Analysing smelly old books.

Dr L.T. Gibson, Dr. C. Robertson, Dept. of Pure and Applied Chemistry, WestCHEM,
University of Strathclyde, 295 Cathedral Street, Glasgow

1.0 VOC survey

A sampling campaign of indoor air was undertaken in 2008 to assess the typical concentration of indoor air pollutants in 8 National Libraries and Archives across the U.K. and Ireland. Partners involved in the study included the National Archives of Scotland (NAS), National Library of Scotland (NLS), British Library (BL), Cambridge University Libraries (CUL), the National Archives (TNA), Trinity College Library (TCL), National Libraries of Wales (NLW), and Oxford University Libraries (OUL). At each site, two locations were chosen that contained various objects in the collection (paper, parchment, microfilm, photographic material etc.) and one location was chosen to act as a sampling blank (placed in a corridor or entrance hallway).

1.1 Sampling techniques

A combination of sampling techniques (passive and active) were used to determine the concentration of organic acids, aldehydes and other volatile organic compounds (VOCs) in the indoor air environment. Palmes diffusion tubes used in passive sampling campaigns (for acetic acid[1], formic acid[1], formaldehyde[2] and sulfuric acid determination) were deployed for 28 days. Active sampling pumps connected to sampling tubes containing Tenax TA were used to trap a wide range of volatile organic compounds (VOCs) in a 24 hour period. Curators were trained to deploy sampling tubes and activate sampling pumps to collect air samples on-site.

During this survey it was observed that each location differed in the type of building housing the collection, the air handling systems used, as well as the items stored within selected sampling sites. Some locations were known to hold approximately a quarter of a million documents consisting of different types of material in addition to paper (microfilm, parchment, photographic material etc.). Additionally access within sampling locations was allowed (and necessary) during sampling.

1.2 Summary of sampling results

At each location surveyed no measurable concentration of sulfur dioxide (< 1μg m^{-3}), and low formaldehyde vapour concentration (< 18 μg m^{-3}), were detected regardless of sampling location. In contrast acetic and formic acid vapours were detected in all locations with, for the most part, higher acetic acid levels in sampled areas containing objects (locations A or B) compared to background locations (location C), see Figure 1.

The active sampling results indicated that a number of analytes were consistently observed in all locations (A-C) at low concentration regardless of sampling location; heptane, toluene, ethylbenzene, o-xylene, p-xylene, nonane, benzaldehyde and decane. In contrast, other analytes (cyclohexanone, 4-ethyl toluene, 1,3,5-trimethyl benzene, 2-ethyl toluene, 1,2,4-trimethyl benzene, limonene acetophenone and camphor were observed in some, but not all locations. It was therefore recognized that determination of actual analyte concentrations was not the best use of the collected data: rather examination of chemical profiles (or chemical signatures) might help to relate combinations of VOC patterns to locations with stored objects. As an example see Figure 2 which illustrates the similarities of analyte peaks in the chromatograms collected at one site each at the British Library and Cambridge University Library. To examine such correlations in more detail multivariate analysis was performed on the full data matrix and Figure 3 illustrates just one example of analyte correlations which indicate an association with storage locations compared to background locations. The sampling locations along the x-axis are in the order location A - location B – location C (coloured red for visual aid). Points which lie close to the zero line have similar (average) concentrations of acetic acid, furfural, heptane and toluene. Points which lie above the zero line have similar correlations with these four analytes: low acetic acid, low furfural, high heptane, high toluene. Notably, most of the points above the line were taken at the background location where no objects had been stored. Points which lie below the zero line are also correlated with high concentrations of acetic acid and furfural with low concentrations of heptane and toluene: most of these points are associated with locations B or C where objects were stored. Thus both acetic acid and furfural appear to be measured at their highest concentration when objects are stored in the sampling location – are they therefore indicators of paper degradation? Full analytical results relating analyte correlations to sampling locations will be published in the near future.

1. A diffusion tube sampler for the determination of acetic acid and formic acid vapours in ambient air, L.T. Gibson, B.G. Cooksey, D. Littlejohn and N.H. Tennent, *Analytica Chimica Acta*, **341** (1997) 11 - 19.
2. A Passive Tube-Type Sampler for the Determination of Formaldehyde Vapours in Museum Enclosures', L.T. Gibson and A. Brokerhof., *Studies in Conservation*, **46**, (2001) 289 - 303.

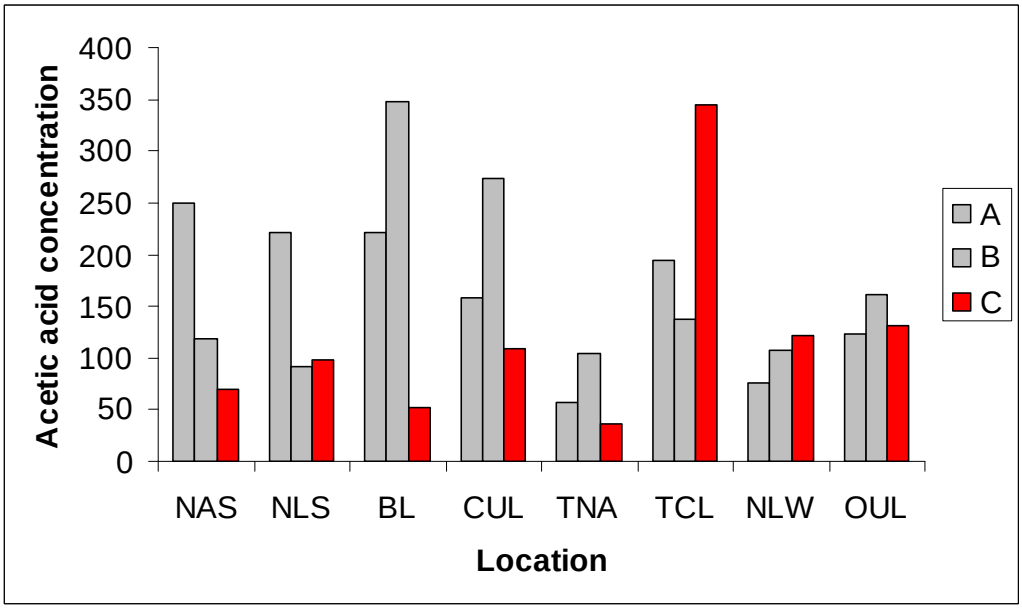

Figure 1: concentration of acetic acid (μg m^{-3}) measured at various sampling sites.

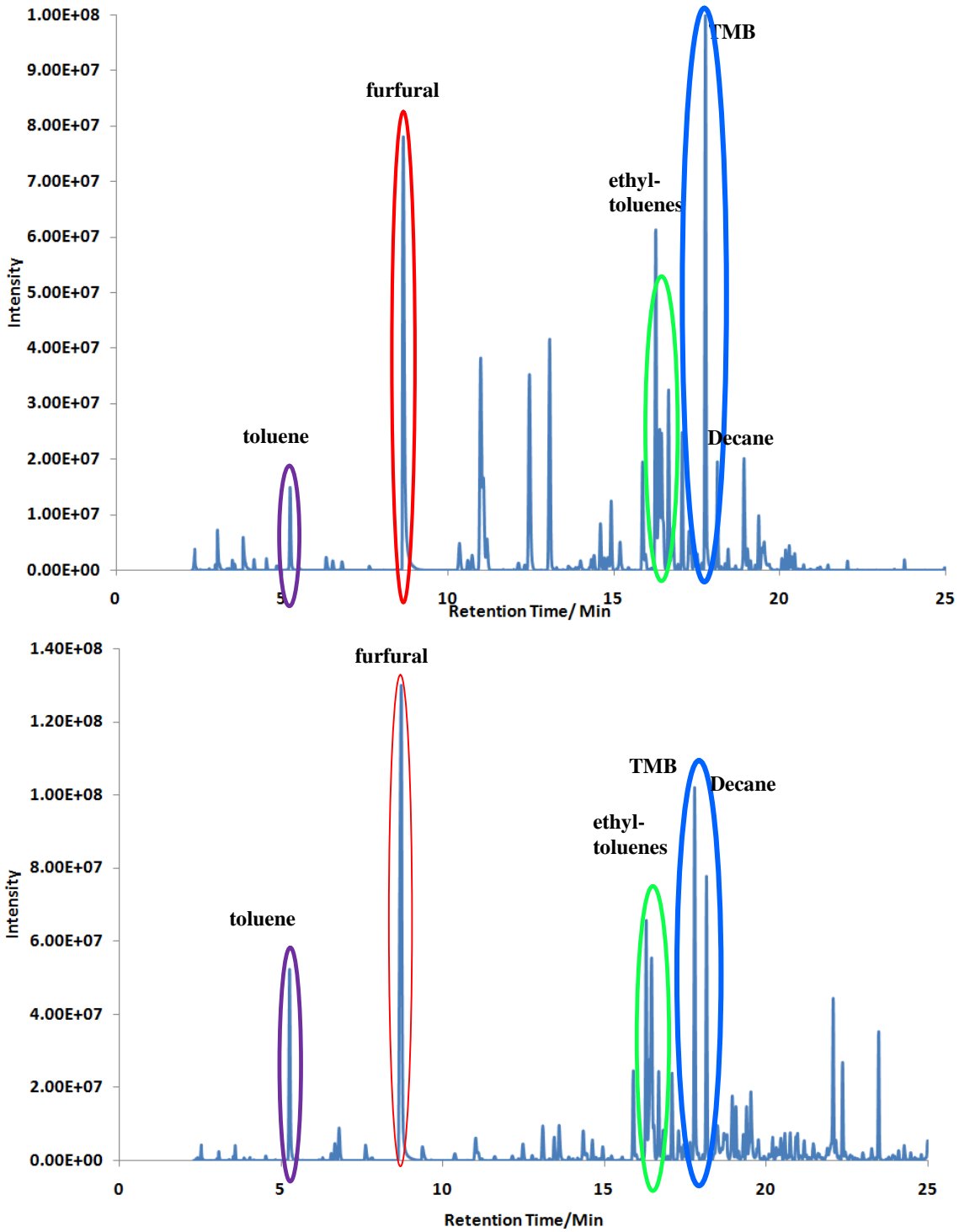

Figure 2: VOC profiles of locations at the British Library (top profile) and Cambridge University library (bottom profile).

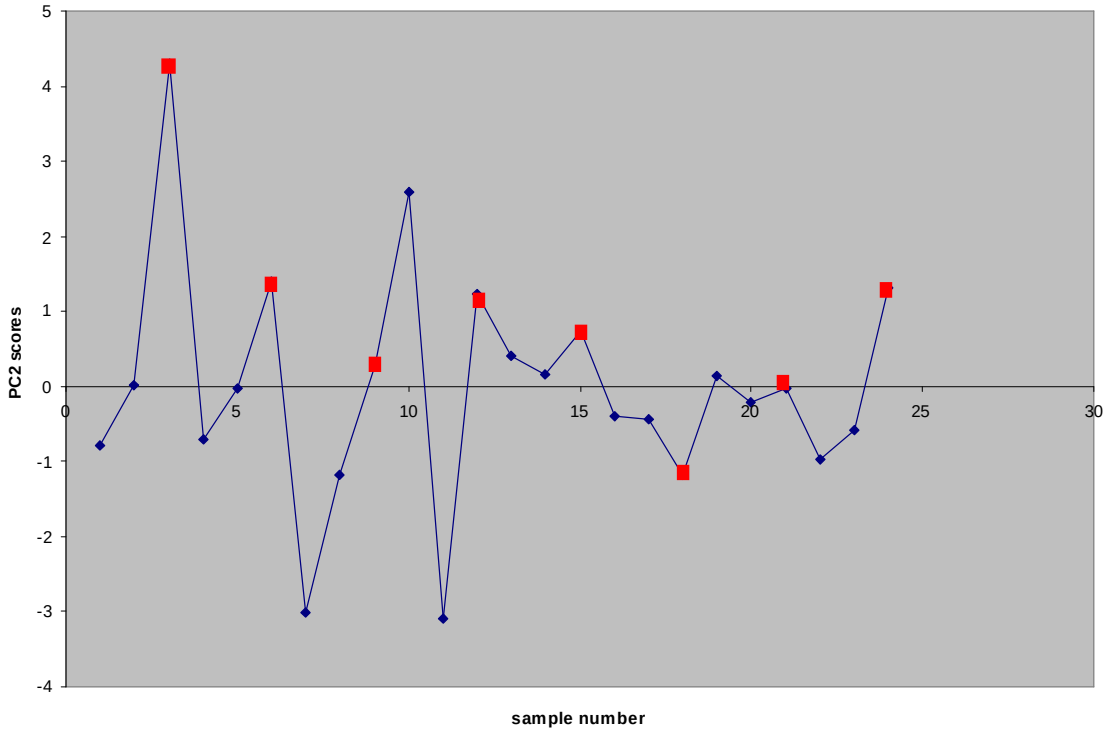

Figure 3: Results of multivariate data analysis illustrating the trend of PC2 with sample number.