

Title: Environmental Assessment Without Limits at The National Archives

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## **Introduction**

Environmental Assessment Without Limits at The National Archives

The National Archives (TNA) is engaged in a retrospective Annual Environmental Assessment (AEA) of conditions in its repositories. The AEA results will inform the future development of preservation strategies and policies along with upgrades and maintenance of the building and its systems. The assessment reports on four elements affecting TNA's collection: chemical degradation, environmental stability, mould growth and the impact of external environment conditions; enabling monitoring of the relative changes in stewardship of the collection over time and significantly, the analysis is made without reference to standards and guidelines for relative humidity (RH) and temperature (T).

## **Main body of text**

### **Context**

TNA is the official archive for the England, Wales and the UK government. One of the main aims of TNA is to preserve and protect its 11 million records that date back over 1000 years. From Domesday Book to digital files and databases, TNA is responsible for their care and making them accessible to all.

TNA's collection is stored in 15 repositories; the three main repositories are in the 1978 building referred to as Q1; 12 are in the 1996 Q2 building. The larger Q1 repositories are open plan, with an area of approximately 6500m<sup>2</sup> each. The repositories in Q2 are approximately 700m<sup>2</sup> to 1000m<sup>2</sup> each, and are arranged over four floors. The air-conditioning system serving Q1 includes four plant rooms in the basement of the building, with each plant room serving the quarter of the building positioned above it. The air-conditioning system in Q2 has dedicated air handling units (AHU) for each repository. These vast heating, ventilating and air conditioning (HVAC) systems are complicated and costly to operate and maintain.

It is against this background, along with the need for UK public bodies to meet government set sustainability targets and a growing concern for greater environmental responsibility globally, that the repository environments needed to be better understood. The AEA makes an important contribution to this understanding; providing critical evidence to inform TNA's strategic plans and enabling a retrospective evaluation of the

preservation storage environments by creating a comparative and accessible annual record of the conditions in the repositories.

This assessment marks a distinct departure from evaluating environmental performance based on a narrow range of environmental success measures, to an evaluation based on an assessment of a range of interdependent factors that impact on the preservation of the collection. These are: chemical degradation, environmental stability, the probability of mould growth and the impact of the external environment on the conditions achieved inside the repositories.

#### *Chemical degradation*

Isoperms [1] were used to assess chemical degradation. In the original development of the isoperm lines, '1' was arbitrarily set to cross at 50%RH and 20°C. However, TNA's system is set to operate at conditions to the left of isoperm '1' (for most repositories set points are 18°C and 50% RH). This results in a target relative permanence of 1.33. To achieve improved preservation conditions therefore, relative permanence would need to be higher than 1.33.

#### *Environmental stability*

In order to provide a measure of environmental stability, skewness, a statistical measure of the degree of asymmetry of a distribution [2] was employed. Environmental conditions in the repositories are controlled by TNA's air-conditioning system around certain set points. Given the allowable fluctuations ( $\pm 1^\circ\text{C}$  and  $\pm 5\%$  RH), when the system is working successfully, the data should be clustered tightly around the set points, resulting in a low skewness.

#### *Mould Growth Hazard Index*

A Mould Growth Hazard Index (MGHI) was developed as an indication of the likelihood of mould growth in the repositories, since accurately predicting mould growth is far more complex. The MGHI is based on the number of days to mould germination as a function of the combination of RH and T according to mould germination isopleths at 20°C [3]. Each combination of RH and T, providing that RH is above 65%, has a MGHI that is proportional to the time spent under that combination of conditions. The total MHGI of each monitoring point is the sum of all the resulting MGHI for all RH/T combinations at that point over a month.

#### *Impact of external environment*

TNA uses a monthly Key Performance Indicator (KPI) to monitor the level of success in providing appropriate environmental conditions in the repositories. The KPI is calculated based on the percentage of time conditions were outside the required RH and T ranges for each repository. The KPI is calculated at 21 different zones across Q1(13) and Q2(9). For each zone the KPI fails if conditions were outside the specified limits for more than 10% of the time during a month. If more than 10% of zones in Q1 or Q2 fail, then the monthly KPI fails.

This section of the AEA correlates the KPI to the external dew point (DP). DP was chosen as it encompasses both RH and T and it is the term HVAC engineers are familiar with in relation to the capacity of a system to condition fresh air. This section highlights the capacity of the HVAC system along with any shortfalls in its operation and management. Therefore expectations of what the system can achieve throughout the year can be managed.

## Method

The AEA uses environmental monitoring data (RH and T) collected with a wireless radio-telemetry system by Hanwell Instruments Ltd. The sensors record conditions every 15 minutes. There are 127 sensors deployed in the Q1 repositories, and 13 in the Q2 repositories including one in the Photostore. There is also an external sensor on the roof of the Q2 building.

Data from each sensor is exported in Microsoft Excel files each month, manipulated to clean any interference data and saved with appropriate file names to facilitate the rest of the process. A series of Excel spreadsheets has been developed with functions that automatically draw the relevant data from the Excel files and generate graphs for each element of the report. It is estimated that 12 million individual data points of RH and T are used and combined to complete the full annual assessment.

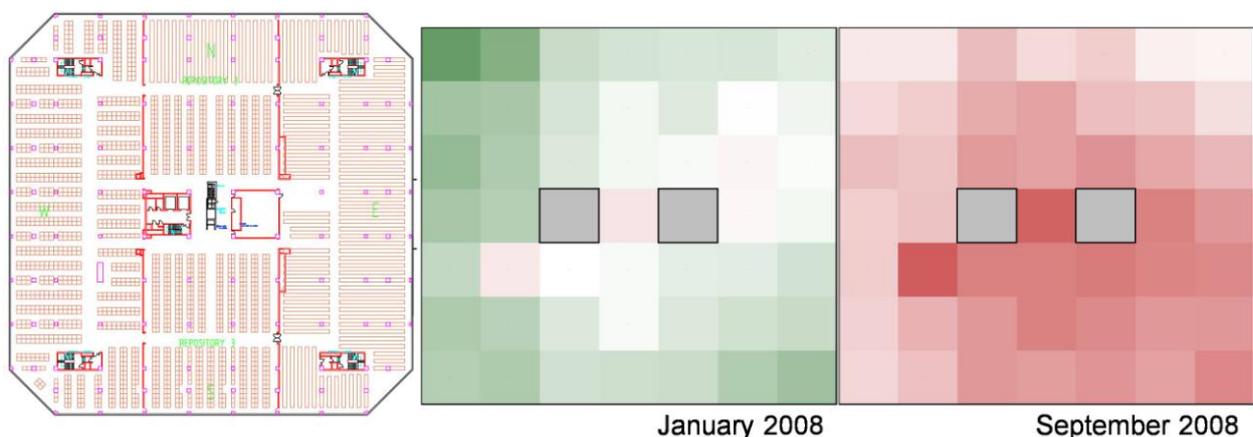
The graphical representation of the various elements of the report includes monthly 2D colour coded maps or 3D bar charts of the repositories in Q1 that can be animated in monthly sequences of relative permanence, changes in skewness and MGHI across the repository space. Repositories in Q2 do not require spatial graphs because the environment is consistent across the space.

## Results

### *Chemical degradation*

Relative permanence is generally higher on the perimeter of the Q1 repositories due to the HVAC air supply ducts, which deliver air at low temperature. This sometimes results in unsatisfactory high RH in certain areas, but as isoperms are weighted towards T, these areas must be examined in conjunction with the rest of the AEA elements before conclusions can be drawn.

Annually, permanence follows the external seasonal variation, peaking high in the winter months and dipping low during the summer (Figure 1). However, there are distinct differences between the conditions achieved by the four HVAC plants in Q1 during certain months. The HVAC system serving Q2 is more powerful, hence seems to be less affected by external conditions.

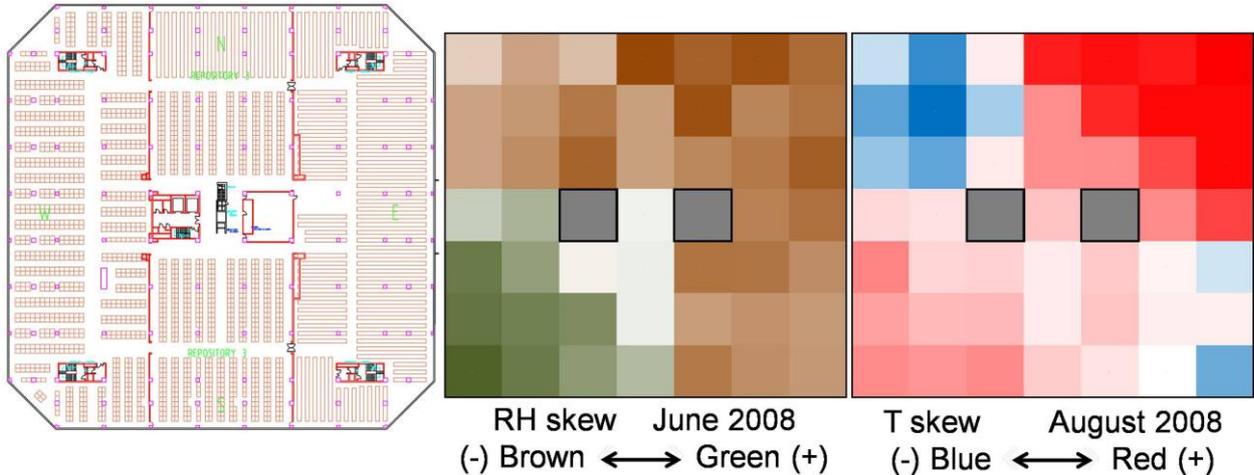


**Figure 1. Example of permanence maps for 3rd Floor Q1. White is a permanence value of 1.33 while higher values become greener and lower values more red.**

### *Environmental stability*

There is significant difference in the stability provided by the four plants serving Q1. Some months they even appear to be peaking in opposite directions (Figure 2). For most of the time negative skew in RH mirrors positive skew in T and vice versa.

However there are instances when both RH and T have the same skewness, which indicates either a mechanical fault in the system or the effect of exogenous factors.

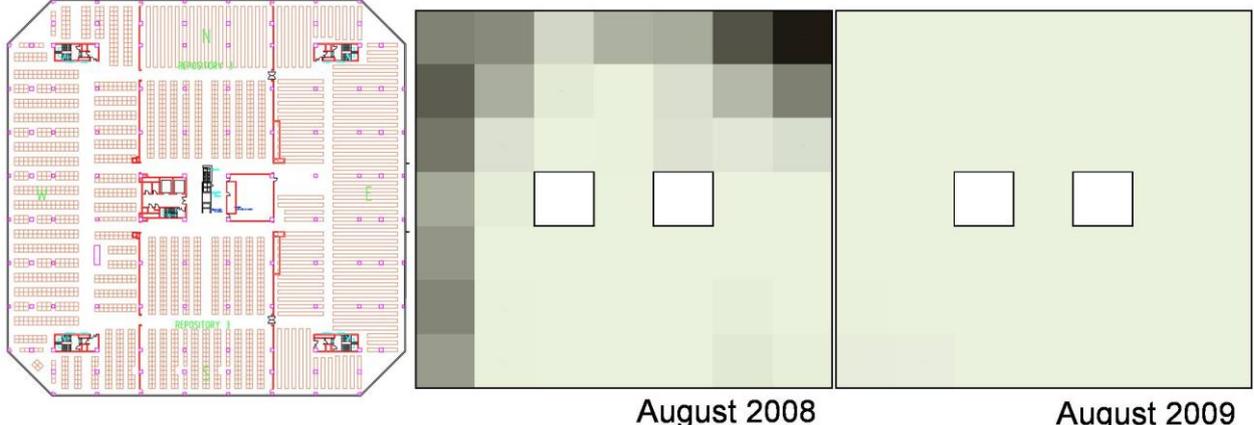


**Figure 2. Examples of skewness maps of 3rd floor in Q1 showing difference in the operation of the 4 HVAC plants. White is a value of zero skewness.1**

In Q2, the RH generally seems to be following the external seasonal change in dew point, with the corresponding temperature shift. Contrary to what would be expected, the warm summer months of July and August show very small skew. Clearly the HVAC system in Q2 copes with external high temperatures whereas in Q1 internal temperature follows the external seasonal variation to a greater extent.

*Mould Growth Hazard Index*

MGHI is zero for most of the year, but increases for the months of July, August and September in Q1 while Q2 repositories show a consistently zero MGHI. As expected, the MGHI is higher around the perimeters of the Q1 repositories due to the high RH resulting from the cold air supplied in there. This correlates well with both the low values in permanence and the internal KPI percentage of success. Since the first assessment in 2008, there has been a significant reduction in MGHI in Q1 repositories in 2009 (Figure 3), as a result of adjusting the operational T set point of the HVAC system during the summer months, based on the information provided by the 2008 AEA.

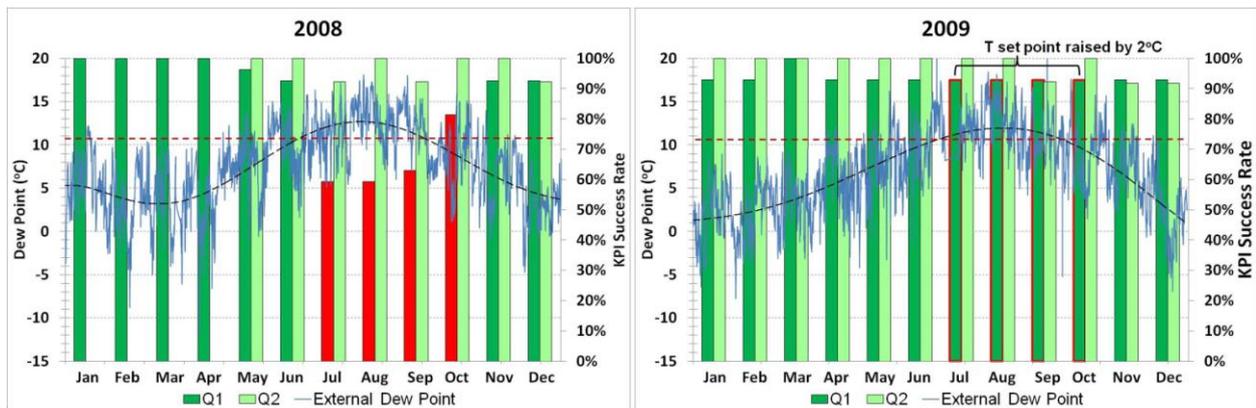


**Figure 3. Comparison MGHI map of 3rd floor in Q1. The darker colours correspond to higher MGHI.**

*Impact of external environment*

The external DP follows an annual cycle of low levels in the winter months gradually rising in the summer to peak around August. In 2008 TNA’s KPI failed for the months of

July, August, September and October in Q1. This suggested that when external DP is above 10°C, the HVAC system cannot dehumidify the incoming air enough to achieve the required environment. However, it is unusual for October to fail the KPI due to high levels of RH, especially considering that DP was on average around 7.5°C. Therefore the failure in October is more likely to be due to shortfalls in the operation and maintenance of the system. Based on this information, in 2009 the KPIs were achieved every month (Figure 4), because during the months with high DP the T set point of the HVAC system in Q1 was adjusted to accommodate the limitations in dehumidification.



**Figure 4. Comparison of the impact of the external environment between 2008 and 2009 due to adjustment of the temperature set point at the HVAC system.**

## Conclusion

The AEA focuses on the quality of the environment provided for TNA's collections without reference to any published standards for environmental conditions. The only limits imposed in the report are decided and used internally to suit corporate objectives and can be changed without compromising the ability to relatively compare the AEA year to year. The report also makes the results of environmental monitoring more accessible to those both making the decisions and those maintaining environmental systems. Finally, the four sections of the report must be interpreted as a whole in order to draw useful conclusions from it. The AEA at TNA has already proven invaluable in informing decisions that have improved conditions in storage, management of the HVAC systems and strategic plans for reduction of energy consumption; all without reducing the level of care TNA provides for its collection.

## Bibliography

[1] Sebera, D.K., "A Graphical Representation of the Relationship of Environmental Conditions to the Permanence of Hygroscopic Materials and Composites." In Proceedings of Conservation in Archives: International Symposium, Ottawa, Canada, May 10-12, 1988. Paris, France: International Council on Archives, 1989.

[2] (Electronic Version): StatSoft, Inc. (2010). Electronic Statistics Textbook. Tulsa, OK: StatSoft. URL: <http://www.statsoft.com/textbook/>.  
(Printed Version): Hill, T. & Lewicki, P. (2007). STATISTICS Methods and Applications. StatSoft, Tulsa, OK.

[3] Ayest, G. 1969. The effect of moisture and temperature on growth and spore germination in some fungi. Journal of stored product research, 5, 127 – 141.

## **Short CV**

**Kostas Ntanos** trained as a conservator in Greece before receiving an MA in Conservation Science from the RCA/V&A Conservation in 2005. He is currently working as the Head of Conservation Research and Development at The National Archives, UK.

**Sarah VanSnick** studied architecture at Carleton University and Collections Conservation and Management at Fleming College in Canada, graduating in 2007. She is currently the Conservation Research Assistant at The National Archives, UK.