Monitoring Deposited Dust in The Old Library, Trinity College Dublin

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Abstract

A study is currently being undertaken to characterise the accumulation rate, distribution, particle size, type and source of dust in the Old Library, Trinity College Dublin, in order to investigate its impact on the collection of more than 300,000 books and manuscripts held there. The majority (approximately 200,000 books, dating from 15th – 19th century) are held on open shelves in the Long Room and Gallery. As well as being a research facility, the Old Library is an exhibition space, and a major tourist attraction as home to a renowned medieval manuscript (the Book of Kells, *c.800). It is open to the public seven days a week, almost year-round.*

1. Site context

The campus of Trinity College Dublin is an island of over 40 acres, situated in the heart of the city *(fig. 1)*. As such, it is surrounded by heavily trafficked roads and neighbours busy building sites as the urban landscape is continuously revised. The Old Library (c. 1712-1732) is the repository for the university library's treasures, one of the landmark buildings on campus, and a protected structure. The principal space is a double height room (Long Room and Gallery), located on the first and second floors of the three-storey purpose built structure. This space is approximately 65m in length with an estimated volume of 9000m^3. Bookstacks in the Long Room and Gallery are arranged along the north and south side of the space, perpendicular to the external walls *(fig. 2)*.

1. Trinity College Dublin, campus map (Old Library marked with a star).

Almost half a million visitors pass through the Old Library annually, following a defined route. Visitors enter at ground floor level on the south side of the building (colonnades enclosed c.1890), visit the exhibition and gift shop on that level, arrive at the Long Room via the staircase in east pavilion (remodelled mid-1960's), walk around the Long Room (no public access to the Gallery), and return to the ground floor by descending the centrally located staircase (enlarged c.1990).

Only a very small proportion of the collection is housed in environmentally controlled conditions, the majority rely on the 'passive' micro-environment within the building. Windows are single glazed timber framed, and are habitually opened during the warm summer months when visitor numbers peak. A double row of ropes separates visitors from bookstacks in the Long Room by at least 1.2m. The Long Room and Gallery are the daily workplaces for several people including preservation assistants, security guards and library staff.

2. Why study dust?

Apart from being visually undesirable [1. Lithgow *et al.*, 2005], dust is hazardous to cultural heritage as it can accelerate and complicate degradation [2. Brimblecombe *et al.*, 2009], and is a potential health hazard [3. Morawska & Salthammer, 2004]. Dust is a heterogeneous mixture of organic and inorganic matter. Its constituents are not necessarily separate or friable, and may have adhesive qualities. Particles can be large or tiny, inert or reactive, benign or harmful. The mechanisms by which particulate matter accumulates mean that it can vary from sample to sample, and even from season to season within the same environment. Consequently, dust is challenging to characterise.

Due to the nature of the Old Library it would be impossible to eradicate all dust and create a 'clean room'. Therefore we must try to understand the dust:
Accumulation rate – can we establish how much dust is deposited during a certain period of time?
Distribution – is the same amount of dust deposited everywhere in the Old Library, or are there areas where there is less or more dust?
Particle size – are most of the deposited particles sub-micron, micron, or millimetre sized in diameter?
Particle type & source – can we assess where most of the particles come from i.e. the collection, visitors, the building, wider environment?

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2. Long Room and Gallery looking east.

3-4. Dusty books.

Particle deposition is the result of a complex interaction of physical and chemical processes, influenced by environmental variables. With regard to the Old Library, location within Long Room, Gallery, Attic or Colonnades, proximity to window or aisle, or gap between book head and overlying shelf may all be factors which influence dust accumulation. Surface texture and the presence of water (as vapour) may also play a part. Particle size has a considerable effect on particle deposition rates, and there is a relationship between increasing deposition velocity and increasing particle diameter [4. Christoforou *et al.*, 1993]. Air velocity adjacent to surfaces and the temperature difference between a surface and the adjacent air are important factors governing the deposition rate of fine particles [5. Nazaroff *et al.*, 1990]. Coarse particles (>10μm) settle onto horizontal surfaces under the influence of gravity, while fine particles (such as elemental carbon produced in combustion systems) are capable of depositing onto vertical surfaces by diffusion and thermophoresis [6. Salmon *et al.*, 2004].

In 2003 the Department of Preservation and Conservation initiated investigations into the high levels of dust on the collections in the Old Library to determine whether it constituted a risk to the preservation of the collection or to staff handling the collection, and if the source of the dust could be readily identified. As the entire collection was affected and the soiling impacted anyone handling or using the collection, a complete clean of the books was overdue and essential *(fig. 3-4)*. After a 12 month trial preservation project, fundraising under the banner 'Save the treasures of the Old Library' was launched in 2005. This project aims to remove the dust from books and shelves, to provide minor repairs to bindings, and to record the condition, structure and treatment of each volume in a database. The work is carried out by teams of preservation assistants, who are trained and supervised by a conservator. With the estimated cost of the project at 2 million, a thorough investigation of the particulate pollution levels in the Old Library was required.

Existing dust samples were analyzed using XRD (x-ray diffraction) by the Geology Department, TCD. Macroscopic particles were also separated visually. The results indicated that:

- sources of the dust on the collection come from both inside and outside the structure;
- there was a significant amount of coarse inorganic particles on the collection;
- a significant portion of the dust was products of the collection such as leather, resin, wax and paper – this suggested that the collection was decaying;
- some constituents of the dust are hazardous to library collections.

These findings heightened interest in the college community about preserving the collection for the future. At this point it was considered important to bring the issues of the collection to a wider audience, and to participate on the international platform of the Cost D42 initiative as a way of benefitting from and participating in a wider dialogue on a little studied area of heritage preservation. Cost D42 was a European initiative (2007-2010) with the main objective of studying chemical interactions between cultural artefacts and the indoor environmental conditions, through field studies and laboratory experiments and to translate the results into preventive conservation practice. Local support from the Library and the Geology Department made it possible to create a PhD project (commenced Spring 2009) focussed on particulate pollution in the Old Library in order to address issues of soiling, damage and monitoring in depth. This project is concerned primarily with contemporary dust, as the existing dust is being removed through the 'Save the Treasures of the Old Library' programme. Through characterisation, assessments may be made as to how Old Library dust might age, and historic damage patterns seen in the collection may be better understood.

3. Monitoring dust accumulation

3.1 Method: 'Loss of gloss' technique

There is no widely recognized or standard method for dust monitoring in museums or historic properties. Ease of use, cost effectiveness and portability were among our requirements. These were fulfilled by the 'loss of gloss' technique, which uses a standard glass microscope slide as a dust collector. The concept of dust soiling a glossy surface and its subsequent measurement using a standard 45° angle dust meter was published by Brooks & Schwar [7. Brooks & Schwar, 1987]. Schwar went on to develop the technique [8. Schwar, 1994], and Adams later published a modification of the technique [9. Adams, 1997]. The dustiness of the slide after exposure for the desired period is quantified by measuring the reduction in surface reflectance relative to a clean unexposed slide. The instrument for measuring the reduction in reflectance has a light source, one or more detectors, and digital display of gloss level. The device is calibrated using a base-plate of known reflectivity and 'zero-reflectance' standard. A Novo-Gloss Trio by Rhopoint Instruments – with detectors at 20°, 60° and 85° angles – was used. The 60° angle was regarded as the reference angle, and the reflectance measurements generated by the instrument as 'gloss units' (GU) have been used here *(fig. 5)*.

All glass slides are cleaned with acetone, and the clean measurements recorded at the beginning of the sampling period. At the 60° angle, the Novo-Gloss Trio measures an elliptical area of approximately 157mm^2 on a glass slide. A template was made to facilitate the measurement of the same ellipse when the slide is clean and dirty, thereby reducing operator error and allowing clean and dirty measurements for each slide to be directly comparable. These 'differences' were used to assess and compare soiling in our experiments. Prior to use, a study was carried out to assess instrument precision. Results were within the specifications outlined by the manufacturer.

The use of glass microscope slides has several advantages. They are widely available, inexpensive, well characterised, easy to handle and inconspicuous when in situ. However, glass slides are not directly comparable to the objects in the Old Library, therefore measurements obtained may only be suitable for qualitative interpretation unless relationships to real surfaces can be demonstrated. There are significant unknown factors in passive sampling. Dust deposition is not necessarily linear and it is easy to imagine how losses from a glass slide dust collector could occur. Furthermore, the relationship between water vapour (humidity) and particle attraction/repulsion/retention is complex and little understood, as is the thermal discrepancy between the glass slide and object studied. Comparison of acquired data with other similar studies is not straightforward as local conditions and materials will vary, as might sampling period and instrument used for measuring reflectance.

5. Novo-Gloss Trio by Rhopoint Instruments.

3.2 Experiment 1: general soiling patterns

Preliminary studies indicated that particulate deposition appeared to be greater at Gallery level than at Long Room level, and that there tended to be greater deposition levels in the area of the centrally located staircase. Based on this, an experiment was designed to:

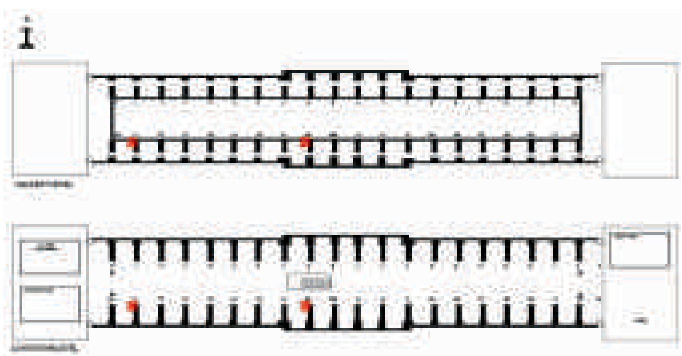
1. compare soiling between the centre and west sides of the Long Room and Gallery;
2. examine if there were seasonal differences in soiling;
3. assess if there was a difference in dust distribution over a defined vertical range.

Four dust collection sites were selected: two in the Long Room (LRI, LRII) and two in the Gallery (GI, GII). All sites were on the south side of the room, and those in the Gallery were directly overhead those in the Long Room *(fig. 6)*. A purpose built stand with shelves at 10cm intervals was made for each collection site and all stands were attached to existing bookstacks (*fig. 11*).

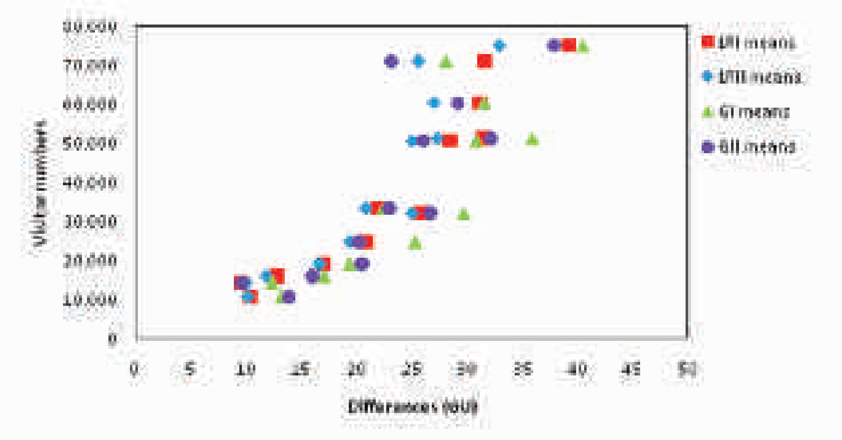
In the Long Room, stands had a vertical range of 0m (floor level) to 2m, and were located approximately 1.2m from the visitor route and 3m from the nearest window. Due to the Gallery balustrade, stands in these upper locations had a vertical range of 1.2m above floor level to 2.1m, and were approximately 2.4m from the nearest window. Each shelf held one glass slide which was measured every 31 days (monthly), and one glass slide which was measured at the end of the sampling period (duration). Other dust collectors were trialled but will not be discussed here. The sampling period was from 03 August 2009 to 10 August 2010.

Results:

1. In general terms, soiling was greater in the centre of the room than in the west, and soiling in the Gallery locations was greater than Long Room locations. The centre Gallery location (GI) had the highest overall average deposition in 8 out



6. Location of dust collectors (Experiment 1).



7. Visitor numbers plotted against mean differences (Experiment 1).

of 12 months. With regard to the slides exposed for the duration of the sampling period, the centre Gallery location was the most soiled of the four, and west Long Room (LRII) was the least soiled. 'Loss of gloss' measurements were not linear. It appears that the instrument measurement is not linear, and soiling is not linear, and we have not yet been able to disassociate the two. The sum of twelve monthly measurements was not equal to the single measurement of the duration slide. In fact, the sum of monthly averages was approximately three times the duration average for each location.

2. When average deposition for each location was plotted against the months, all are highest during Aug/Sept and drop down to the lowest recording in Dec/Jan, then pick back up in Feb. When average deposition for each location was then plotted against visitor numbers the strong relationship suggested that this variable was highly influential *(fig. 7)*. Large visitor numbers, the summer months, and increased ventilation are all closely connected in the Old Library. It is impossible to single out one as the main cause of increased soiling.
3. In order to examine vertical distribution of dust deposition, the data for all months was averaged by height. Vertical distribution may display some interesting local trends, but averaged vertical distribution for 12 months shows none *(fig. 8)*.

3.3 Experiment 2: a closer look at soiling patterns

A follow up experiment broadened the area examined and was designed to:

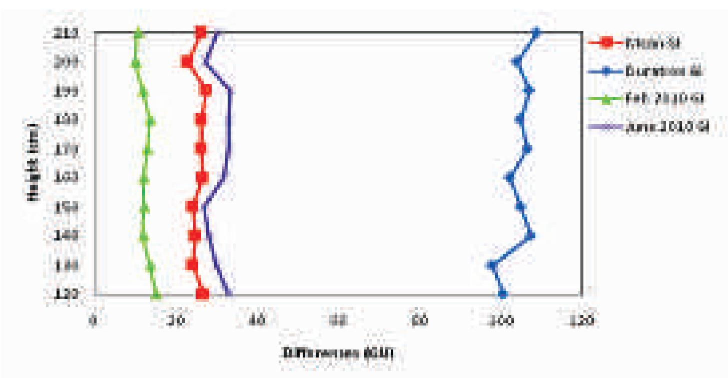
1. compare soiling between locked storage areas and public areas;
2. assess if there is a difference in soiling between either end of the same shelf;
3. assess if there is a difference in soiling from front to back of shelf;
4. identify soiling 'hot spots'.

Sampling locations included the East Attic, Upper Colonnades, Lower Colonnades (locked bookstacks with limited staff access); the Fagel cage (locked bookstack and workspace of preservation assistants), four sites in the Gallery (limited staff access); and four sites in Long Room (public space) *(fig. 9)*.

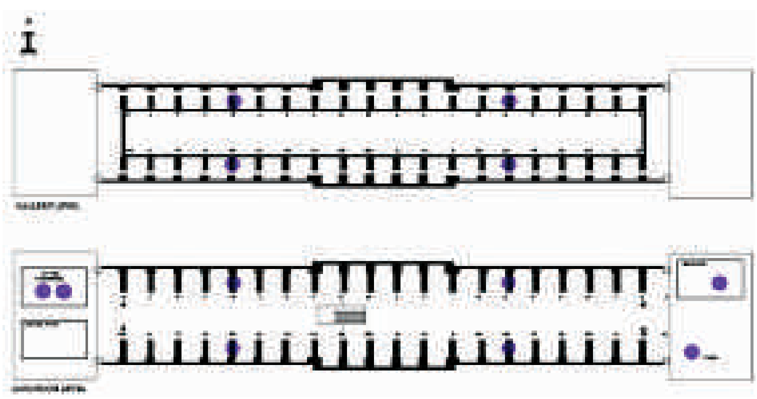
Book shaped boxes (book blocks) were fabricated to imitate the dimensions of the volumes temporarily removed from shelves to accommodate the experiment (*fig. 12*). The heights and depths of all shelves were considered. A pair of book blocks was placed at each sampling location, at either end of the shelf. At the front and back of each book block were a glass slide which was measured every 31 days (monthly), and a glass slide which was measured at the end of the sampling period (duration). Other dust collectors were trialled but will not be discussed here. A data logger measuring ambient temperature and relative humidity was also placed at each location. The sampling period was from 10 June to 13 December 2010.

Results:

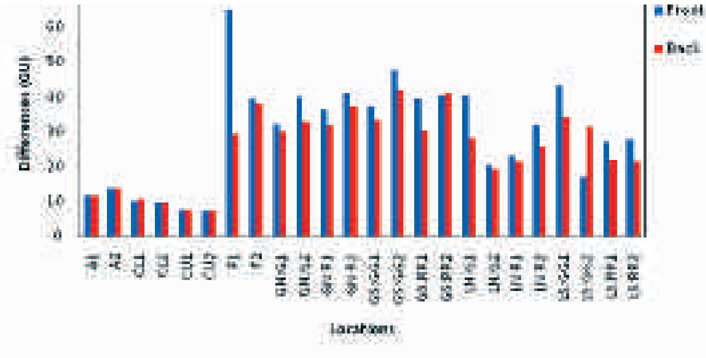
1. As may be expected, the locked bookstacks with limited staff access (i.e. enclosed areas with the least human activity) had the lowest soiling. Soiling from highest to lowest was: Fagel cage, Gallery, Long Room, Attic, Lower Colonnades and Upper Colonnades. In areas where there is day to day human activity, there appears to be a drop off in soiling from July to December. When monthly and six monthly averages are compared, the pattern is almost identical. Therefore it is reasonable to conclude that monthly averages provide a good indication of a longer term average for the same locations.
2. Where there was little soiling, location on shelf made no difference. In areas where soiling was high, the end of a shelf closest to human activity was consistently more soiled than a more sheltered end, even if that end was in proximity to a (closed) window.
3. In general terms, over a six month period the front of a shelf was more soiled than the back. However where there was little soiling no significant difference was observed *(fig. 10)*. The gap to overlying shelf and how the shelf is packed appears to be influential. A large gap and a loosely packed



8. Differences over a vertical range (Experiment 1).

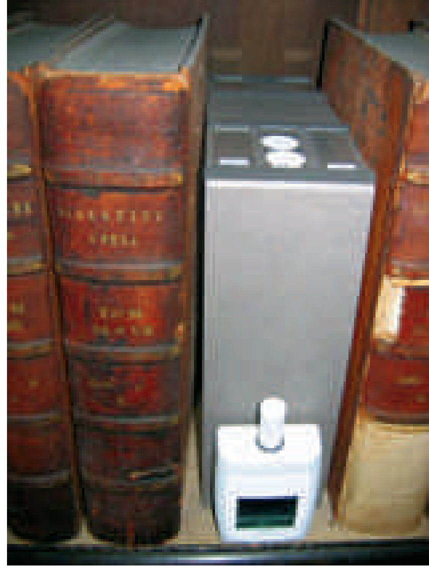


9. Location of dust collectors (Experiment 2).



10. Differences after 6 month period (Experiment 2).

11. Shelves (Experiment 1).



12. Book block (Experiment 2).

shelf provide more available surfaces for deposition than a small gap and a tightly packed shelf.

4. Over the longer period of 6 months, it seems that the east end of the Long Room close to the walkway is a dust hot spot, as considerable differences have been recorded here. The passageway area of the Gallery, both north and south sides also seem to be soiling hot spots. All of these locations are associated with regular staff or visitor activity, however it cannot be assumed that the same deposition patterns are at play in all locations.

4. Conclusions

An understanding of dust in the Old Library will inform the preservation requirements of the collection, and allow a reasonable prediction of the useful lifespan of books stored on open shelving in a working library that is almost 300 years old. It is both expensive and damaging to the collection to maintain a continuous programme of cleaning.

For the foreseeable future, the 'passive' microclimate which exists in the Old Library will remain unchanged. Based on our research to date, we can be confident that dust would continue to accumulate even if the building were to be closed to visitors, as it would penetrate through leaky windows and be generated from the inevitable degradation of interior finishes and the collection itself.

While there are inherent limitations to the 'Loss of gloss' technique and the use of glass slides, there are valid and persuasive advantages. One of which is its portability, allowing many measurements to be made at many sampling locations. The data presented in this paper is based on 2718 individual measurements at sixteen locations within the building.

Our research has demonstrated that soiling from dust deposition varies throughout the year and varies greatly within the building. This has allowed us to identify dust hot spots. Analysis of data from the experiments described above is ongoing as characterisation of dust with instrumental analysis is carried out. The existence of different types of dust in different areas is being studied. Data from dust collectors other than glass slides is also being assessed and possible correlations are being tested.

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