4.1. Introduction

There is a need for the care of plastics in collections. Museums should undertake a survey of plastics through their collections in order to avoid potentially serious problems in the future. A survey in the UK shows that the most prevalent type of degradation for plastics, besides dust and dirt, is cracking or crazing, with discolouration and fading (Keneghan 2001). The proportion of objects showing serious signs of deterioration was very small.

The problems are complex. Most of us have experienced the sudden failure of a plastics material through degradation. A pattern of behaviour often observed in plastics collections is where one article which has shown no sign of degradation rapidly deteriorates while its neighbours appear unchanged. This emphasises the need for regular inspection of plastics in collections, especially because the products of degradation often accelerate or initiate deterioration both in plastics and other materials in the vicinity.

A primary technological investigation of plastics with respect to their conservation starts with a visual inspection of their surfaces. Preliminary examination and characterisation of objects are the most important aspects of conservation and restoration. All relevant data about an object has to be collected before an appropriate conservation strategy can be developed. Knowledge of factors that damage plastics is also required because one can only recognise damage by knowing its origins.

When considering the cleaning of plastic materials and the decision of whether or not to preserve the patina that are sometimes found at surfaces, one must consider the typology of the object or artwork requiring treatment. The use of plastics involves both the worlds of design and of contemporary art. Sometimes, these forms of creative expression appear to be closely linked by their aesthetic similarities, but in reality they differ greatly in terms of expressive intentions and basic functions. Objects of everyday culture and design are normally destined for a specific function, while works of art do not necessarily have a specific physical function other than that of aesthetic expression pleasure and are produced as unique objects or as limited editions.

A designer sells his creation to an industrial producer, who in turn decides how long the object should "live" by continuing production or withdrawing the object from the market. Thus, it is the manufacturer who decides to limit an object's availability to the consumer market, and turns it into a collectable object for both the private market and design museums. By contrast, an artwork is not created for any predetermined or practical use. An artwork is subject only to instruction for its exhibition and conservation, which ideally should be given by the artist.

Cleaning a plastic object requires consideration of the highly specific nature of synthetic and semi-synthetic materials, and particularly their degradation pathways. In fact, as has been demonstrated by research and studies in the POPART project, one deals with highly perishable materials that often display signs of ageing in the form of structural deformations, stiffening of the material and chromatic alterations.

When a decision to conserve plastics is taken, conservators consider two options, namely preventive or active. Preventive conservation may be defined as activities that limit the rate and extent of degradation of materials by implementing procedures for storage, exhibition, packing and transport. In practice, preventive conservation involves limiting artefacts' exposure to factors which cause degradation including oxygen, water, heat and light.

Active conservation treatments comprise invasive activities which stabilise and strengthen degraded artefacts, limit further degradation and help to preserve their original significance. Active treatments for plastics include cleaning, consolidation, impregnating, coating, adhering and filling. Established active conservation treatments for plastics are few in number compared with their preventive conservation equivalents (Huys and van Oosten 2005). This may be attributed to the high sensitivity of many deteriorated plastics to physical forces, organic liquids, aqueous solutions and water itself which give active treatments a reputation of high risk and irreversible (van Oosten *et al.* 2009).

Because developing and evaluating active treatments require considerable resources, the areas selected to be of focus in the POPART project were cleaning, consolidating and coating of plastics. These three areas were considered by POPART partners to be worthy of research because they are techniques frequently required by artefacts but poorly understood.

Although surveys of the condition of museum collections containing plastics in the United Kingdom, Scandinavia and the

Netherlands and most recently as described in Chapter 2 have concluded that approximately 75% of collections require cleaning, the practice is still poorly developed largely due to the fear of damaging the plastic irreversibly (Shashoua and Ward 1995). Dirt on plastics most frequently comprises oily materials from handling and use prior to collection and particulates from air. Because plastics are good electrical insulators, they hold dust using static electricity. In addition, soiling may be present at surfaces as a result of degradation processes. Phthalate plasticisers migrate to surfaces of PVC with time and hydrolyse slowly to produce white crystals of phthalic acid or anhydride (Wilson 1995, 56). If not removed, these can contaminate other objects or packing materials. Cleaning may also be necessary to remove stains, spots and residues, whether they are degradation products or arise from an external cause.

Cleaning involves the removal of every substance located at the substrate/environment interface of an object, which causes damage to its materiality or meaning, which has neither been applied intentionally by its creator nor is a sign of its historical use (Bollard 2007, 2008). Cleaning techniques can be divided into mechanical and chemical. Mechanical cleaning comprises the use of cloths, brushes, sponges, pressurised gas or particles to physically push or suck dirt away from surfaces. Plastics exhibit poor resistance to abrasion. Those with a glass transition temperature (Tg) approaching ambient are theoretically most at risk of scratching from mechanical cleaning processes. Most plastic types in museum collections have Tg values above 20°C, indicating that they are in a glassy, stiff state at room temperature. The exceptions are polyethylene, polypropylene, synthetic rubbers and plasticised PVC which are rubbery. Scratches are areas with higher reactivity than their surroundings and are therefore more vulnerable to chain scission, reduction in tensile strength and permanent damage. In addition to a loss of physical properties, the presence of scratches changes the light reflecting properties of surfaces, resulting in a loss of gloss.

Chemical cleaning may be based either on water, aqueous solutions of detergents, organic solvents or chemical reagents that react with dirt. The purpose of chemical cleaning is to dissolve dirt, residues or other unwanted material at surfaces. A mechanical component is also necessary to displace the dissolved dirt. The decision whether to use water or organic solvent based cleaning agents depends both on the type of dirt present, its solubility and on the chemical properties of the plastic's surfaces. The molecular weight and polarity of the plastic, its condition and the presence of previous conservation treatments will influence the effectiveness of cleaning agents.

Prior the initiation of POPART project, solvents were not recommended for cleaning plastics. The risks of swelling, dissolving and extracting additives from plastics are higher than those from aqueous washing agents (Sale 1995). Another risk to be considered when applying solvents to rigid transparent plastics such as polystyrene, polycarbonate and polymethylmethacrylate is stress cracking or crazing, correctly known as Environmental Stress Cracking (ESC), which results in the development of white crystalline structures or interconnecting cracks in the body of the material (Fenn 1993). Stress cracking is irreversible and may occur either immediately after application of solvent or may develop gradually after weeks or months. Organic liquids that do not usually attack a polymer in an unstressed state can attack an area weakened by localised stress causing a micro fracture due to separation of polymer chains.

Selection of liquids to clean plastics surfaces while minimising the risk of damage may be achieved in two ways. The trial and error approach involves applying drops of cleaning agents to a test piece or a hidden area of the object and examining the results with time. A more systematic approach is to compare the polarity of the liquid with that of the plastic in order to avoid those liquids which are most likely to dissolve or soften the object. The term solubility parameter was first used by Hildebrand and Scott in 1950 and describes systems used to quantify the principle of “like dissolves like” (Hildebrand and Scott 1950). Solubility parameters are experimentally determinable measures of the forces of attraction which hold molecules together. Based on solubility parameters alone, it is clear that water is unlikely to damage the surfaces of plastics and that acetone based materials are likely to soften or dissolve cellulose nitrate, poly(methyl methacrylate), poly(vinyl chloride) and polyethylene terepthalate. Published solubility parameter values usually refer to new polymers without additives and not to degraded plastics formulations found in objects in museums. As a result, theoretical predictions for cleaning agents should be evaluated practically before cleaning museum objects.

The second most necessary active conservation treatment after cleaning is coating or consolidating degraded or crumbling surfaces. In contrast to those applied to museum plastics, coatings for industrial plastics are used to decorate as well as protect them from handling and from degradation factors including ultraviolet light, high temperatures, mechanical force such as abrasion and chemicals. Conservators are frequently asked why plastic artefacts cannot be coated on acquisition to protect them from future degradation. The answer contains both ethical and technical components. The principle of irreversibility, adhered to as far as possible by professional conservators, is difficult to apply to the process of coating plastics. Since coatings have to adhere to or otherwise interact with surfaces in order to remain in place, it is almost impossible to successfully coat plastics without partial dissolution or etching of surfaces (Coxon 1993).

For coating to be effective, the lacquer or paint must first wet the plastic and spread over its surfaces. For a coating to wet a plastic effectively, it should have a surface tension lower than the plastic's surface tension. Surface tension is defined as the force per unit length exerted by one surface. Plastics have considerably lower surface tension values than, for example, metals. As a result, all polymeric coatings can readily wet metal surfaces. It is more difficult to find coatings with lower surface tensions than plastics, particularly polyethylene and polytetrafluoroethylene. A dilute, water-based coating is unlikely to wet plastic because the surface tension of water is 73 $mN.m^{-1}$ compared with only 30-45 $mN.m^{-1}$ for most plastics. A surface contaminated with silicone (18 $mN.m^{-1}$) from, for example, previous treatment with waterproofing polish, will also be difficult to wet and coat.

Additional considerations for selecting a coating is that its refractive index (RI) is similar (within ±0.06) to that of the original plastic surface, particularly if both are transparent, that any thinning solvents do not induce stress cracking and that its degradation pathways do not initiate or accelerate degradation of the artefact. It is likely that the refractive indices of plastics will change with time because most polymers yellow on degradation.

The two approaches possible when applying coatings or consolidants to a cellular structure such as a foam are either to apply a thin film which seals the cells or to selectively coat only the cell walls. Sealing the cells may result in a thick, inflexible glossy coating which changes both the appearance and elasticity of the foam. Coating cell walls minimises changes in appearance and flexibility but is technically more complex to achieve. Consolidants may be applied via a nebulising system driven by air pressure which produces droplets with volumes of 1-10 µm. The droplets are finer than those formed by spray guns which produce droplets up to 100 µm. Smaller particles penetrate deeper into the cells than larger particles, coating the walls and leaving the cells open, allowing the foam to retain its elasticity (van Oosten 2011).

The main challenges associated with studies in cleaning, consolidating and coating as conservation treatments will be discussed in detail in the rest of this chapter.

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