A holistic appraisal of environmental conditions in the National Archives, UK

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Abstract

The National Archives (TNA) UK, formally the Public Record Office, houses over 10 million records that span over a thousand years of English and British history. The collection currently occupies approximately 180km of shelving and is stored in two purpose built, environmentally controlled buildings at Kew, London. This facility opened in 1996 and was designed in accordance with best practice guidance at the time, as set-out in British Standard 5454. This standard recommends that environmental storage conditions be maintained at 16-19°C ±1 and 40-65% RH ±5%. Prior to the move to Kew the collection had been stored in uncontrolled environmental conditions at a site on Chancery Lane, central London, for approximately 150 years.

TNA has always taken seriously the preservation of its records. It supports a comprehensive preservation programme, which includes rigorous environmental control. However, recent mechanical problems with the air-conditioning systems, coupled with a greater appreciation of the high cost, both financial and environmental, in maintaining these mechanical systems designed to meet BS5454, prompted a comprehensive review of our current environmental control programme.

This paper will set-out the context for environmental standards maintained at TNA, it will describe the background issues prompting a holistic appraisal of TNA's current environmental provision, it will describe the findings of research projects underpinning our review, and will discuss how it is striving to translate research findings to support the environmental appraisal and to inform its future programme of stewardship.

Research projects supporting the environmental appraisal: a summary

IDAP 150: a comparative study of two groups of parchment records

The conservation science section assessed two groups of parchment records stored in two contrasting microclimates for a period of approximately 150 years. Using IDAP (Improved Damage Assessment of Parchment) protocols, this project aimed to determine if there was a difference in the deterioration of historic parchment records kept in two environments. The Conservation science assessed two groups of parchment records that had been stored in contrassting microclimates for a period of approximately 150 years. Results thus far indicate no significant difference between the two groups, although the interpretation of these findings is open until the fibre assessment is completed.

Risk assessment models

Using risk assessment models developed over the last ten years, TNA is undertaking a comprehensive evaluation of hazards to its collection. The risk assessment will help prioritise work and ensure responsible resource management.

Climate mapping exercise

A climate mapping exercise is underway in all storage areas. The results will be used to develop TNA's environmental monitoring programme as well as to improve the hardware and the Building Management System (BMS). In addition, we have experimented with the operation of the air-conditioning system and the response of the ambient storage conditions. The effects of these changes were monitored in the storage areas and inside the storage boxes. The evidence gathered from this exercise is being used to establish the thermal stability of the building, and to adjust the air-conditioning settings.

Volatile organic compounds (VOCs)

To understand more about the air quality in TNA's storage areas, we are collaborating in a research project led by The British Library and in collaboration with other partners. This project will characterise and quantify volatile organic compounds present in archive collections.

Collections characterisation

In an effort to ensure appropriate environmental conditions for all the materials in the collection, we are systematically surveying environmentally

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sensitive materials e.g. plastics and photographs, to estimate their condition in order to predict their life expectancy. This information will enable us to prioritise our work and allocate costs effectively.

Introduction

Over the last ten years, the critical environmental parameters affecting paper-based collections. Emerging risk assessment models and the potential of cost-benefit analysis protocols applied to preservation problems are just two examples of cross-disciplinary thinking that is invigorating critical appraisal of preservation policies and practices. Against this background, the Department of Collection Care in The National Archives (TNA) is taking a leading role in delivering a holistic and critical evaluation of current preventive environmental practice within the context of developments in preventive conservation advanced over the last ten years.

The National Archives is the official archive for England, Wales and the central UK government, containing 900 years of historical records from *Domesday Book* (1086) to the present, with records ranging from parchment and paper scrolls to recently created digital records and archived websites. TNA currently holds more than 10 million parchment and paper-based records that occupy 180km of shelving. Before 1978 the records were stored in central London at a site in Chancery Lane. This was a purpose built facility for court records, which in 1838 became the Public Record Office. In 1978 part of the collection was moved from Chancery Lane to Kew in a newly opened extension that provided five repositories. In 1996 a further extension opened adding a further extension opened adding a further 12 repositories. The main entrance of The National Archives links the 1978 and 1996 buildings, known to staff as Q1 and Q2 respectively. Today most of the records are kept on the Kew site with some 20% stored in Deepstore, a salt mine in Cheshire. There were further changes in the development of the Archive. TNA is a constantly evolving organisation; The name changing from Public Record Office (PRO) to The National Archives in response to the merge of the Historic Manuscript Commission (HMC) and PRO.

Figure 1. The National Archives, Kew, London UK

The context: TNA's current provision for environmental monitoring and control

Until a proportion of the records were moved to Kew in 1978, the collection was kept in uncontrolled environmental conditions, so the move clearly marked a significant shift to an improved standard of care. Both buildings at Kew operate air conditioning systems, although each has different air handling and conditioning system. Each is maintained and serviced under a separate Building Management System (BMS), outsourced to a private contractor. Both systems were designed to meet the recommendations in British Standard 5454 [1] which specifies a temperature set point between 16-19°C with ±1°C fluctuation. The relative humidity set point is between 45-60% RH with ± 5% allowable fluctuation.

The scale of operation necessary to maintain environmental standards within the recommended parameters for these two buildings is both daunting and complex. The air conditioning system servicing the repositories, public areas, and offices is controlled by eleven plant rooms in Q1 and nine in Q2. There are 22,000 litres of water in the system in Q2 alone, which is chilled to almost freezing temperatures in order effectively to condition the incoming air. In recent years the two systems have not always coped with extended periods of hot weather during the summer months, nor were they designed to do so. The two systems operate at capacity 365 days a year; this has proved both costly and sometimes ineffective.

There were a number of other factors giving rise to the holistic appraisal of environmental standards policy. First the mechanical limitations of TNA's current air conditioning system, that inevitably will worsen over time, and indeed may be exacerbated in view of the predicted warmer summers in the UK. Our data gathering exercise identified the existence of highly variable local environments in the repositories. Second, given the very few BMS sensors used to monitor the environment, the existence of local environments, not surprisingly, was unknown. Lastly, the newer of the two air conditioning systems in Q2 was already over 10

years old and as expected nearing the end of its useful life and therefore we needed to make provision for its maintenance and replacement.

While we appreciated a compelling need to upgrade TNA's environmental control system, we firmly believe future modifications should be nested in a sustainable environmental policy. TNA is committed to a 'greener' policy, and is actively engaged in developing environmentally responsible and sustainable practices. Tackling climate change is also high in the UK government's agenda, as shown by a recent announcement that all public sector buildings in the UK will soon be required to display their carbon footprint and define and agree targets to reduce carbon emissions [2]. Understanding and responding to the effects of climate change on cultural heritage is an enormous challenge being taken up in the cultural heritage sector, as demonstrated by current research underway in this area [3].

Appraising current policy: recommendations, standards, guidelines

TNA's current environmental standards, like those of most libraries and archives in the UK, are guided by the recommendations in BS5454. The extent to which this 'gold' standard should determine practice is currently being debated in TNA. The foreword to BS5454 makes clear that the standard is a series of recommendations in the form of guidance, although BS 5454 is too often interpreted as a strict definition of storage climate. The slow process of revision also means current thinking on environmental issues and innovation is not captured quickly and consequently the standard is soon out of date. Defined and easily interpreted numerical boundaries for environmental requirements is convenient and therefore attractive to advisory panels and government inspection bodies; however, it does not address the complexity of thoughtful environmental management. Future published guidance, we believe, will place greater emphasis on a risk-based approach to collection management, and will be informed by a range of information such as the kinetics of decay and questions of environmental sustainability.

The environmental appraisal has also prompted us to re-examine the scientific evidence underpinning BS5454. Recommended values of relative humidity and temperature around the mid range were selected primarily on the basis of human comfort and mechanical feasibility, as pointed out by S. Michalski [4]. Other published guidelines [5, 6] have recognised that a single set of recommendations for all contexts is inappropriate. The size, type, the condition of the collection, available resources, storage conditions and local climate are just some of the factors that need to be considered when developing recommendations.

Next steps in TNA's review of environmental standards

The Department of Collection Care is leading the critical evaluation of current preventive environmental practice in consultation with other departments such as Estates, Security, Information Technology and Financial Services. The first step in the environmental review will be to upgrade the air-conditioning system to provide seasonal drift of relative humidity and temperature set points. This change departs somewhat from the long-held view of providing constant climatic conditions and in addition may occasionally lead to levels outside those currently recommended. This accepts that environmental hazards are found in collections, but these risks can be mitigated; it also recognises that different environments are appropriate for collections with different needs. We are also learning from other institutions taking this approach that significant cost savings can be made, and the impact on the environment lessened.

Providing evidence/building a picture: Comparative study of two groups of parchment records

To accumulate the evidence necessary to understand the complex environmental problems and to inform our decisions around TNA's environmental policy, we interpret published research findings as well as supporting other research projects, independently or in collaboration with other external partners. For example, over the last year we have undertaken a comparative study of two discrete groups of parchment records. Varied storage locations through the centuries coupled with the lack of any environmental monitoring data from the National Archives prior to 1998 makes it impossible to associate the current state of preservation of our collection of parchment documents to specific factors of degradation or even further to specific environmental conditions. However, between 1830 and 1994 the collection was stored in the Chancery Lane building. Although there was no mechanical environmental control there were prevailing environmental conditions in the different floors of the building, dictated by their topography

and the building's construction. The move of the records from Chancery Lane to Kew and the development of the Improved Damage Assessment of Parchment (IDAP) [7] protocols presented a great opportunity to undertake a comparative study of the natural ageing of historic parchment documents in uncontrolled environments with that of the controlled environment of the repositories in Kew. Building on the work of the IDAP programme, we assessed two groups of parchment records stored for a period of approximately 150 years in very different microclimates. All the documents examined from the two Groups dated between 1450 and 1500 so they were already more than 350 years old when The Public Record Office was created at Chancery Lane in 1830. Our investigation aimed to determine which of the two sets of conditions had the greatest impact on the overall deterioration of the documents.

The first group of documents (Group A) examined for this study, consisting of two classes of records (C1 and JUST 3), stored on the top floor of Chancery Lane. The second group (Group B), from one class (C4) was stored in the basement. Anecdotal information suggested that the top floor was consistently hot and dry while the basement was known to be cool and damp, as it was situated over the River Fleet, which could be seen from manholes in the floor. Conservators boxing the collection prior to the move to Kew reported the obvious difference in the flexibility of the records stored in those two locations.

The documents from C1 sometimes stitched on the corner and possibly were lightly cleaned during the stitching process. In contrast, JUST 3 had been subject to extensive conservation treatment in 1959, which included humidification and subsequent pressing. A paper strip or 'guard' was also attached on the left side of each document to enable each record to be stitched together and bound in small pamphlets with covers made of bookbinding cloth. Class C4 is a collection of loose parchment documents never subject to any conservation treatment.

To determine the physical condition of the documents, 50 samples of collagen fibres were taken from individual documents from each class, and tested according to the IDAP protocol for Hydrothermal Stability Shrinkage Activity, measured using the Micro Hot Table Method (MHT). The datasets of the shrinkage temperatures of the two groups of documents were statistically checked for outliers and then compared by means of two-tailed F-test and t-test at a 95% confidence level, to determine if the mean values differed significantly (fig. 2).

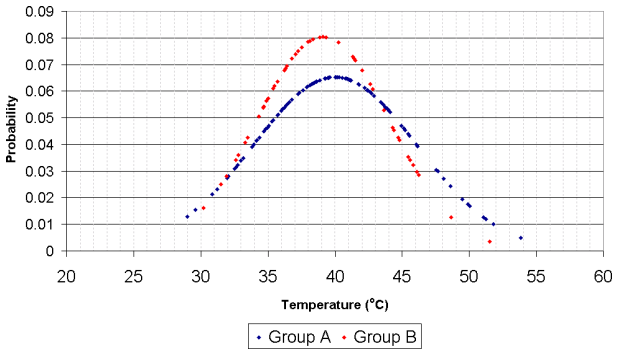

Figure 2. Distribution of shrinkage temperature for Group A and B.

The mean shrinkage temperature for the documents from Group A was 40.0ºC and for Group B 39.1ºC. Statistical analysis showed no significant difference between the two.

However, when the two classes in Group A were examined separately, the mean shrinkage temperature of class JUST 3 was 2.7°C higher than the one of C 1 series, both were stored on the same floor in Chancery Lane. Statistical analysis between JUST 3 and C 1 showed a significant difference between their two mean values.

There are numerous factors that can influence the shrinkage temperature of parchment, for example the animal species, the part of the skin the sample was taken, the method of production, previous storage conditions and past conservation treatments. The large number of variables expected with parchment documents is evident in the wide standard deviation calculated for all three classes. Accepting that all three classes of documents were exposed to the same environmental variability throughout their lifetime, the difference in shrinkage temperature is likely to be caused by the manufacturing process, effects of previous conservation treatments, or variables in the skin itself e.g. species type.

Interestingly, most of the documents from class C4 were deemed unsuitable for delivery to readers due to their dirty, creased and fragile condition. However, analysis showed the C4 documents were in the same state of preservation as C1. The results of this study have prompted a number of questions and therefore careful interpretation and further investigation before drawing firm conclusions. At this stage we can conclude that neither of the two extreme environmental conditions seem to have affected one group of documents more that the other. The two groups of documents have either been affected by the two contrasting environmental conditions or the environmental variability of the

last 150 years, even though conditions must have been on average more extreme, did not exceed the variability of the uncontrolled environment of the previous 350 years. Thus the 150-year period has not cause significantly more damage than what had already been caused until then.

In line with previous work focused on the response of humidity-sensitive materials to RH fluctuations, this preliminary conclusion may suggest that flat-line environmental control for collections of unbound parchment documents exposed to uncontrolled environments for most of their lifetime might not be necessary. Collections exposed to large fluctuations would be able to tolerate at least half of that fluctuation without any additional damage [8]. Therefore the benefits to the long-term preservation of the collection are minimal in comparison to the costs involved in maintaining an extremely stable environment. This view is also supported by the current risk assessment of TNA's collections.

Finally, this project will contribute to the continuous development of the IDAP assessment protocol by submitting all the experimental data to the IDAP database. It has also emphasised the need for coupling shrinkage temperature measurements with fibre assessment, in order to avoid misinterpretation of experimental results.

Risk assessment project

Using the risk assessment model developed by Dr Robert Waller, Canada, [9] we have identified and quantified the risk to the collection due to inappropriate environmental conditions. The magnitude of risk due to conditions that fall outside the recommended values in BS5454, when viewed in relation to other risks may not necessarily indicate a priority on the preservation agenda. Environmental conditions are only one element affecting the preservation of the records and therefore must be assessed accordingly when allocating resources for the mitigation of risks to the collections. The results of the risk assessment numerically demonstrated that the risks associated with inappropriate levels of RH and T is far greater than the hazards posed by fluctuating environmental conditions.

Climate mapping exercise

Indications suggesting the existence of microclimates within the repositories prompted a data gathering exercise to be carried out in 2007. The exercise involved dividing each of the repositories into several 1000m^2 areas. Forty data loggers that record T and RH were arranged in a grid within one area at a time, and left to record for 48h before being moved to the next area, until the entire floor space was covered. A static data logger in the centre of each repository was used as reference sensor and a map of the differential RH and T was constructed for each space. All data loggers were set to record at 15-minute intervals. Even with a short monitoring period, the exercise to map the whole repository floor space in both buildings was estimated to take more than three months.

Climate maps for each repository were constructed by subtracting the readings of each data logger from the readings of the data logger in the centre of the repository. The maximum difference in %RH (%ΔRH) and temperature (ΔT) that was recorded during the 2-day monitoring period of each square on the grid is graphically presented in Figure 3. Similar maps were also constructed for the average %ΔRH and ΔT, in order to distinguish between events that occurred only for a short period of time and areas in the repositories where environmental conditions were on average at different levels.

Despite the limitations of the monitoring exercise, the results conclusively showed areas on each floor with very different environmental conditions. This is in contrast to the environmental picture of the repositories created by the existing monitoring programme and BMS, which was very similar to what the data logger in the centre had recorded, and interestingly conformed with the recommendations set out in BS5454. Information from the climate maps and the data generated from individual data loggers led to a much better understanding of the necessary improvements in the monitoring programme, environmental control system and air distribution. More importantly, the evidence showed the air-conditioning system was more efficient and less affected by the external environment, human occupancy, and the furniture arrangement i.e. shelving than was first thought.

In addition, we have also investigated the effects on the stability of the storage conditions of changing the operational patterns of the air-conditioning system, as well as the microclimates inside the storage boxes. The air-conditioning was switched off and the environmental conditions were monitored inside and outside a typical storage box. The conditions inside the repository remained virtually the same even after seven hours without a supply of conditioned air. Therefore, it was not possible to fully assess

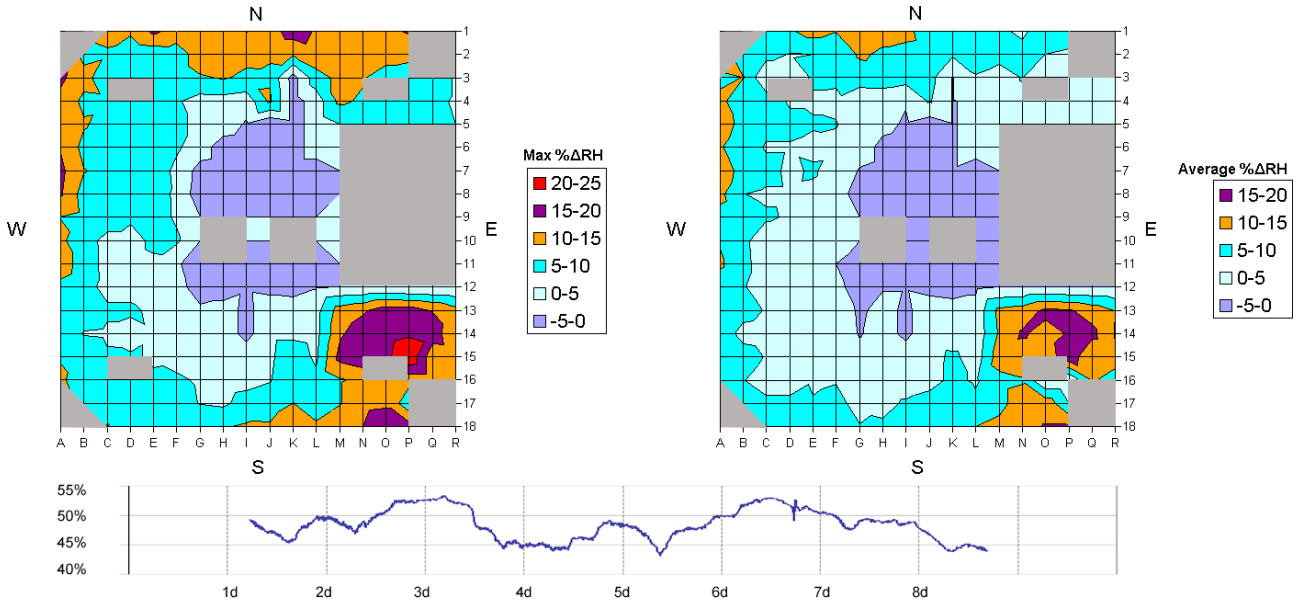

Figure 3. Climate maps of the second floor repository in Q1 (surface area 7,377 m²). The graph along the bottom shows the RH recorded at the centre of the repository over an eight-day period.

the buffering capacity of the storage boxes against fluctuation of ambient environmental conditions in situ, but we gained useful insight of the thermal and moisture stability of the building envelope. Data from further trials will inform the operation schedule of the air-conditioning system and as long as environmental conditions remain stable we might reduce operating hours of the air conditioning.

Volatile organic compounds (VOCs)

Our environmental review is currently focused on temperature and relative humidity control, with a planned evaluation of internal air quality. To this end we are collaborating in a project led by the British Library to characterise the off-gassing of volatile organic compounds (VOCs) in archival collections with the view to correlating condition to the quantity and type of VOCs found. The ultimate aim of the project is to produce a diagnostic tool for the assessment of such collections. It is also envisaged that the results of this study will inform understanding of the degradation processes and the interactions of materials kept in microclimates.

The environmental review currently underway in TNA is just one element contributing to a new approach to collection stewardship. We are also actively profiling the collections to identify environmentally sensitive materials where more tightly controlled microclimates may be more appropriate. For example, a survey of the photographic collection is underway to identify the range and quantity of photographic materials found in the collection. The range of modern archival materials, such as plastics, some of which are already showing signs of decay. The purpose of this is to provide the necessary evidence to enable an improved, informed top-down approach to stewardship.

TNA's multi-faceted approach to collections stewardship is not unique, although rare on the scale presented here in TNA. It is envisaged that we will continue to collect comprehensive evidence in the ways set out in this paper to enable stewardship policies and practices to be revised accordingly.

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