AREA

Area, 2016, doi: 10.1111/area.12313

Using rates of gravestone decay to reconstruct atmospheric sulphur dioxide levels

Rob Inkpen*, Howard D Mooers and Michael J Carlson****

*Department of Geography, University of Portsmouth, Portsmouth, Hampshire PO1 3HE

Email: robert.inkpen@port.ac.uk

**Department of Earth and Environmental Sciences, University of Minnesota Duluth, Duluth, MN 58812, USA

Revised manuscript received 16 September 2016

Decay losses from marble gravestones spanning the last 130 years were measured using the lead lettering index (LLI). The relationship between decay loss and gravestone age can be described using a power function of the form decay loss = a(age)b. For locations where decay is likely to have been dominated by 'normal' rainfall, the value of b tends to 1, while for locations where decay losses were higher in the past b tends towards a value of 2. Using Lipfert's dose–response function it is possible to postdict atmospheric sulphur dioxide concentrations using rainfall records and yearly decay rates derived from the power functions. Comparing the derived historic atmospheric sulphur dioxide concentrations between locations, the highest levels are found in the industrial location of Swansea compared with the relatively high historic levels found in urban area such as Oxford, Birmingham and Portsmouth. Suburban or rural locations tend to have very low concentrations.

Key words: *gravestone erosion, atmospheric pollution, reconstruction*

Introduction

Estimation of sulphur dioxide concentration in urban atmospheres in the UK before the 1960s depend on proxies, such as industrial and commercial activity (e.g. Inkpen 1989), coal records or cathedral repair records (e.g. Brimblecombe 1977; Viles 1996; Inkpen 1999). Reconstructing past sulphur dioxide levels provides important information on the nature of the decay environment experienced by historic buildings and their responses to these conditions. In particular, the potential presence of cumulative and thresholds values for the impact of atmospheric pollutants for stone decay could be analysed looking at historic records of building repair within quantified historic atmospheric pollution environments. Historic pollution levels also provide an important environmental context for understanding the efficacy of environmental regulation, and public health related issues (Spik *et al.* 1993; Greenstone 2004); an understanding that can be used to predict the potential impact of increasing urbanisation.

Likewise, other techniques of environmental reconstruction such as dendrochronology can benefit from information about atmospheric pollution conditions under which tree growth occurred because variations in these can affect growth and therefore the interpretation of past climates (Martinelli 2004; Muzika *et al.* 2004; Stravinskiene *et al.* 2013).

Recently Bonazza *et al.* (2009) and Brimblecombe and Grossi (2008) used the Lipfert dose–response functions, derived under contemporary conditions, to postdict past decay rates. Inkpen *et al.* (2012) used these dose–response functions to compare modelled rates with measured rates. Inkpen (2013) rearranged the Lipfert dose–response function (Lipfert 1989) to determine past sulphur dioxide from the decay rate of marble gravestones in three urban locations. The integrative rate method employed, however, was at a relatively low decadal resolution and was limited by the number of samples in each decade, the spread of the data and sensitivity to individual extreme values as well as being time-consuming to apply.

Investigations have shown that measurement of surface recession of lead-lettered Carrara marble gravestones provides a robust and repeatable measure of acid deposition (e.g. Meierding 1981; Cooke *et al.*