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Original article

# The effectiveness of dust mitigation and cleaning strategies at The National Archives, UK

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ABSTRACT

Cultural heritage institutions allocate considerable resource to mitigating the risks of dust in their collections. In archives and libraries boxing collections and cleaning regimes go some way to address the problem. However, evidence of the efficacy of these methods is difficult to validate experimentally as dust is very difficult to see. To evaluate the efficacy of our boxing and cleaning programmes, The National Archives' Collection Care Department developed a method that used UV-fluorescing powder to mimic the movement and dispersal of dust during experimental cleaning and handling scenarios. Visual evaluation of dust dispersal enabled a qualitative assessment of the efficacy of existing collection cleaning techniques. Photographs and videos confirmed the value of vacuuming as the most efficient method of removing dust in comparison to other methods, and validated the usefulness of folders and boxes in limiting dust deposition and transfer onto archival documents.



## 1. Introduction and research aim

The National Archives (TNA) is the UK government's national archive for England, Wales, and the United Kingdom. Situated in Kew, west London, TNA houses almost 180 km of archival documents that span 1000 years of history. The collection is comprised of mainly paper and parchment documents in many formats including volumes, bundles, folders, rolls, and flat sheets, but also photographic, plastic, and textile material.

Dust presents a risk to cultural heritage collections as it can discolour or disfigure heritage materials. Surface cleaning to remove dust can cause mechanical damage to the surface. Extensive research into dust within museum and historic house contexts has addressed the risks it poses to collection items during open static display [1–4]. However, in an archive or library context, collection material is frequently retrieved and handled, which introduces the possibility of dust transfer from storage areas to collection items via people's hands.

The majority of collection items in The National Archives are housed in boxes or bags on open shelves in restricted access areas with controlled environmental conditions. Typically collection materials are transported in boxes to and from the public reading rooms where the boxes are then opened, closed, and the documents are handled. Approximately 5% of the collection is requested for viewing each year, with the most popular documents being requested 10 times a year.

Currently, the busiest areas of the storage areas are cleaned twice and the quieter areas once, every four years. To prevent damaging the collection neither water nor chemicals are used during cleaning. Cotton cloths, microfiber cloths, and lamb's wool dusters are used for collection material while metal shelving is cleaned using a fine mist of distilled water sprayed onto a cloth. Floors are cleaned using static mops and vacuum cleaners.

In-between these cleaning cycles a layer of dust accumulates on the boxes and shelves, so we needed to understand the risk that this presents to the collection. How much dust is too much? The study of dust in heritage institutions to date has concentrated primarily on source identification through monitoring and characterisation [5–7] and there is a lack of qualitative and quantitative assessment of recommended mitigation strategies such as cleaning tools and archival enclosures.

This investigation therefore aims to address this knowledge gap by assessing the effectiveness of boxes as part of a wider dust mitigation strategy and by identifying the most effective cleaning method for TNA's archival storage areas with the view to informing practice in other collections. Two specific scenarios were identified for investigation: one, the probability of dust transfer when delivering documents to a reader (Dust Transfer Testing) and two, the effectiveness of different cleaning tools and techniques to remove dust in archival storage areas (Cleaning Technique Testing).

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The evidence emerging from this research informed cleaning programmes at TNA, and has potential for other collections as well. To ensure that the results were clear, the evidence of transfer and removal of accumulated dust needed to be visually recorded. SEM-EDX analysis showed the dust in TNA's storage areas to be composed of small sized particles and fibres of similar colour to the boxes, suggesting that the boxes were the source of the fibres. Given this information we considered the small particles to be of most concern in dust transfer given the possibility of it being abrasive and ingraining into archive material. We chose to replicate this aspect of TNA's repository dust using a UV-fluorescing Glitterbug® powder. Fluorescent substances such as this are used as tracers in theft detection, pest tracking, and leak detection. The Glitterbug® (Brevis) product line is designed for use in hand hygiene training [8]. The powder has a similar particle size to the smallest dust particles present in TNA's storage areas, 4–5 μm wide. Consequently, its behaviour is expected to reliably mimic that of dust in some aspects. A more accurate replication of TNA's repository dust and consequently its behaviour could have been achieved through the inclusion of UV-fluorescing fibres and powders of larger particle size, and assessing the powder for changes in adhesion due to RH fluctuations, however this was not deemed necessary for the scope of this research.


**Fig. 1.** Cleaning tools that were evaluated. (A) 100% pure lamb's wool duster. (B) Dusting brush. (C) Dust Bunny Reusable Nylon dusting cloth. (D) Microfiber cloth. (E) Chintz Duster, 100% cotton dusting cloth. (F) Nilfisk vacuum cleaner with HEPA filtration and brush head attachment.

## 2. Materials and methods

### 2.1. Materials

Both experiments used UV-fluorescing Glitterbug® powder evenly distributed onto a surface using a fine woven metal wire mesh (A5 size, 0.239 mm aperture, 0.063 mm wire diameter SS304 Grade) that was overlaid onto a fine mesh sieve.

Lighting for photographing the results of the experiments consisted of two 3-tube Kaiser 5569 UV-lamps in which each tube was 18 watt UV-A Wave length: 366 nm with a light emitting area of 64 × 21 cm. Office lighting was also used. Following risk and COSHH assessments, appropriate protective clothing was worn.

#### 2.1.1. Additional materials for the Dust Transfer Tests

The Dust Transfer Testing used three archival boxes, each containing non-accessioned folders filled with papers to mimic standard storage protocols. A trolley was used to transport the boxes to a table covered with 350 μm grey archival cover paper.

#### 2.1.2. Additional materials for the Cleaning Technique Tests

The Cleaning Technique Testing used a highlighter, Staedtler® Mars plastic eraser, grater, smoke sponge, and sheets of 350 μm grey archival cover paper and 100 μm Melinex® to mimic the surface of boxes and shelves, respectively.

Cleaning tools were selected for testing based on one of three criteria: their current use for cleaning TNA's archival storage areas, being commercially promoted or professionally cited within conservation literature as appropriate for cleaning archival storage areas. The following cleaning tools were tested (Fig. 1):

- 100% pure lamb's wool duster, in use by TNA cleaning contractors.
- Dusting brush, in use by TNA Collection Care Department (CCD) staff for cleaning.
- Dust Bunny Reusable Nylon dusting cloth, sourced from a conservation supplier.
- Microfiber cloth, in use by TNA cleaning contractors.
- Chintz Duster, 100% cotton dusting cloth, used in conservation practice.
- Nilfisk vacuum cleaner with HEPA filtration and brush head attachment, recommended in professional guidance for cleaning library storage and in use by TNA CCD conservation staff for general cleaning.

### 2.2. Method

Experiments were designed to address five questions: 1. What happens to accumulated dust when an archival box is handled, opened and the documents removed? 2. When a dusty box has deposited dust onto a surface, what degree of transfer occurs between the surface and a clean file? 3. How effective are the cleaning tools and techniques tested at removing dust from boxes and shelves? 4. Which cleaning tool and technique is most effective? 5. Can conservation cleaning methods fully remove ingrained dust?

#### 2.2.1. Dust Transfer Testing – dust transfer from dusty box during handling

Three document boxes each containing replica files were positioned side-by-side on a trolley to replicate the storage of boxes on shelving. UV-fluorescent powder (approximately 0.25 g) was scattered as finely and evenly as possible over the tops of the boxes using a fine mesh laid over a fine sieve, to replicate the dust levels on boxes in storage prior to cleaning. The first box was carried from the trolley to a table and opened. Each of the files within the box were removed and placed on the table next to the box. The first five and last pages in the last file in the box were handled and viewed. All files were then returned to the box, the lid replaced and the box returned to the trolley. This handling sequence was repeated with the second and third boxes. The handling of the three boxes was repeated 15 times with a re-application of approximately 0.12 g of UV-fluorescing powder in-between.

One person completed handling of all of the boxes. Hands were cleaned before but not during testing. The experiment was initially completed under office lighting to minimise the risk of changes in handling of the boxes due to seeing where dust had transferred to. Subsequently, handling was completed under UV lighting to view the movement of UV powder during handling.

After the first and sixteenth handling sequence, surfaces, boxes, and box contents were inspected under UV and office light to determine the extent of dust transfer.

#### 2.2.2. Dust Transfer Testing – transfer from dusty surface to clean folder

A clean four-flap folder was placed and lightly pressed onto a piece of archival card covered in the loose and ingrained UV-fluorescing powder remaining from one box handling sequence outlined above. This action mimics the ideal handling of a full

**Table 1**
Effectiveness of different cleaning tools at removing fluorescent powder from a card surface when viewed under office and UV lighting.

| Tools | Ingrained Powder | | Powder redeposited at lift point | | Powder deposited on re-contact of tool with surface | |
|---|---|---|---|---|---|---|
| | Office | UV | Office | UV | Office | UV |
| Lamb's wool duster | 1 | 1 | 0 | 1 | 0 | 1 |
| Brush | 1 | 1 | 0 | 1 | 1 | 1 |
| Dust Bunny cloth | 2 | 1 | 2 | 1 | 1 | 1 |
| Microfiber cloth | 2 | 1 | 1 | 1 | 1 | 1 |
| Chintz Duster | 2 | 2 | 1 | 1 | 0 | 1 |
| Nilfisk HEPA vacuum cleaner – brush tool | 3 | 1 | 3 | 3 | 3 | 2 |

Scale for relative quantity of powder visible: 0 = large proportion of powder still visible, 1 = some powder still clearly visible, 2 = most powder removed, 3 = all powder removed.

file during use. After inspection under office and UV lighting the folder was pressed firmly onto and slid across the surface to mimic heavier handling. The presence of powder on the folder was visually assessed under UV and office light.

### 2.2.3. *Cleaning Technique Testing – individual cleaning tests*

For each cleaning method approximately 0.12 g of UV-fluorescing powder was distributed as evenly as possible through a wire mesh and fine mesh sieve onto a 45 cm × 45 cm area of archival card or Melinex®. Each cleaning tool was applied to half of the area by wiping from back to front. The cleaning tool was then immediately lightly pressed onto a clean area of the surface to evaluate the potential for transfer of powder from one location to the next. The tool was shaken to remove loose powder and again lightly pressed to a clean area of the surface to evaluate the potential for transfer of powder from a tool that users might consider clean.

The effects of the cleaning tools (Table 1) on the surface distribution of powder were visually assessed under office and UV light for: loose or ingrained powder in the cleaned area; loose powder at the point of lift of the tool from the surface after cleaning; and loose or ingrained powder at the areas of contact of the tool with the surface before and after cleaning of the tool. A scale of 0–3 was used to indicate the visibility of powder present with 0 being the most visible and 3 indicating no visibility.

### 2.2.4. *Cleaning Technique Testing – five-in-one cleaning tests*

Five cleaning methods (vacuum, vacuum followed by barely-damp microfiber cloth, dry microfiber cloth, lamb's wool duster, lamb's wool duster followed by barely-damp microfiber cloth) were tested side by side on one sheet of archival card and one sheet of Melinex® for direct visual comparison under office and UV light. The method was the same as for the individual testing of cleaning methods with the exception that a larger area, 40 cm × 80 cm, was covered with approximately 0.25 g of UV-fluorescing powder.

### 2.2.5. *Cleaning Technique Testing – conservation removal of surface dirt*

A section of the card containing the ingrained UV-fluorescent powder from the individual cleaning test using the 100% lamb's wool duster was cleaned using a Staedtler® Mars plastic eraser (latex-free) in both grated and ungrated forms and a smoke sponge. Cleaning was undertaken under UV lighting until no more fluorescent residue could be removed. The cleaned areas were then compared under UV light and office light.

## 3. Results and discussion

### 3.1. *UV-fluorescent powder as a substitute for dust*

The UV-fluorescing Glitterbug® powder was highly successful in visualising the transfer of dust during handling and cleaning experiments (Figs. 2–10). The presence of powder ingrained or loose on a surface and circulating in the air was easily observed under UV light. Under office lighting conditions, less loose and ingrained powder was visible on surfaces and no circulation of powder in the air was observed.

### 3.2. *Risk of dust transfer to documents*

The Dust Transfer Testing clearly demonstrated that boxing archival documents and housing them in folders visibly decreases the risk of contact between dust and archival documents. How-

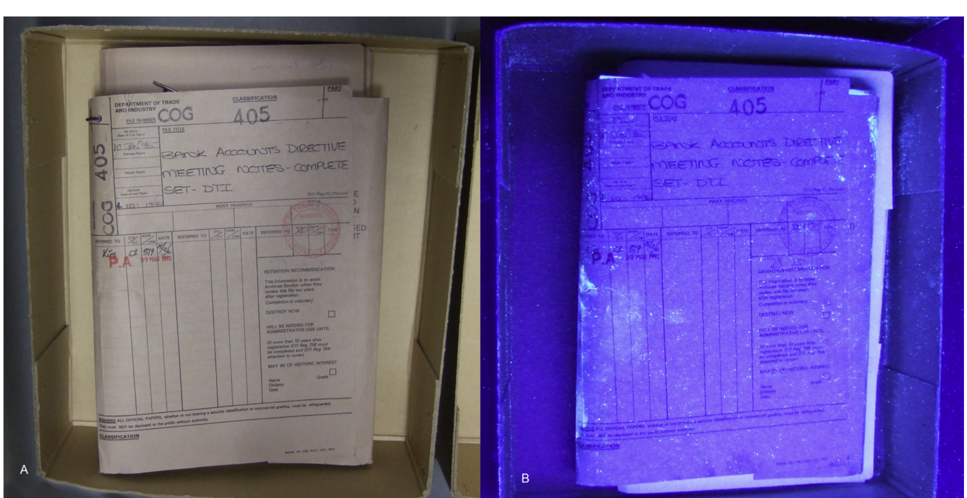


**Fig. 2.** Powder transferred to files visible under (A) office lighting and (B) UV lighting.


**Fig. 3.** Powder remaining on hands after 16 dust transfer sequences (A) as seen under office lighting and (B) as seen under UV lighting.

ever, small quantities of powder, visible only under UV light, did get into the boxes during use. The majority was deposited onto the outer surfaces of the folders rather than onto the documents. While there was negligible accumulation after each opening, after repeated openings dust accumulates in the boxes and affects the appearance, legibility, and potentially the chemical stability of the documents inside.

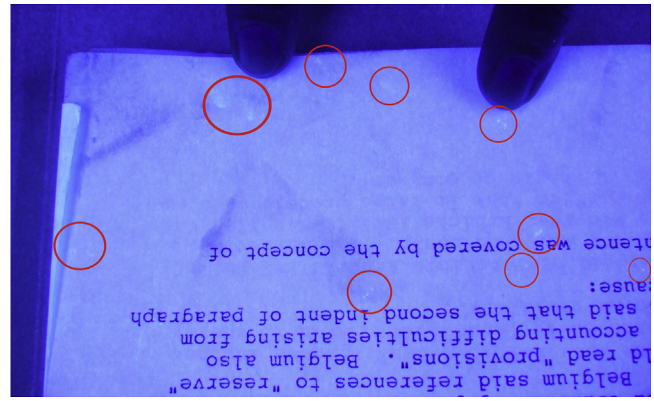

**Fig. 5.** Traces of powder that were found on a document after 16 dust handling exercises visible under UV lighting.

During the experiments the majority of powder transferred from the boxes to the floor, the clothes and hands of the handler, the surfaces on which the box was placed e.g. trolley, shelf, table, and the records/folders inside the box (predominantly the top record/folder in the box) (Fig. 2). Much of the transferred powder was only visible under UV light. Consequently clean-looking surfaces may not be dust-free.

The transfer of powder occurred both directly, through contact of a powder-covered box, surface or hand with a clean surface, and indirectly, through circulation of powder in the air and subsequent deposition. Directly transferred powder was often ingrained into the surface while indirectly transferred powder was often loose on the surface. Loose powder could then be ingrained into the surface or transferred to and ingrained into other surfaces following further handling.

After completing sixteen dust transfer sequences transfer of powder had occurred to the handler's hands (primarily the palms) (Fig. 3). This resulted in subsequent transfer to the records, primarily the edges of the uppermost folders (Fig. 4), and to a lesser extent the documents inside. Indirect transfer was shown to be a particular risk to the edge of pages where an archival document is handled most frequently (Fig. 5). It is therefore important to minimise the quantity of dust entering the boxes through direct or indirect transfer by, for example, removing dust from the outside of boxes and shelving and cleaning hands as often as possible.

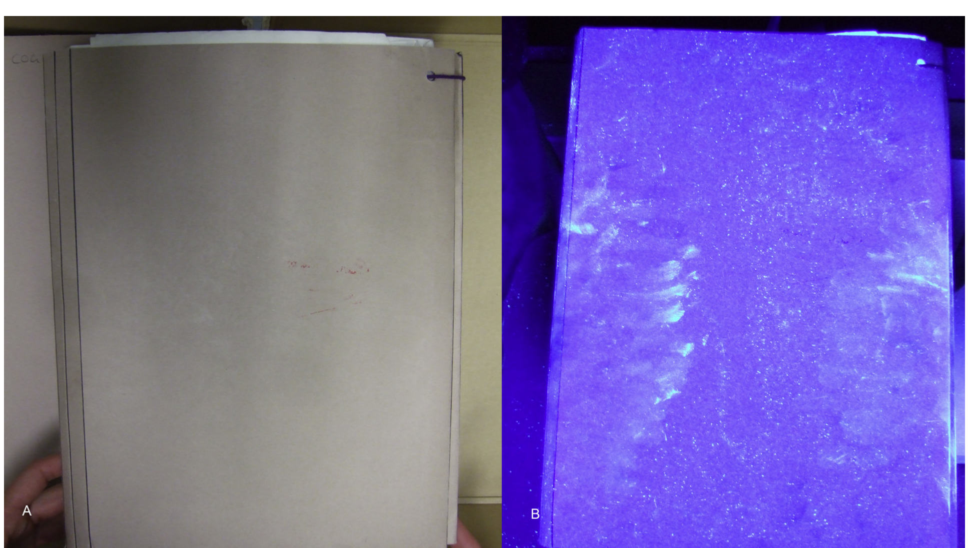


**Fig. 4.** Powder transferred to file folder during handling (A) as seen under office lighting and (B) as seen under UV lighting.

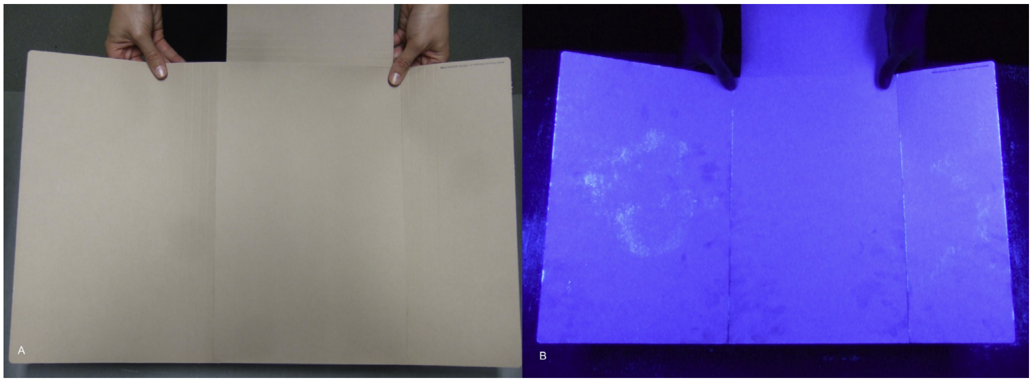

**Fig. 6.** Powder transferred to the outside of a new archival folder that has been moved left and right on a surface with ingrained powder (A) viewed under office lighting and (B) viewed under UV lighting.

Direct transfer of powder also occurred from powder-covered surfaces to other surfaces. Powder was also shown to transfer from the table top to a clean folder both with and without firm pressure (Fig. 6). More powder was transferred when pressure was applied to the folder and some of this was visible under office lighting. It is therefore important to keep hands and surfaces clean during handling of collection material.

### 3.3. *Efficacy of cleaning methods*

#### 3.3.1. *Individual cleaning tests*

Qualitative evaluations of all of the individual cleaning methods are found in Table 1 for tests on archival card to represent the surface of boxes and Table 2 for tests on Melinex® representing the surface of shelves.

Of all the methods tested vacuuming was the most efficient, because it permanently removed the UV-fluorescent powder from the card surface without making the powder air-borne, thus minimising powder redistribution. Minimal levels of powder transfer from the tool to the card occurred before and after cleaning with the brush accessory. The results were only noticeable under UV light whereas the results from the other cleaning techniques were often visible even under office lighting.

The lamb's wool duster picked up a large proportion of the powder, but held on to it ineffectively. Consequently a pile of powder was left at the lift and initial touchdown points. Importantly, powder was visibly circulated in the air during cleaning and subsequently deposited on nearby surfaces where it could be seen under UV. Similarly, the brush moved the powder but did not hold onto it causing the majority to be left at the lift points and some to be circulated in the air.

All of the cloths tested held some powder and caused little circulation of powder in the air. However when the cloths were folded powder was dislodged and redistributed on surfaces. The microfiber cloth retained more powder than the cotton cloth, and the barely-damp microfiber cloth retained further still due to its dampness.

Contact between any of the cleaning tools and the card surface led to the ingraining of some powder into the card. The cloths and lamb's wool duster ingrained powder more than the vacuum with brush attachment (Fig. 7).

#### 3.3.2. *Five-in-one cleaning tests*

The difference in the effectiveness of each of the cleaning tools is clearly visible in the five-in-one tests particularly under UV light and, to a lesser degree, under office light. The observations made confirmed those from the individual cleaning tests. Vacuuming proved to be the most successful cleaning method on both Melinex® (Fig. 8) and card (Fig. 9). A barely-damp microfiber cloth was effective in removing remaining powder from the areas of Melinex®

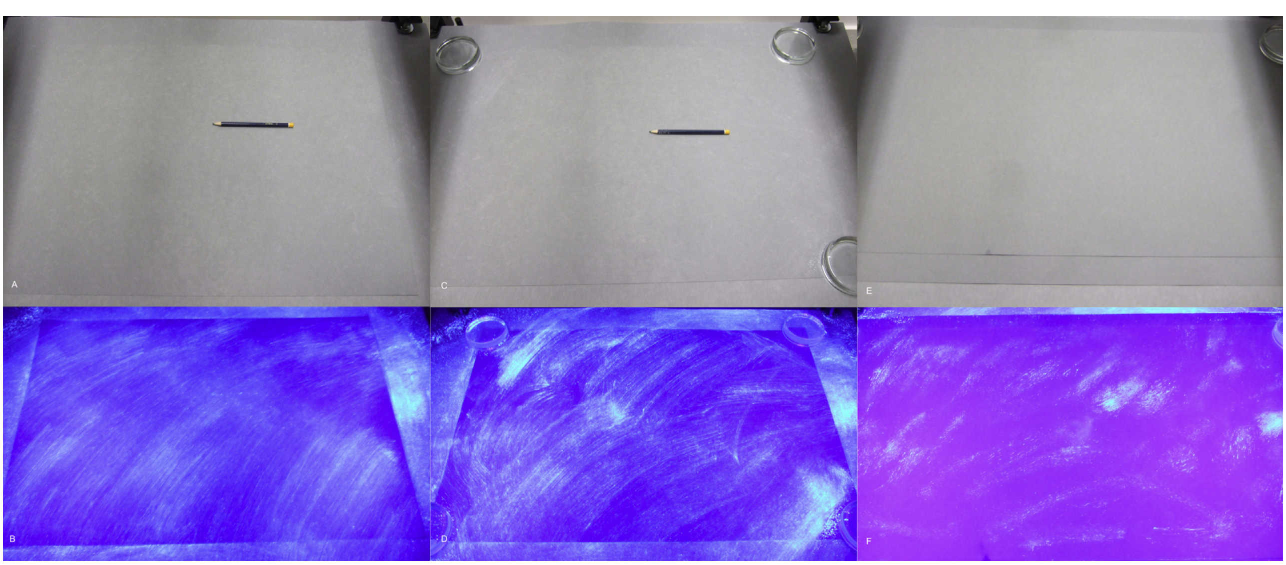

**Fig. 7.** Card surface after cleaning under office lighting (top row) and UV lighting (bottom row) with (A and B) 100% lamb's wool duster, (C and D) microfiber cloth and (E and F) Nilfisk HEPA filter vacuum cleaner with brush attachment.

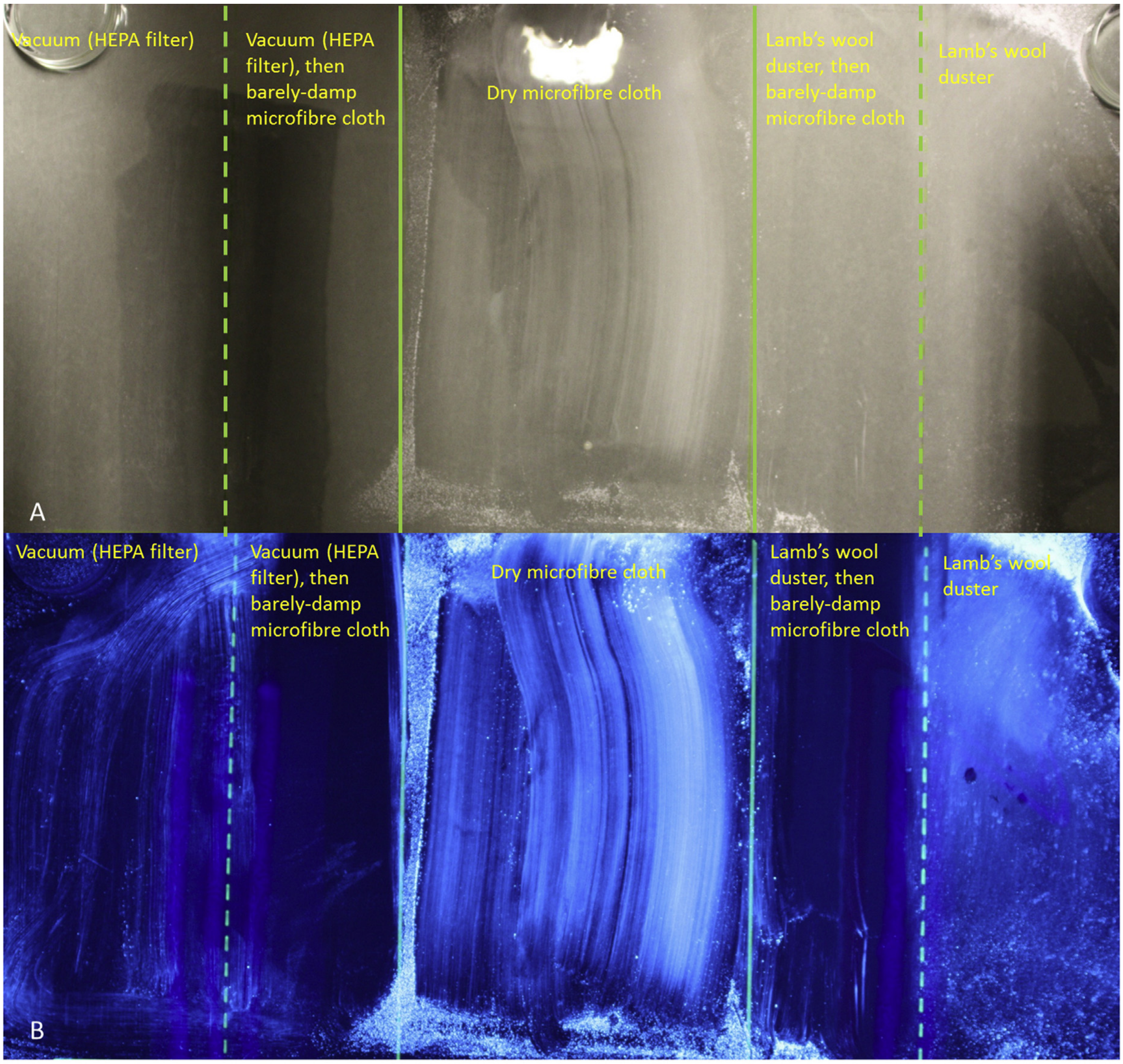


**Fig. 8.** 5 in 1 cleaning test results carried out on Melinex® to simulate the surface of shelving in (A) office lighting and (B) UV lighting.

that had been pre-cleaned using the vacuum cleaner or lamb's wool duster. This method also removed powder from the card but ingrained powder remained. Since moisture should not be used on collection material and their housing, it is recommended that the barely-damp cloth is only to be used on the metal shelving and window ledges in the storage area.

*3.3.3. Conservation removal of surface dirt*

The Staedtler® Mars eraser was the most successful at removing ingrained powder from the card however, despite conservation-grade cleaning, powder was still present in the card. This was only visible under UV light thereby highlighting that clean-looking surfaces may still contain ingrained dust (Fig. 10). Over time, a build-up of ingrained dust could cause discolouration to the surface, provide a potential food source for pests and mould and impact the chemical stability of any archival material. As it cannot be fully removed once ingrained it is imperative for dust ingress into boxes and subsequent transfer onto collection material to be prevented and for clean hands and surfaces to be used during handling of collection material.

**Table 2**
Effectiveness of different cleaning tools at removing fluorescent powder from a Melinex® surface when viewed under office and UV lighting.

| Tools | Ingrained Powder | | Powder redeposited at lift point | | Powder deposited on re-contact of tool with surface | |
|---|---|---|---|---|---|---|
| | Office | UV | Office | UV | Office | UV |
| Barely – damp microfiber cloth | 2 | 2 | 1 | 1 | 0 | 1 |
| Lamb's wool duster | 2 | 0 | 0 | 0 | 1 | 1 |

Scale for relative quantity of powder visible: 0 = large proportion of powder still visible, 1 = some powder still clearly visible, 2 = most powder removed, 3 = all powder removed.

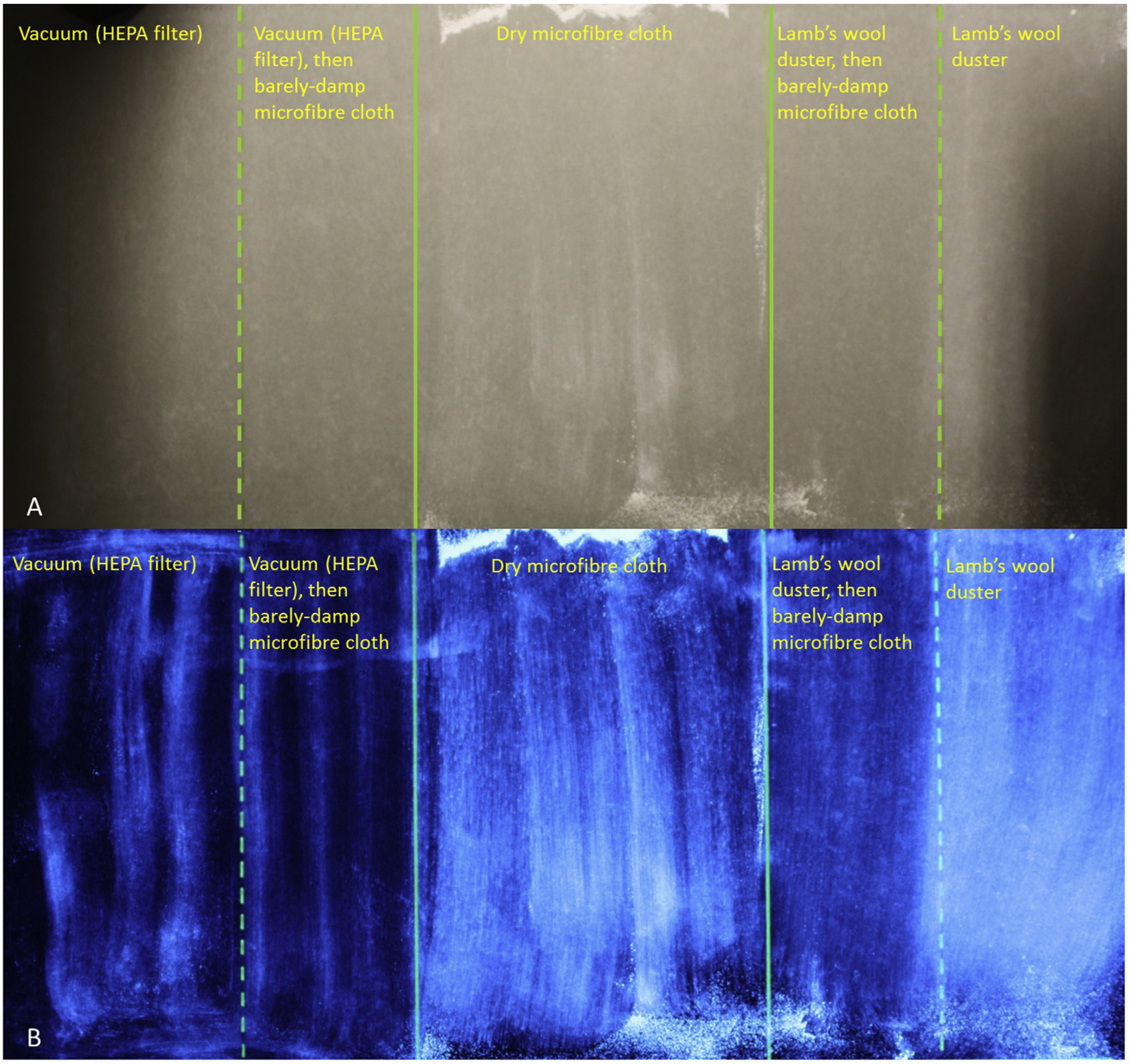


**Fig. 9.** 5 in 1 cleaning test results carried out on card to simulate the surface of an archival storage box in (A) office lighting and (B) UV lighting.

## 4. Recommendations

Evaluation of the evidence provided by these experiments resulted in recommendations to TNA's Estates and Facilities Department. These recommendations then informed discussions between departments as tenders were being drawn up for the contract that included the cleaning of TNA's archival storage space. The recommendations were:

*Cleaning shelving and window ledges*

- Vacuum (with HEPA filter) the shelf or window ledge and then use a barely-damp microfiber cloth to remove remaining dust. If vacuuming is not possible, use a damp microfiber cloth followed by a dry microfiber cloth (to remove moisture) as the dust stays on the damp cloth more than on a barely-damp or dry microfiber cloth. Note that to maintain maximum control of moisture within the storage areas during cleaning, the cloth must be sprayed with distilled water rather than the shelf. Water must not come into contact with collection material or their boxes.

*Cleaning boxes*

- Vacuuming the boxes followed by a dry microfiber cloth at the same time as cleaning the shelving is recommended. All sides of the boxes should be cleaned. As a minimum, a dry microfiber cloth must be used to clean the exposed areas of the box that are most likely to accumulate dust.
- Before use in or transfer from the storage areas, wipe boxes using a dry microfiber cloth. This will minimise the dust transferred to the documents when handled.

In addition, the research supported a number preservation practices that are already in place and that should continue as it has been demonstrated they play an important role. These include:

*Housing the collection*

- Boxing the collection is an effective way of minimising the risk of dust to collection material by keeping the vast majority of dust away from archival documents.
- Secondary housing such as folders are an effective method of further minimising the contact of dust with collection material, although some dust particles are still able to reach the records themselves.

*Cleaning of shelving*

- Use a top to bottom approach when cleaning i.e. top shelves first, and clean bays that back onto each other at the same time to minimise transfer from bay to bay while cleaning.

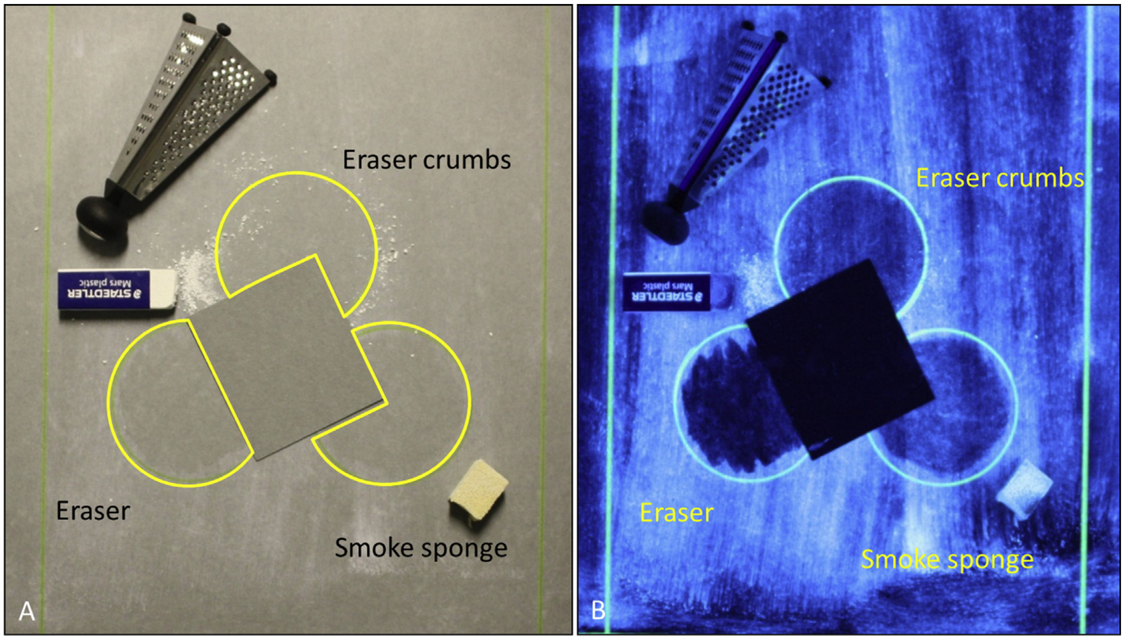


**Fig. 10.** Removal of powder using different mechanical conservation cleaning techniques with the results seen under (A) office lighting and (B) UV lighting.

*Clean hands*

- Current guidelines for staff and the public require that hands be clean before handling archival documents. This research demonstrates that there is cause for cleaning hands as often as possible while handling archival documents to minimise the risk of dust transfer.

## 5. Conclusions

The use of UV-fluorescing powder of similar size to the smallest dust particles present in TNA repositories has been valuable in evidencing the transfer of dust and establishing the efficacy of dust mitigation strategies. UV light showed the presence of low quantities of the powder that were not visible under office lighting conditions. Powder transfer occurred directly via contact between surfaces and indirectly via air circulation. The powder was easily ingrained into the fibrous surfaces of paper documents and boxes after which it could not be fully removed using conservation cleaning methods. Boxes and folders were effective at protecting the enclosed records from the majority of powder although low quantities of powder did get into the boxes on each opening. Consequently, removal of dust from archival storage areas in addition to the use of secondary housing such as folders, is key to mitigating the risk posed to the collection from the transfer of dust. Vacuuming (HEPA filter required) was the most effective method of removing dust without direct or indirect dust redistribution. Due to the high chance of dust redistribution, lamb's wool dusters are no longer in use in TNA's repositories. Microfiber cloths are more effective than the other cloths tested and damp cloths are more effective than dry. However, damp cloths are only to be used on shelves and window ledges as moisture should not be used on boxes housing collection material. A series of recommendations for cleaning storage areas has been made based on experimental results to colleagues in the Estates and Facilities Department to inform TNA's latest cleaning contract. As a result, some areas in storage are now being vacuumed and Collection Care staff is carrying out further testing on cleaning tools to ensure dust removal is optimised within the new cleaning contract arrangements.

## Acknowledgements

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