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Technical Note

A Systematic Approach to Selecting Inexpensive Conservation Storage Solutions

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The appropriate storage of heritage artefacts is vital to their long-term survival, but selecting suitable storage solutions is not always easy due to the number of potentially conflicting factors that must be considered. For example, the method of housing should be compatible with both the objects themselves and with the local environment; it must offer adequate support and protection; it should ideally be inexpensive, readily available and easy to use. Following the discovery of objects in the British Library's collection which were showing initial signs of damage due to inappropriate storage, a systematic approach to selecting and assessing potential housing solutions was devised, as reported herein. A particular aim was to use containers, materials and testing regimes that could be sourced easily and affordably, thus permitting the rapid rehousing of all of the items identified as being at risk. This approach also places such test protocols and storage solutions within the reach of smaller collections with limited budgets and resources.

Introduction

The British Library, like many other heritage institutions, houses a very wide variety of artefacts that form an important part of our cultural heritage. Part of the Library's remit is to ensure their survival for future generations. To do so requires a combination of conservation (both interventive and preventive) and good curatorial practice, to ensure the suitable and sympathetic repair of damage, appropriate housing and storage, and the limitation of future risks.

The deterioration of collections has a number of clear causes, one of which can unfortunately be the steps taken to preserve them. The case study presented below is a perfect example of this, and gave rise to the work outlined in this paper: During a survey of some of the items in the Library's collection damage was observed, and on examination it appeared that this had largely been caused by unsuitable storage and handling in the past, specifically in this case the use of housing materials which were intrinsically inappropriate although they had been employed in line with the best practice of the time.

Damage to objects generally results from the presence of harmful chemicals or inappropriate environmental conditions, which can cause and sustain a variety of degradative reactions. The factors that lead to damage will vary significantly depending on the composition and structure of individual items, and neighbouring objects within a collection may be subject to deterioration by markedly different reagents and mechanisms.

The problem of inappropriate storage has three main causes. The first of these is the widespread adoption of BS5454 (Recommendations for the Storage and Exhibition of Archival Documents), which specifies storage conditions of 16-19 °C, 45-60% RH, adequate ventilation and circulating air free from pollutants, and controlled light intensity excluding UV radiation (British Standards Institution, 2000). This standard was devised for archives of paper and parchment documents, but is not necessarily suitable for all collection materials. The relatively high humidity has the potential to be particularly problematic for sensitive metals, for example. This effect may be exacerbated in areas where collection items of different types are mixed, especially if the localised environment is adjusted to suit the predominant material types, thereby putting minority materials at risk.

Damage may also potentially result from attempts, for reasons of budget, convenience and availability, to adopt a limited range of storage systems, mounts, etc., for the entire collection. As with the difficulties encountered if a single environmental protocol is employed, damage may result from the use of storage materials which, whilst appropriate for the majority of collection items, are inappropriate for some specific objects and artefacts.

The final part of the problem arises not from understandable attempts at unifying and simplifying collection policy, but from the use of materials and conditions which should not have been employed regardless of the nature of the collection items. In most cases this is due to the

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use of materials which are at hand at the time, combined with a lack of understanding of the way in which these will interact with the collection items. Examples include the use of adhesives that emit volatile acids over their lifetime, foams that are prone to degradation and which will release aggressive chemical species in the process, boards and papers that are not acid-free, etc.

The first element can be remedied by ensuring that each type of collection item is housed in its own appropriate environment. This ideal, however, is rarely achievable given limitations imposed by resources, space, collection management policies and building infrastructure. The latter two aspects are easier to address, by ensuring that storage solutions are appropriate to the objects they house. However, this requires that both the objects themselves and any materials to be used in their storage are adequately characterised, and any potential interactions between them understood. This may result in additional protective measures being required such as desiccants or barrier layers.

Although the work presented here stemmed from a specific set of inappropriately housed and thereby damaged objects (as outlined in the case study below), it was decided to approach the problem in a systematic manner that could be applied more widely in the future. This approach was divided into four broad phases, which are addressed in greater detail subsequently:

- Understanding the object and its susceptibilities.
- Selection of potential new storage solutions.
- Assessment of stability and compatibility.
- Provision for long-term monitoring and assessment.

A particular aim of the work was to assess the extent to which inexpensive, readily available storage solutions (for example, food grade storage containers) can be used in place of the traditional resource - and labour - intensive methods often adopted in the past. If these kinds of storage systems prove to be suitable, this will enable problematic collection items to be rapidly rehoused without significant costs, thereby making such solutions available to any parts of the collection that require them, rather than having to prioritise those items deemed most valuable or most at risk, whilst leaving others to continue to degrade. Such an approach will also be of particular value to small collections with limited funding and resources, where traditional approaches may be unfeasible (and where problems are often exacerbated by poor environmental conditions caused by older or less suitable buildings). Similar work has also been carried out into the use of non-woven surgical fabrics as inexpensive and readily available storage materials and barrier layers during conservation treatments (Hernandez-Gomez, 2006).

In order to assess the suitability of these materials for the long-term storage of collection items, a number of complementary tests were carried out. Each of these tests is simple to carry out and readily available with minimal specialised equipment. In combination, they give a good indication of the likely short- and long-term behaviour of the materials. These tests were as follows:

- Short-term off-gassing of volatile acids, using appropriate test strips.
- Long-term off-gassing of volatile acids, oxidants and sulphur compounds, via Oddy testing.
- Surface pH measurements.

Understanding the Object and its Susceptibilities

The first step in the formulation of a new storage strategy for an object is to understand its material composition and structure, and how this will influence its long-term stability and susceptibility to degradation. For example, metals are generally at risk in moderate to high humidity environments, but most organic materials require at least moderate humidity to prevent desiccation and fragility. These factors will vary on a case-by-case basis (May and Jones, 2006). Once the nature of the object is appreciated, the conditions best suited for its storage can be determined.

Selection of New Storage Solutions

Storage materials should be chosen to allow for the susceptibilities and requirements of the objects they house. Factors to consider include the chemical composition of material; whether the storage solution needs to be airtight; if additional protective measures are necessary (acid scavengers, desiccants, etc.); and if special handling protocols need to be employed.

In general, polymers such as polyester (PET), polyethylene (polythene), polypropylene, polycarbonate, polystyrene and polymethylmethacrylate (Perspex) are all suitable for storage systems as they are chemically stable so are unlikely to degrade over time or release aggressive volatile compounds. Many inexpensive and readily available food grade containers, for example, are made of these materials for exactly the same reasons that make them suitable for housing collection items. The identity of the component polymer can often be discovered by markings or labels on the container itself, such as the SPI resin identification coding system (American Chemistry Council, 2011), but if this is not the case, it may be necessary to approach the manufacturer for more information or carry out further testing using a technique such as infrared spectroscopy.

Additional measures will also have to be considered. For example, if the housing is required to be airtight, is an additional seal of some sort required? If so, then the compatibility of this component will also have to be determined. Is a foam cradle or other support necessary? In this case, it must not only offer sufficient support but also be chemically stable (polyethylene foams such as Plastazote are generally acceptable, but polyurethane foams, commonly used for domestic applications, are prone to degradation and should be avoided). Any papers, boards, fabrics or polymer sheets which are to be used must also be individually considered with respect to both the object and the local environment. Adhesives are particularly important as many are prone to acidic off-gassing, even if they are promoted as being of conservation grade (Stevens *et al.,* 2011). Limited production of volatile acids may be acceptable if the object is in a well ventilated area, but if it is housed in an airtight container this will rapidly prove to be problematic.

Methods of handling objects should be considered - for example, is it appropriate to wear cotton or nitrile gloves, to prevent transfer of sweat or moisture?

Finally, active protection should be addressed. If the item is moisture sensitive but cannot be placed in a low humidity environment, then it is advisable to ensure that the container is airtight and employ a desiccant (for example, silica gel), thus creating a more appropriate internal micro-environment. In general, such sealed micro-environments should not be used without some method of stabilising and maintaining the RH. For materials that are particularly sensitive to, for example, acids or oxidants, then the use of suitable scavengers or active barrier layers may be appropriate. The use of internal indicator systems may also be of use, such as RH indicator strips, as these will highlight potential problems.

Assessment of Stability and Compatibility

The bulk composition of storage systems can generally be determined through labelling, information from the manufacturer or through chemical analysis (spectroscopy, etc.). Although this is of value in determining which materials may be appropriate, it should not be exclusively relied on as a guarantee of the long-term safety of objects housed therein. Polymers, for example, may contain plasticisers and other components in small quantities, but which are nevertheless sufficient to cause problems. Similarly a particular container may be compatible and suitable, but its integral seal may not be; or the foam used in a self-adhesive insulating strip may be acceptable, but not the adhesive itself.

Therefore it is necessary to test the systems and materials chosen to ensure that they will not present problems over the long term. This can be achieved using a set of simple tests which can be carried out with basic equipment. Although these analyses may appear to be time consuming and repetitive, they require little operator time and not only make certain that inappropriate storage solutions are not adopted, but if good records are kept they can allow suitable materials and containers to be more readily selected in future (and, of course, shared with other institutions facing similar problems).

The tests employed in this work are outlined in the experimental section, below.

Provision for Long-Term Monitoring and Assessment

It is recognised that collection items are unlikely to remain under the supervision of a single individual, and that anyone who subsequently becomes responsible for them will need to know how to look after them (such as monitoring to ensure that consumables are replaced when required). As specialist knowledge cannot be assumed, a simple advice sheet was devised, detailing, for example, characteristic colour changes of desiccants and scavengers that can be periodically checked to assess the quality of the storage conditions.

Experimental - Assessment of Stability and Compatibility

Short-Term Off-Gassing

The immediate off-gassing behaviour of the samples was assessed using *Image Permanence Institute 'A-D Strips'*, originally intended to monitor the condition of photographic media, but also well suited to investigating the production of volatile acids by other materials. A sample of approximate weight 1g was placed in a boiling tube with a test strip and sealed with a stopper. This was left overnight and the colour of the strip then compared to a reference standard. This standard uses a colour change scale to indicate the degree of off-gassing, from '0' (no deterioration, hence no acidic off-gassing) to '3' (critical, hence significant off-gassing). Any indication of '1' or greater was considered unacceptable for use with collection items.

Oddy Testing (Long-Term Off Gassing)

The longer term off-gassing behaviour of the specimens was assessed using the Oddy test (Robinet & Thickett, 2003), a common method of determining the suitability of materials for conservation purposes. A specimen of approximate mass 1g was placed in a boiling tube, along with a vial containing 1ml water. Three clean metal tokens (copper (Cu), silver (Ag) and lead (Pb)) were suspended above the sample on a polyester thread. As a control, a further vial of water and set of tokens were placed in an empty tube. The tubes were sealed with a ground glass stopper which was secured in place with heat-shrink tubing. They were then placed in an oven held at 80 °C, and left for 28 days, after which they were removed and the tokens examined for signs of tarnishing or corrosion - Cu tests for volatile oxidants, Pb for volatile acids and Ag for volatile sulphur compounds. (Other types of metal coupon can be used to test for different volatiles, as appropriate for the susceptibilities of different types of collection items.) Even moderate tarnishing, observed on any of the coupons, was considered to indicate that the material was unacceptable for use with collection items.

Surface pH Measurements

In addition to testing the potential of the materials to produce harmful off-gassing, surface pH was also measured, as some materials will become more acidic without releasing volatile acids, thus potentially damaging items in immediate contact. Both new specimens and those subjected to artificial aging through the Oddy test were assessed in this way. The measurement was carried out by moistening the surface of the specimen and applying a piece of universal indicator paper, then noting the resultant colour. Materials to be used in close proximity with collection items should not be significantly acidic or alkaline.

By combining the information from these individual experiments, it is possible to gain an understanding of the short- and long-term off-gassing and surface behaviour of the materials. From this it is possible to determine whether or not they are likely to be suitable for the storage of the items in question.

Case Study

The British Library holds a broad range of non-paper material, including items made completely or partially from metal, such as dies and plates in the Philatelic Collection composed of steel, copper or aluminium (Hanson *et al.*, 2011). Many of these were discovered to be showing signs of rapid deterioration due to a rehousing programme approximately 12 years previously (Figure 1).

This programme involved transferring the dies, which exhibited no signs of corrosion or chemical deterioration, from the galvanised steel cans that originally housed them to drop-back boxes to protect them from physical damage. The new boxes were constructed from a range of boards, foams, adhesives and fabrics.

Once the damage had been discovered, analysis of these boxes showed them to be made of a variety of non-conservation grade materials, including acidic board, PVA and animal adhesives, polyurethane foams and fabrics containing bleach residues (Figures 2(a) and 2(b)). The volatile species released by these components generated a highly detrimental environment within the boxes. This was also exacerbated by a number of additional factors, including: the relatively high humidity of the Philatelic Collection (55-60 % RH) used to ensure the stability of the adhesives found on the verso of many of the stamps; the presence of cellulose acetate in neighbouring objects, generating ethanoic acid; and the use of boxes constructed from oak, which is known to release acidic gases, particularly at high or fluctuating humidities. Unsuitable handling practice was also in evidence due to the presence of fingerprints which had become etched into the metal surface through the corrosive action of sweat (Figure 3).

Fig. 1: Corrosion found on a die plate.

New storage solutions were sought using the procedure outlined above. The dies and plates were rehoused in food grade polyethylene containers of appropriate size, which were made airtight using an appropriate sealing strip (*Tesa 'Draught Excluder, Omega Profile'*) (Figure 4). Internal structures and supports were constructed from Plastazote (polyethylene) foam, Tyvek (non-woven polypropylene fibre sheet) and Perspex (poly-methylmethacrylate). Reusable silica gel bags were employed to ensure a low internal humidity; corrosion intercept strips were included to act as acid and pollution scavengers; RH indicator strips were placed

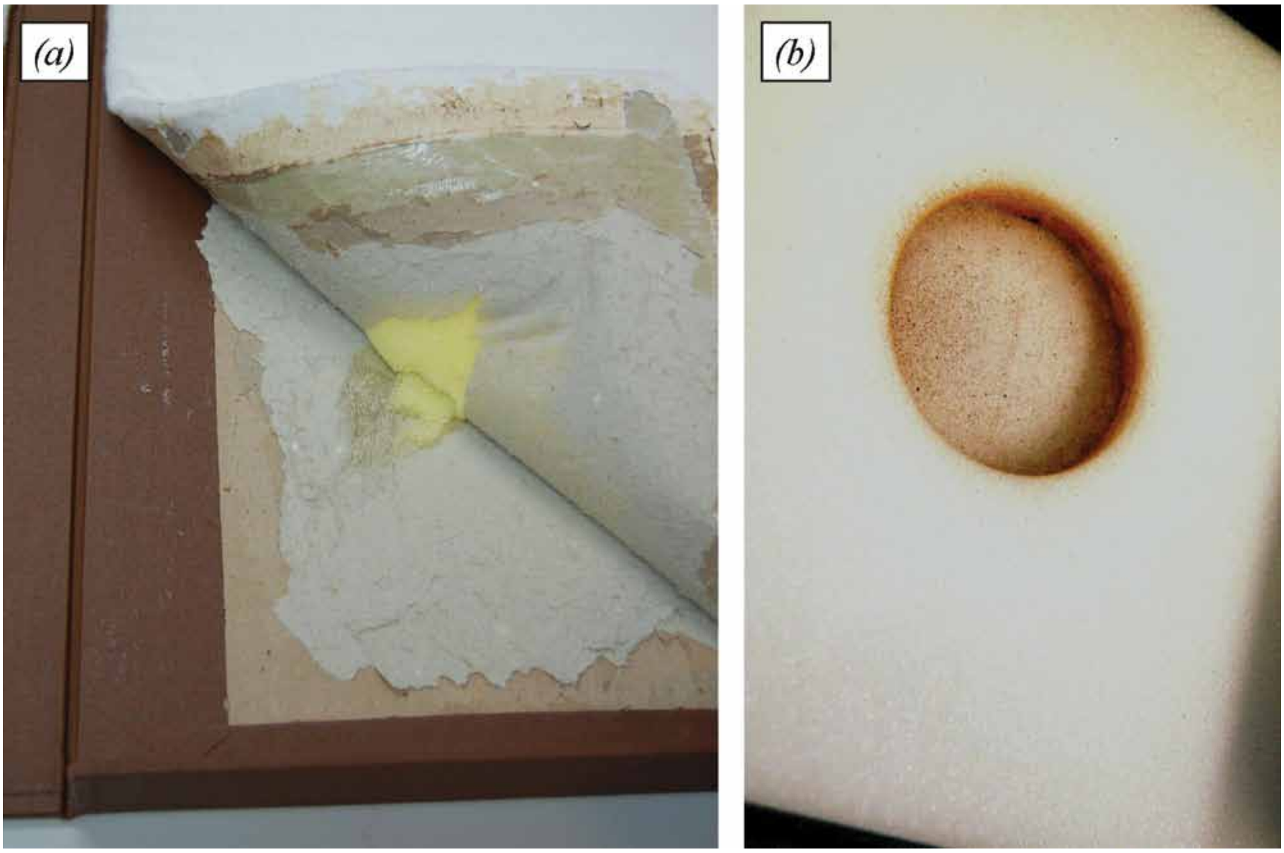

Fig. 2: Inappropriate housing materials: (a) board and adhesive; (b) foam.

Fig. 3: Fingerprint induced corrosion.

in each container to allow the humidity to be monitored. Nitrile gloves were recommended for future handling, as latex rubber gloves contain sulphur compounds that can tarnish metals and cotton gloves can accumulate sweat, salts and residues of washing agents. Finally, an advice sheet was prepared to allow the colour changes in the silica gel, corrosion intercept and RH indicators to be readily interpreted by curators and conservators (Figure 5).

All of the metal items identified as being at risk have now been fully rehoused following this method. An initial biannual monitoring regime has been established to ensure the continued good condition of the items; after two years the assessment period will be reconsidered and adjusted according to the rate at which the consumables are expended. As other collections are brought forward by curators, damaged items or those perceived to be at risk of future deterioration will be similarly rehoused.

Conclusion

In conclusion it can be seen that by carrying out a systematic series of simple tests, it is possible to determine the suitability, or otherwise, of alternative and novel storage solutions. Importantly this may allow inexpensive and readily available materials to be used with confidence, in place of expensive specialist products, thus providing more suitable conditions for greater numbers of collection items and offering appropriate storage solutions to smaller collections and institutions with limited resources.

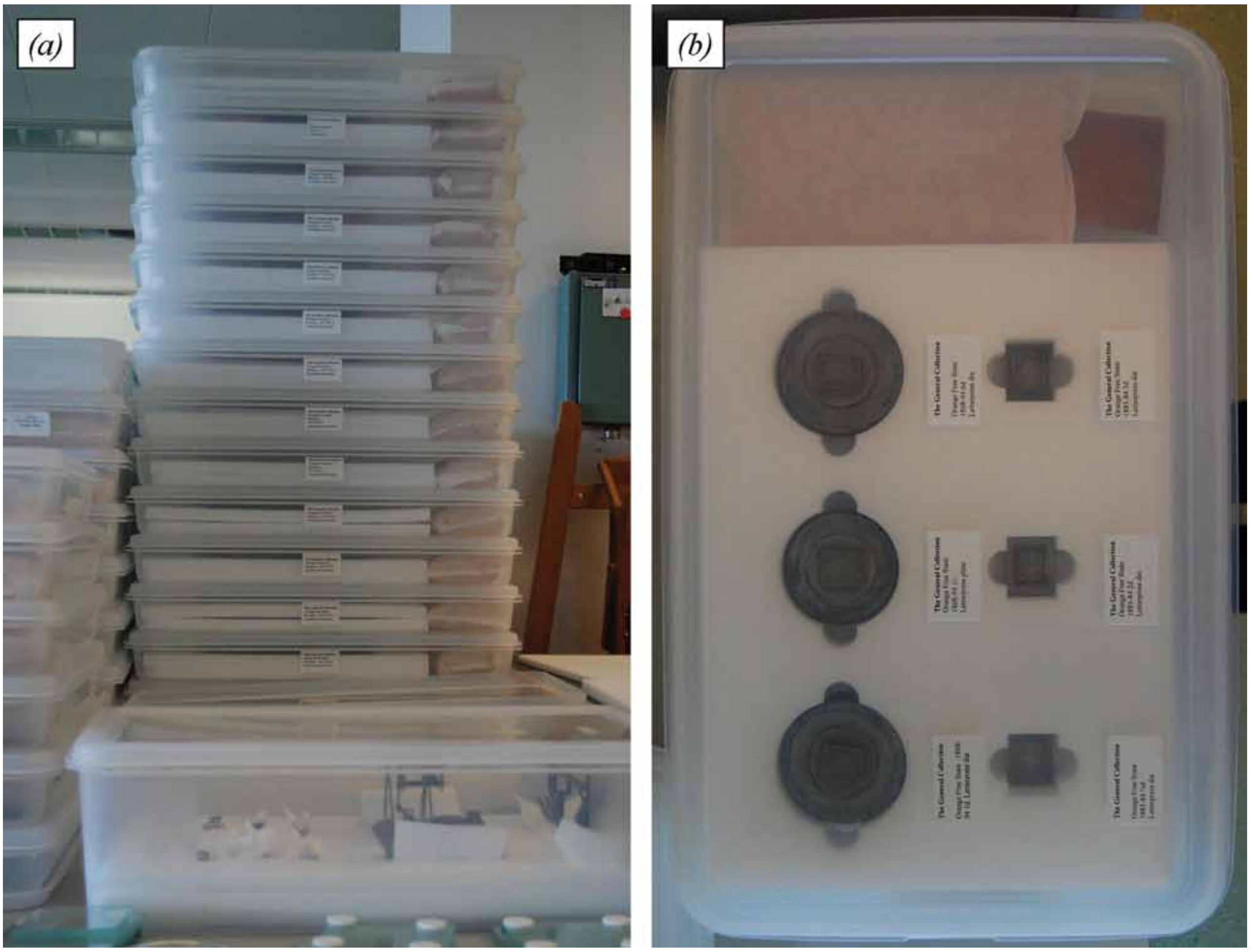

Fig. 4: (a) The new storage system in use; **(b)** an individual storage container - the transparent lids allow the housed items to be readily identified; the silica gel package and the corrosion intercept material can be seen in the box at the top of the image.

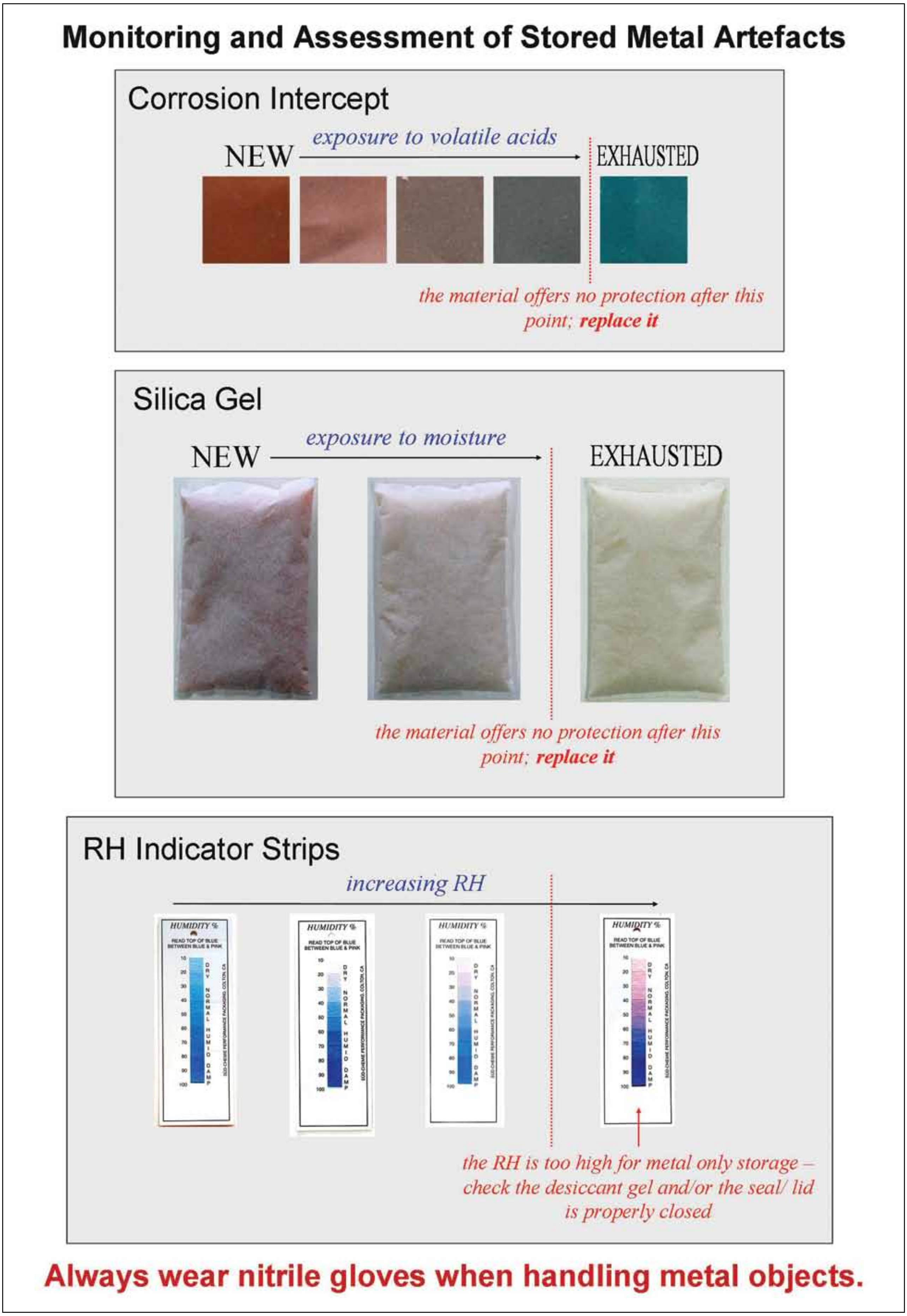

Fig. 5: Advice sheet for long-term condition monitoring and assessment.

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