould being less constrained by lack of water compared to bacteria, and mould growth being limited by the water available in the substrate material [90].

Insects use wax and textiles for food, shelter and breeding. The Hemipheres family can consume wax and lay their eggs on it, and *Lepidoptera* such as moth and *Lepismatidae* such as silverfish, feed on fabrics, leather, wool and feathers [91]. Darker wax is more prone to *Galleria mellonella* L. wax moth attack [44]. Insect biological residues are acidic and can change the pH of the objects, causing physical and chemical alterations [91].

Rodents have been reported to have chewed on the clothes and the cabinet housing an effigy [31].

Problems due to handling and transportation

Wax effigies are particularly vulnerable to damage during handling and transportation. Given the complexity of clothed wax effigies, damage may occur both on their surface, as well as in their structure. Typical damage includes soiling, greasing, staining, scratching, surface abrasion, small or large tears in the textiles, loss of decorative elements, and wax breakages and losses. Handling objects with bare hands can leave greasy stains on the surface of objects.

Disasters in wax museums

Effigy collections are susceptible to disasters as any other museum, yet the nature of such exhibits makes them more prone to damage and harder to recover after a disaster. Known disasters in wax effigies collections trace back in 1630, when a fire at the Chiesa della Santissima Annunziata in Florence and neglect of the remaining works resulted in the destruction of all of the Renaissance wax effigies [21]. The Madame Tussaud's in its over 250 years of its existence, has suffered from disasters including a shipwreck in 1822, a fire in 1925, wartime bombing in 1941 [15] and several vandalism attacks, mostly against the figures of Hitler and Osama bin Laden.

Fire is the greatest threat for wax effigies collections due to the highly flammable and heat sensitive materials that effigies are made from. In 1988, a fire destroyed the Southwestern Historical Wax Museum in Texas, USA, founded in 1963, and among losses were the Bonnie and Clyde wax figures and the original Death Car that had been used in the homonymous film Figure 4. It should be noted that objects are not only at risk of flames and high temperature, but also from smoke and its products.

Natural flood and leaking are another threat to wax effigies. Problems of the building design, poorly made installations and pipelines, inadequately maintained roofs and draining systems are some of the causes of flooded areas [92]. Naturally caused floods are more frequent nowadays as climate change is producing more intense natural phenomena including elevated humidity, higher water levels and more frequent flooding [93]. Older buildings are not usually flood-proof, and some are built below sea

Figure 4. The Southwestern Historical Wax Museum in Texas *(a)*. The same museum under the 1988 fire *(b)*. It housed Bonnie and Clyde wax figures and the Death Car used in the homonymous *(c)*. The fire destroyed the wax figures completely, and caused severe damage to the car *(d)*. Original photographs from Ballinger, F.R. 'Bonnie and Clyde wax display-the Southwestern Historical Wax Museum' (n.d.), in Bonnie & Clyde's Hideout, http://texashideout.tripod.com/wax.html (accessed 2019-12-01).

level, rendering them vulnerable and prone to flooding [92]. Water damage can lead to biological damage if not treated urgently, especially to the organic materials of wax effigies, such as textiles, wood and leather. Other damage due to flooding and leakage includes dampness, mud or soiling, swelling, discolouration, rust on the metallic parts, etc.

Wax effigies, made from a really fragile and brittle material – wax – and comprising of many different parts, are very prone to earthquake damage. Objects respond in four different ways to earthquake activity: remain stable, rock, slide or overturn [94]. Vibrations can be disastrous for the various parts of the effigies, causing mechanical damage, cracks, surface flaking, breakage and detachments.

Guidelines for the preventive conservation of wax effigies

Preventive conservation is the mitigation of deterioration and damage to cultural property through the formulation of procedures for setting and controlling appropriate environmental conditions, integrated pest management, control of pollutants, handling procedures, guidelines proper storage, exhibition, packing, transport and a plan for preparedness and response to emergency situations and disasters. Preventive conservation is an on-going process that continues throughout the life of cultural property and does not end with interventive treatment. It is intended to minimize the negative effects of poor environmental conditions to which objects are exposed, and to reduce the probability of future damage by creating a suitable, steady environment, where the external environmental conditions do not disturb the internal ones, which in turn are set and controlled according to the needs of the exhibits. Microclimates could be created for the most delicate wax objects, the term referring to the composition of the environmental physical state of an area, resulting both from the natural atmospheric conditions such as humidity, sunshine, temperature and air, as well as from human activity including body heat, artificial air conditioning and lighting [95]. The various parameters that may cause damage to the wax effigies should be identified, evaluated, detected and controlled regularly [42].

The main and interrelated elements of managing museum collections according to ICOM (International Council Of Museums) [96] are the recording of each object, the protection and preventive conservation of objects and the controlled access of viewers to the collections. First, the materials present in the objects need to be recorded and understood. Secondly, the environment in which each effigy is stored or exhibited should be studied for parameters known to affect museum objects. Thirdly, one should study how these parameters interact with all of the materials present in each effigy. Then, harmful conditions should be minimized or eliminated. Finally, basic guidelines for care, handling and cleaning should be followed and access of the visitors to the collections should be controlled.

A challenge to the preventive conservation of clothed wax effigies is the fact that they comprise a variety of construction materials, clothing items and accessories, each having different needs. In historical, fully dressed effigies, most of the garments are completely invisible to the museum visitors, as they are covered by other clothing items, yet they are not displayed separately, following the decision that the figures should be dressed with all the garments they wore when they were produced [25]. Contemporary wax effigy artists should be able to produce guidelines on their display and environmental conditions for their proper future preservation.

Recording of the materials of wax effigies

To understand the causes of deterioration of clothed wax effigies in a collection, it is important to first understand the construction technology of each individual effigy and record the materials present and the ways they interact to one another. The complex nature of effigies makes the process of preservation more complicated since it needs to include and work equally protectively for all the materials: wax, textiles, pigments, acrylics, glass, metals, etc. and other materials present having a historical value such as old paper labels and inks, and also conservation materials such as adhesives applied in previous treatments, each of which has different needs and require different environmental conditions. Each effigy in a collection should be studied individually in order to propose a preventive conservation plan tailored to its needs. Detailed record drawings, X-rays and CT-scans can be employed to reveal a great amount of information without the need for disassembling. Optical microscopy (OM) can be used to identify the nature of starch in the wax mixture [48] and the types of fibres on the costumes. Fourier transform infrared spectroscopy (FTIR), direct inlet electron ionisation mass spectrometry (DI EI-MS), high temperature gas chromatography (GC) [5], and micro-chemical tests can be employed to determine the precise composition of the organic substances in wax mixtures [49]. X-ray fluorescence (XRF), micro-Raman spectroscopy, FTIR, micro-chemical tests and scanning electron microscopy-energy dispersive X-ray spectroscopy (SEM-EDX) can be employed for the identification of inorganic components in the wax [48-49] and the inorganic materials of the effigy, costume and accessories.

Creating and controlling a stable environment

First, the museum building should be completely insulated from the external destructive factors such as atmospheric pollutants, humidity, temperature and insects. Walls, ceilings, roofs, windows, doors, pipelines and other elements should be inspected to see if improvements can be made to eliminate deterioration factors.

Then, the appropriate conditions need to be created for each exhibit, depending on the materials of each effigy, and the props and exhibition setting. The presence of conservation materials on the effigies should also be taken into consideration. The preservation proposal plan should focus on environmental parameters such as RH, T, light, atmospheric pollutants and biological agents including insects, rodents, fungi and microbial attack. These parameters need to be constantly or regularly recorded, with data loggers, pest and dust traps to check on the effectiveness of the measures applied, allowing for museum keepers and conservators to interfere and proceed to changes when necessary. High-resolution microphotography on the exhibits, superimposition in a computer program and mathematic estimation of the occurrence of small differences can be a valuable tool for the detection of alterations not immediately visible [42].

The number of visitors entering the museum should be controlled and limited to the internationally accepted number of one person per 3-5 m^2 [96].

Suggested measures for temperature

Wax objects must not be placed near heat sources such as radiators or air conditioning units, nor in front of windows, and must not be in contact with external walls as the T and humidity of the wall can pass directly to the object. To maintain an appropriate T, central heating or air conditioning can be used to supply air at the desired T levels. T suggested for wax are 10-20 °C [48] and 15-20 °C [42] with a daily variation of ± 1.5 °C. However, the rest of the materials of an effigy should be taken into consideration. T suggested for glass, plastic [97], paper and wood are 18-20 °C, 18-21 °C for textiles [98], < 20 °C for bone and ivory [99], < 25 °C for bone and fur [99], 21-25 °C for leather [99], and 15-23 °C for feathers [99].

Suggested measures for relative humidity

40-50 % RH has been suggested for wax [48], levels also suitable for wax effigies comprised of a diversity of materials, with a maximum fluctuation of ± 3 %. Yet, RH for mixed objects containing organic materials and metals should not exceed 40 % [100]. Different than the above values are the suggested RH levels of 45-55 % for bone and ivory and 45 % for fur [99], whereas plastics usually require RH of higher values, i.e. > 50 % for rubber, > 55 % for casein and > 60 % for keratin and shellac [97].

RH indicators and humidity buffering materials such as Art-sorb, Pro-sorb or silica gel can be placed in showcases, according to the air volume of each cabinet [42].

Suggestions for light

Exposure to sunlight should be avoided by installing blinds or curtains and placing filters or protective films on the windows [42].

Using low wattage lights, eliminating UV radiation, reducing the number of lamps, diffusing the light, limiting the exposure time using motion sensors or by switching off lights when the gallery is empty of visitors, and using dimmer switches are principal rules for the use of artificial light in museums [42, 101]. Attention should be given to the choice of light, as filters may influence colour temperature and colour index [42] obstructing the correct display and enjoyment of the collection. Lamps inside showcases or close to their glass surfaces must be avoided, due to the absorbance of heat that will create a dangerous microclimate for wax [42] and silk.

Some of the preferred artificial light sources for museum collections are halogen lamps [102] with UV-stop systems and built-in dichroic quartz tubes capable of absorbing large percentages of UV and heat emissions [103]. Halogen lamps have the advantage of producing adjustable, clear, bright light that brings out the natural colours of the objects. However, from September 2018, halogen lamps are no longer sold across the European Union, as energy intensive and inefficient and are gradually removed from the market [104]. Cold light such as optical fibres or LED can be used to illuminate large surfaces in open areas, work excellent for heat-sensitive materials and have the capacity to filter UV and IR radiation [105]. Light transmission systems such as optical fibres are best for wax artefacts [42]. PMMA LED optical fibres with halogen generators with a colour temperature close to 3000 K equipped with IR and UV filters can transmit light without loss of intensity through the glass of the showcase, with negligible heat transmission [42].

The standard values for wax are maximum light intensity around 150 lux and maximum UV-radiation level at 75 μw/lm [48]. Maximum allowed direct exposure time for wax is 3000-5000 hours per year [42]. These levels should be adjusted according to the needs of each effigy, taking into consideration the light absorbency of the exposed surfaces, the presence of unstable dyes, pigments, degraded layers, sensitive textiles such as silk, etc. It should be kept in mind that in 1986 [106], it was established that 50 lux are enough to ensure that the visitor is operating well inside museum collections, therefore preventive conservation and museum standards have since adopted these levels for a variety of materials. Light intensity in general, for items such as wax, textiles, paper, plastics, glass and wood should not exceed 50 lx. Annual light exposure should not exceed 10,000 lx • h/a, and UV radiation should not exceed 10 μW/lumen.

Suggestions for pollutants

Standards in the air quality of the wax museums and acceptable pollution levels have not been yet established. Several researchers have studied the deposition velocities of key museum pollutants onto various materials [75], yet a study especially made for wax museums has not been yet performed. Therefore, in order to understand pollutants that may affect a wax effigy collection, a study should be performed to list the pollutants present in the external and internal museum environment, and the ways they interact with the effigies, based on known studies.

Some meteorological stations provide readings of pollutants in the air of big cities. A simple method to record indoor pollutants is to apply dust traps, small pieces of a sticky material, at various rooms at different heights, and analyse the trapped particles using SEM/EDS. Passive monitoring of pollutants can be achieved through commercial passive sampling devices (PSD) the function of which is based on a colour indicator that changes colour when in contact with the examined pollutant [74]. Environmental dosimeters can measure various organic and inorganic pollutants and assist in the study of the degradation [107] of the various materials present in an effigy.

The first step to reduce pollutants is making the museum building as airtight as possible, in example by installing double doors to reduce the inflow of air from outdoors. Materials for sealing windows, doors and also showcases to act as barriers to gas contaminants are Marvelseal 360 (layers of aluminium film sandwiched in nylon and polyethylene) or polyethylene film, that for aesthetic reasons can be coated with polyester laminate, Mylar, Melinex R, pH neutral cardboard, cotton, linen with an appropriate colour and texture for the design of the exhibition [42].

The air within the museum environment should be chemically filtered through the museum ventilation system and removed through ventilation exhausts, to avoid internally generated pollutants from building up [75]. Air filters which retain relatively large particles, such as dust and pollen, HEPA filter or bag filter systems that hold particles up to 0.1 microns and carbon filters or special filters that neutralize organic matter could be used, preferably in each air duct [76]. Alternatively, elements reacting with the detected contaminants could be placed inside showcases; in example, activated carbon to block acid emissions [42].

The flow of air pollutants towards the wax effigies and their settings should be limited. The air flow can be controlled through mechanical ventilation, directed to rooms or zones as desired [75]. Chemical air-filtration, e.g. by the use of activated carbon can improve indoor air pollution levels [75, 108] and chemically-filtered air could be re-circulated, thus not only reducing the levels of both externally and internally produced pollutants, but also the cost of internal T and RH control as well [75] .

To keep exhibition areas clean, vacuum cleaning must be daily performed. Provided that storage areas are not frequently accessed, cleaning should be performed regularly, such as once a week. For various surfaces, such as shelves, electrostatic cloths should be used to avoid dust dispersion. Frequent site control for the presence of dust particles may be achieved through the installation of collectors, such as glass microscope slides or aluminium substrates coated with a sticky substance, at various points and heights [109]. Cleaning materials should be carefully selected so that they do not include acidic or basic compounds that can damage the wax effigies [42].

Pest management and control of bioinfestation

It is preferable to act proactively in order to avoid the stage of an insect infestation, as the process of disinfecting a site is difficult, expensive and dangerous for the objects. Insulating the interior of the museum, maintaining stable environmental conditions to avoid the creation of a fertile environment for reproduction and living, and performing frequent controls, are highly recommended. The establishment of a number of air changes per hour can inhibit fungal and bacterial growth activity [42]. Avoiding food sources in the exhibition areas and maintaining regular housekeeping is essential for preserving and minimising the likelihood of pests. Birds, rodents and nests should be controlled and removed from the museum surrounding area as they disperse a large number of blood-emitting ectoparasites, which in turn attract other species of insects. Monitoring by using insect traps in places such as the corners of the floor and window frames is essential [91].

Suggestions for the display and storage of wax effigies

Wax effigies are usually free standing objects and the most common way for exhibition is by placing on a base, the protrusions of which enter the interior of the feet or the torso if the figure wears a long dress. When the effigies are seated, counterweight or different kinds of mounting are placed at their back as a support. The base must provide balance to the object according to its gravity centre, should be mechanically attached to the object, and not just glued and must be constructed in such a way that will allow the ease of handling and transferring. Its construction materials should be chemically inert. Glass and polymethyl methacrylate (PMMA), also known as acrylic glass, and known under trade names such as Plexiglas, Perspex etc., are inert materials with a sufficient hardness and non-porous surface that makes them ideal for display use. PMMA is a light, hard, stiff material, resistant to fire, striking, UV radiation and inorganic acids [110].

Maintaining the clothes on the wax effigy should be preferred in order not to disrupt the entity of the object. In doing so, the three-dimensional fabrics are protected, as folds and creases on the textiles are avoided in a similar way as when using mannequins or three-dimensional hangers to exhibit or store heavy garments. It should be kept in mind that direct contact of fabrics with the wax, metal, plastic, rubber or any other material used to make the body of the effigy, consists of a possible threat for the clothing, and friction may also occur in the case of historical effigies that wear multiple layers of clothing. The body of the effigy must therefore be insulated before the fitting of the costume, and each clothing layer must be supported and protected, respecting its integrity and avoiding altering the volumes on the effigy [50]. Down-proof

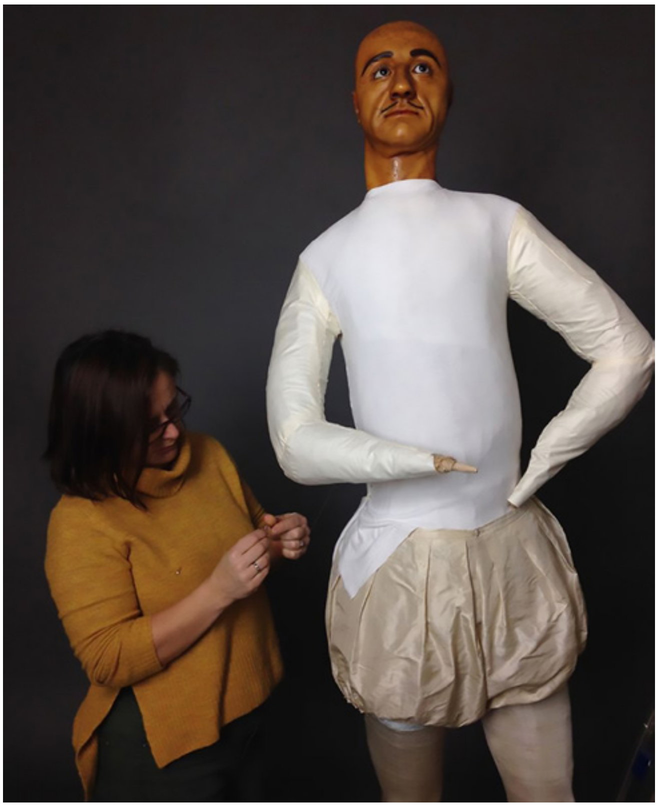

Figure 5. Rachel Rhodes at Zenzie Tinker Conservation covering Charles II effigy from the Collection of Westminster Abbey with down-proof cotton and Tyvek for preventive conservation purposes. Image courtesy of the Dean and Chapter of Westminster.

cotton to contain the dust and residues of the filling of the torso, cotton jersey to isolate wooden parts, Tyvek to isolate the wax have successfully been used on wax effigies [50] Figure 5. Acid free tissue paper would not be a proper idea as it can stick on the wax surface and also absorb acids very quickly. Polyester film such as Melinex, or polyester wadding, are not suitable materials either, as during hot periods these materials can actually stick on the wax surface.

The environmental conditions of the storage and exhibition rooms and the way that clothed wax effigies are placed in it are important. Underground levels or floors closer to the roof that usually exhibit higher humidity levels and higher temperature levels respectively, must be avoided. An annual stable storage climate at approximately 40-50 % RH and 20 °C is desirable.

It is generally advised that the effigies be stored as a whole, particularly when dealing with historical objects. Each effigy should be placed on a specially designed base that will offer ease of handling and transferring. Covering with Tyvek or cotton fabric will protect effigies from dust and contaminants.

There are cases however that a historical effigy may be displayed in parts. An interesting case is the 1603 effigy of Queen Elisabeth I, the original wooden head and hands of which were replaced by waxen ones in 1760. When in 1994 dismantling for the needs of its conservation revealed that the wooden figure, corset and drawers were original to the 1603 effigy, conservators decided to display them separately and constructed a totally new figure to display the costume, head, hands and feet [27].

In cases where only parts of the effigies have survived i.e. the wax parts of the heads and limbs, or parts of the clothing, the different parts may be treated separately. Using appropriate construction materials for creating shelves and boxes in which the objects will be stored is important. Small parts such as hands and feet may be stored in groups placed into boxes. Each object should be wrapped in acid free tissue or Tyvek, and mounted on packing materials which can provide shock protection. Additional insulation materials are desirable if the environmental conditions are unstable. Three-dimensional parts should be placed on storage materials, such as Ethafoam, conformed to the shape of each object. Heads could be stored using specially formulated polyethylene foam sleeves such as Ethafoam or Plastazote LD45 and placed into individual boxes made of acid free cardboard or polypropylene (PP) and always on a lower level within the storage area, to avoid possible fall. Storage on metallic shelves can be employed to place the boxes, preventing future damages that could occur from possible fall, and protect the objects from dust and dirt.

In cases where only the garments have survived, storage methods vary depending on the type of each garment. Three-dimensional textiles that are in good condition and do not carry heavy decoration such as metallic or plastic decoration can be placed on suitable padded hangers and be covered or placed in clothes storage bags made of non-woven materials i.e. Tyvek. Heavily decorated garments should be stored horizontally, to avoid damages to the textile structure induced by weight. These should be placed in drawers or boxes, after placing rolls of free acid tissue at the folding points, to soften and loosen the creases. Accessories should be stored separately from the garments, placed in cases of Ethafoam or Plastazote LD45, in special cabinets or boxes.

Suggestions for handling and transportation

Minimising handling and unnecessary moving around of clothed wax effigies is highly important. Handling complex wax effigies should be done with care and attention. The waxen surface should never be touched with bare hands. Latex, nitrile or vinyl gloves must always be worn, and jewellery, woollen or fuzzy clothing should be avoided.

General principles for object handling and transport should be followed. A plan should be prepared and rehearsed prior to the day of transfer. This should include the number and roles of the people involved, the way that each object is to be transferred, the route to be followed, the sequence of actions and the time needed. The place where the object will be moved to must have been already prepared prior to the object reaching its destination. Prior to moving an effigy, its stability should be checked and possible risks identified. Fragile parts should be protected accordingly using chemically inert polyethylene foam and acid free tissue paper. The stability of each object should be secured with straps and padding material to minimise pressure and abrasion. Arrangements for the use of appropriate equipment such as trolleys, platforms, boxes, packing materials etc. should be made in advance. Before moving the effigies, the people involved should each be assigned with a specific role, such as opening doors or pushing trolleys and should have rehearsed to check the efficiency of the plan in terms of safety and time required. The moves needed to be made, and the distance to be covered should be studied and minimised to reduce the time needed and the risks involved. Items are to be held firmly with both hands, wearing the appropriate gloves, only from their solid parts, avoiding touching fragile areas such as face, fingers and delicate clothing.

The objects should be placed in properly designed boxes according to the dimensions and needs of each item using acid-free materials, ensuring elimination of object movement due to vibrations during transport. Appropriate labelling must be placed both inside as well as outside the box, preferably with photographs, so that the items can be easily identified before opening, avoiding unnecessary handling. Opening instructions should be provided.

Historical effigies should be transferred cautiously as one piece since the risk of breakage during the dismantling is high due to the materials' brittleness.

Contemporary effigies could be dismantled, with each part packed separately. Their sensitive construction materials, large size and protruding parts like limbs, can make lifting, packing and transfer in one piece quite challenging. Dismantling may take time and effort but can make the whole process of transferring easier and safer. Heads should be handled from the back to avoid touching the delicate painted faces and the sensitive areas of eyes and mouth, always with as less pressure as possible and careful movements. Costumes can be transported horizontally inside boxes, using internal support especially at the crease points, using acid free tissue, polyester pad or white cotton cloth. For transporting lighter costumes in a vertical position, cardboard boxes can be used with Tyvek padded hangers and covers.

Risk management, emergency cases and first rescue measures

The dangers that need to be taken under consideration when proposing a preventive conservation and risk management plan include natural, man-made and mixed risks and disasters. Fires, floods, earthquakes, tidal waves, landslides, volcanic eruptions, technological accidents, car accidents, vandalism, wars and terrorist attacks are some of the likely scenarios that could damage wax effigies on display, on storage, or during transportation. To evaluate the risk that each museum may face, it is important to first identify the risks likely to cause damages, estimate the probability of the occurrence of a disaster, and the consequences it may have for the exhibits. The conduction of a study will lead to results that will indicate the actions that may be repeatedly applied by a group of museum staff, before, during and after a disastrous event. The vulnerability of the individual museum -meaning the ability of its staff and facilities to face, resist and recover from the effects of a disaster- should be thoroughly studied. Vulnerability is different for each museum: the risk of destruction may be the same for two museums, yet the wealthiest one is more likely to have better premises, infrastructure, insurance policies etc., and more likely to have cared for alternative solutions to continue its operation in the case of a disaster, making it less vulnerable than a poorer museum.

There are two main kinds of risks: manageable and pure. Pure risks cannot be avoided while manageable ones can be diminished [111]. Wax effigy collections should manage these risks in the best possible way in order to protect their housed objects from the above dangers, and have their own emergency planning handbook step by step demonstrating the actions needed for its individual needs and facilities [112], including safeness of the workforce, visitors, collections and building, and reassuring return to normal the soonest possible [113]. Evacuation procedures for staff and the public, handling procedures, medical and disaster supplies need to be recorded, and the plan needs to be often reviewed and tested through exercises and checklists. Each staff member needs to be trained and prepared for the task for which they are responsible. Object transportation in case of an emergency should be already agreed and organised with a shipping company, the place where the objects will be transferred should be known in advance, and specially organised to store affected or not artefacts [114].

In case of an emergency, depending on the scale of the disaster, it may be necessary to first secure the building itself before undertaking any type of salvage operation [114]. Some objects may not be immediately movable and may need to be stabilised *in situ* [114]. During evacuation, be realistic, as unnecessary caution may require too much time and acceptances should be made that not all objects are equally valuable and important [92].

International Organisations and institutes such as ICOM, ICOMOS (International Council on Monuments and Sites), ICCROM (International Centre for the Study of the Preservation and Restoration of Cultural Property), AIC (American Institute for Conservation), Getty Institute, etc. support and train museum professionals to plan an efficient response to all kinds of disasters. ICOM conceived the Museum Emergency Planning for museum professionals and experts in emergency-related fields to overcome potential disasters through the forward planning of emergency situations such as earthquakes, fires, flooding, hurricanes or war [115]. Furthermore, a network of Cultural committees created the Blue Shield [116], dedicated to protecting heritage in armed conflicts and natural disasters, and to providing post-crisis support.

Fire

The building must be equipped with fireproof interior lining materials, automatic fire and smoke detection systems and sirens, fire alarm buttons, fire retardant display materials, fire doors, appropriate extinguishing systems [117], fire fighting equipment, emergency lighting, fire exit signs and fire escape routes. All of these must be regularly maintained and tested, and staff should be trained in their use. Power sources should be installed in accordance to regulations and should include maintenance and inspection records [117]. Good housekeeping is essential and includes regular cleaning of waste at the coffee/restaurant areas, laboratories, chemical stores; external smoking areas; and correct disposal of smoking materials. Gaseous systems are recommended in wax effigy collections instead of sprinkler systems, to avoid a reaction with the materials [118]. Wax fire reaction can take place when water is poured on burning wax, similar to when water is poured on burning oil, due to the hydrocarbon molecules that both contain; hydrocarbon fires are greater in intensity, reach a high temperature really fast and continue until exhausted [118].

Floodw

Leakages can be avoided by continuous checks at the drainage systems and replacement of damaged parts, such as pipes. Effigies in exhibition or storage should preferably not be in direct contact with the ground, but rather placed on elevated bases. Storage in basements should be avoided, as these are the first to be affected by floods.

Effigies affected by leakage or flood should be treated within 48 hours to prevent mould growth and deformation of their organic components, to ensure their safety and minimise further deterioration. Good ventilation and a clean environment should be maintained. Objects that have been exposed to water must not come into direct contact with the ground but should be placed on elevated bases to ensure ventilation. Fans and hair dryers with cool rather than warm air, and controlled air flow can be used to dry paper, textiles and hair. Damaged and folded areas can be supported using polyester sheets (i.e. Melinex) or corrugated plastic sheets. Blotting papers, sponges, clean white towers can be used to absorb the water. Textiles and paper should be reshaped while still damp to approximate the original shape [120].

Earthquake

Protecting wax effigy collections and the building they are housed in from earthquakes requires the cooperation of different professionals including seismic engineers, structural engineers, building designers, curators, technicians and conservators. To find the best ways for collections' protection, the tolerance and response of the objects to vibrations [121] should be taken into account.

Effigies could be secured with a variety of passive mounts [94]: added weight on their base or lower parts; form fit insert into hollow part of the objects base or feet; form fit clips; extra support in the interior of the effigy; contour mount on the back side; mono filament tie to secure parts from breaking towards different directions; support either against the wall or on the floor, but never both on the same effigy. A safe way to mount wax effigies can be the use of isolation bases which absorb and neutralise every kind of vibration, alongside extra internal support at the connections of the main body and the protruding parts.

The position of the exhibits inside the building is also important: they should be placed away from items that can fall on them and break or deform them [122].

Conclusion

Clothed wax effigies are complex objects consisting of various materials depending on the time they were produced and the artist that created them. Although the manufacture technology has remained more or less the same, historical wax effigies consist of very different materials employed for the non-waxen parts, and modern effigies may be made of both traditional and contemporary materials. The various materials in an effigy, the variety of construction techniques in one sole collection, and the nature of the different recipes employed for modelling wax, known to be made up by a mixture of organic and inorganic substances, makes the task of proposing a preventive conservation plan quite challenging. Each effigy should be studied individually, its construction materials recorded, and the deterioration factors understood prior to the proposal of preventative measures that can guarantee safe conditions for their exhibition, transport and storage. The construction techniques, materials, deterioration factors and preventive conservation proposals listed in this paper, can assist the keepers of wax effigy collections into formulating an efficient preventive conservation strategy to suit each item's and collection's needs, determining the appropriate environmental conditions for storage and display, formulating an efficient handling and transportation plan, and creating a risk management plan to eliminate the effects of emergency situations.

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