The role of urban lake sediments as historical archives of industrial pollution and health linkages: an example from Daresbury pond, north Cheshire, UK

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Abstract

Research in Halton, northwest England, recognises the health effects of environmental pollution due to the extensive amount of industrialisation the area has experienced since the industrial revolution. The chemical industry still dominates this region, and concerns have arisen over potential links between industrial pollution and high morbidity and mortality in Halton. Recent commissioned work suggests that unhealthy life style and material deprivation are factors affecting health. However due to insufficient data a direct comparison has not been made between temporal pollution patterns and health records to assess impacts of pollution on health. A methodology using characteristics of lake sediments has provided proxy records of atmospheric pollution variations dating from pre-industrial times to present day. Preliminary mineral magnetic results are presented demonstrating the pollution profile of the area, giving a detailed record of changing atmospheric pollution since the lake was formed. In the future this can be compared to health records to identify possible relationships between pollution trends and disease patterns.
Keywords: atmospheric pollution, public health, palaeolimnology, Halton Borough Council.

1 Introduction

Effects of environmental pollution on human health are an increasing concern to local, regional, national and international communities [1]. The sources of pollution are many. However, it is those areas where large-scale industrial activity occurs, especially chemical industries, which are commonly attributed to air, land and water contamination and, as a consequence, are frequently associated with public health issues [1].

The Halton area of north Cheshire (UK), which encompasses the towns of both Runcorn and Widnes, has been an industrial heartland for the national chemical industry for many years (mid 1700s) [2], (Figure 1). As a consequence, contemporary and temporal pollution of the Halton environment, and its associated health implications for local communities, are concerns that have prompted Halton Primary Care Trust (part of the National Health Service) to commission a cross-disciplinary (medical and environmental scientists) research investigation into linkages between the environment and notably high rates of mortality and morbidity in the local area.

This work presents the first analytical results collated from the interrogation of lake sediment stratigraphies retrieved from Daresbury Pond (an urban lake), north Cheshire, UK, establishing them as archives of temporal pollution. The project aims to ascertain if mineral magnetic methodologies can be employed to distinguish local/regional environmental pollution episodes and therefore, ultimately assist examination of linkages between human health histories and those of local/regional pollution.

2 The Halton area

2.1 Industry in Halton

Extensive industries were initiated in Runcorn during the mid 1700s, which included stone, shipping, brewery, skin-yards and quarries [3]. Due to its location, docking facilities on the Mersey Estuary and general improvements in transport facilities (particularly the construction of the Transporter Bridge and Manchester Ship Canal), the area quickly became a haven for chemical industries. By 1855 Runcorn had the reputation of a one-industry town due to a boom in chemical trade [2]. This meant, chemical industries continued to dominate the local area (both Runcorn and Widnes). Unfortunately, the various manufacturing processes emitted malodorous chemicals, gases and black smoke from chimneys of inadequate heights, which began to heavily pollute the area [4]. As a consequence, in 1888, Runcorn was described as the "dirtiest, ugliest and most depressing town in England" [3].

The environmental implications of extensive air pollution, land contamination, chemical waste, drainage problems and the death of vegetation; led to health concerns about premature mortality and ill health of chemical workers, plus health complaints from communities residing to near chemical works [5]. As a consequence, to reduce pollution levels in Runcorn, Alkali Acts were established in 1863. These introduced stringent standards for working conditions in chemical plants and control of by-products produced from chemical processes [2].

Types of industry widened within the area in 1964, when Runcorn was designated as a ‘New Town’ [3]. However, despite development and reconstruction, Runcorn remains a predominately chemical-based industrialised town. Nowadays, pollution levels are considerably less than in the historical past [7]. In the main, this is due to the introduction of air quality standards [6]. However, that said, a wide range of chemical processes still occur around Runcorn and heavy pollution loads are experienced [8]. For instance, in 2003, over 50 industrial businesses were operating at circa 15 sites in Widnes and Runcorn [7].

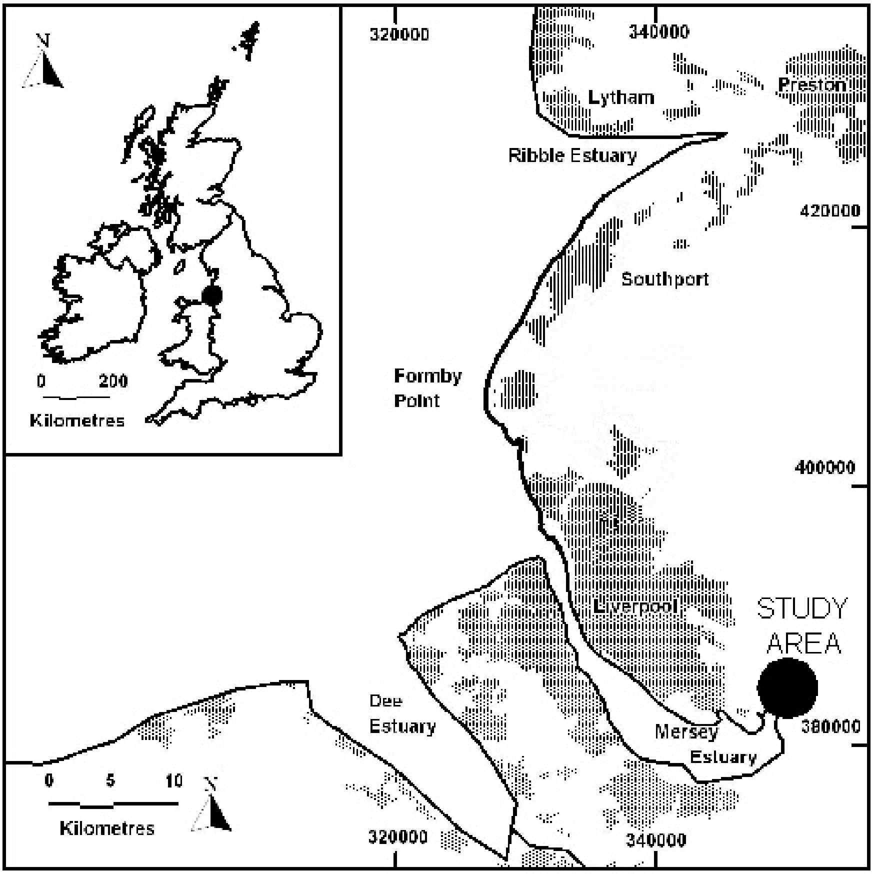

Figure 1: Location map of the Halton study area, northwest U.K.

2.2 Media attention

In 1999, the national media brought attention to the discovery that a quarry at Weston Point, Halton, formerly used for chemical waste disposal until 1972, contained the toxic gas HCBD (hexachlorobutadiene), and was now contaminating nearby homes [9]. Local public concerns arose over the potentially serious health implications of this incident. Given the substantive industrial history of Runcorn and consequential contamination, this has affected public health perceptions, with many neighbouring communities questioning the effects of environmental pollution on their own health [8]. To address these matters, the Halton Prime Care Trust has recognised the importance of understanding local and regional linkages between environmental pollution and human health, and instigated this research.

3 Health in Halton

Halton experiences higher cases of mortality and morbidity than similar areas [8]. Compared to Standard Mortality Ratios (SMRs) for the rest of England, Halton demonstrates higher SMRs from all causes, all cancers, lung cancer and coronary heart disease (Table 1). This illustrates the importance and urgency for investigating attributable health factors in Halton.

Table 1: Health in Halton indicator table using SMRs for all age ranges (1998 to 2000). Data adapted [8].

Health problem	England	North West	Halton
All causes	100	115.20	**120.02**
Asthma	100	100.04	91.60
All cancers	100	109.42	**127.90**
Lung cancer	100	124.17	**159.60**
Bronchitis & Emphysema	99	94.78	**95.14**
Coronary Heart Disease	99	115.65	**133.26**
All circulatory diseases	100	113.69	113.35

4 Urban lake sediments as proxy historical pollution indicators

Amongst other sources, lakes receive atmospheric particulate pollution from industrial and vehicular emissions. Over time the process of lacustrine sedimentation, may allow the development of a pollution record within the sediments [10]. Consequently, urban lakes are unique pollution sinks for measuring, monitoring and modelling industrial environmental contamination [11, 12]. In that sense, urban lake sediment magneto-chemical stratigraphies have been successfully used as proxy indicators of high-resolution atmospheric pollution records in the north Cheshire area (unpublished), for circa 250 year profiles [12].

5 Case study of Daresbury Delph Pond

5.1 Field methodology

Daresbury Delph pond (SJ 574 819), immediately east of Runcorn, is situated near to an urbanised area, adjacent to a busy dual carriage way (4 lane traffic) and a motorway (6 lane traffic). As such, with consideration of prevailing winds (westward) and its urbanised setting, the lake was selected as a site appropriate for holding a long-term pollution record, due to its appropriate location, small size and minimal management history (minimal sediment disturbance). With aid of a small boat, a sediment core (52 cm length, 6 cm diameter) sample was retrieved from the deepest and central part of the lake using a Gilsen corer (plate 1).

Plate 1: Sediment corer being forcefully inserted into soft muddy sediment, deposited on the lake bottom, before its removal under vacuum conditions from Daresbury Delph Pond.

5.2 Laboratory methodology

Sediment was extruded from the core at 5 mm intervals to provide a high-resolution stratigraphic sequence. After drying at 35°C, samples were prepared for mineral magnetic analyses [13]. Initial, low-field, mass-specific, magnetic susceptibility (χ_{LF}) was measured using a Bartington (Oxford, England) MS2 susceptibility meter. Anhysteretic Remanence Magnetisation (ARM) was induced with a peak alternating field of 100 mT and small steady biasing field of 0.04 mT using a Molspin (Newcastle-upon-Tyne, England) A.F. demagnetizer. The resultant remanence created within the samples was measured using a Molspin 1A magnetometer. The samples were then exposed to a series of 'forward' and 'reverse' field sizes up to a maximum ‘saturation’ field of 800 mT

(SIRM), and the isothermal remanent magnetisation (IRM) measured on the magnetometer. Table 2 summarises the parameters presented in this work.

Table 2: Mineral magnetic parameters and their interpretations [13–16].

Magnetic Parameters	Interpretations
χ_{LF}	Mass specific low frequency magnetic susceptibility: this is measured within a small magnetic field and is reversible (no remanence is induced). Its value is roughly proportional to the concentration of ferrimagnetic minerals within the sample, although in materials with little or no ferrimagnetic component and a relatively large antiferromagnetic component, the latter may dominate the signal.
ARM	Mass specific anhysteretic remanent magnetisation: for this work ARM was induced in the samples by combining a peak AF field of 100 mT with a DC biasing field of 0.04 mT. It is particularly sensitive to the concentration of magnetic grains of stable single domain size, e.g. ~0.03-0.06 μm.
SIRM	Mass specific saturated isothermal remanent magnetisation: this is the highest amount of magnetic remanence that can be produced in a sample by applying a large magnetic field. It is measured on a mass specific basis. In this study a saturating field of 0.8 T has been used and will produce saturation in most mineral types. However, some antiferromagnetic minerals may not be saturated in this field (e.g. goethite) and therefore this parameter is often called IRM_{800mT}. The value of SIRM is related to concentrations of all remanence-carrying minerals in the sample, but is also dependent upon the assemblage of mineral types and their magnetic grain size.

5.3 Results and discussion

Magnetic profiles, for the Daresbury Delph Pond core, display notable downcore changes in the magneto-sediment characteristics (Figure 2). For instance, the lowest section of each profile (23 - 52 cm) shows notably lower values than the upper section. That said, there are both differences and similarities between the upper sections of the profiles. The χ_{LF} and SIRM profiles are similar, with peaks at (2 cm and 8.5 cm), whereas ARM is different to both of the other profiles, with a single peak (2 cm). It is proposed that these observations indicate a pre-industrial background period of minimal or natural pollution in the lower corer. In contrast, the upper core observations indicate an industrial period, where pollution increases above background levels to a peak industrial time of maximum pollution. However, if this is the case, the upper core contains two pollution episodes because the χ_{LF} and SIRM profiles show two peaks. Whereas, the ARM profile shows only the upper of the two peaks. Since ARM measurements reveal the presence of ultrafine ferrimagnetic grains, this indicates that the proposed upper pollution episode contains a magnetic fingerprint, which is different to the lower pollution episode. Therefore, these preliminary measurements already suggest that, historically, there have been two different pollution sources, which have been dominant at different times.

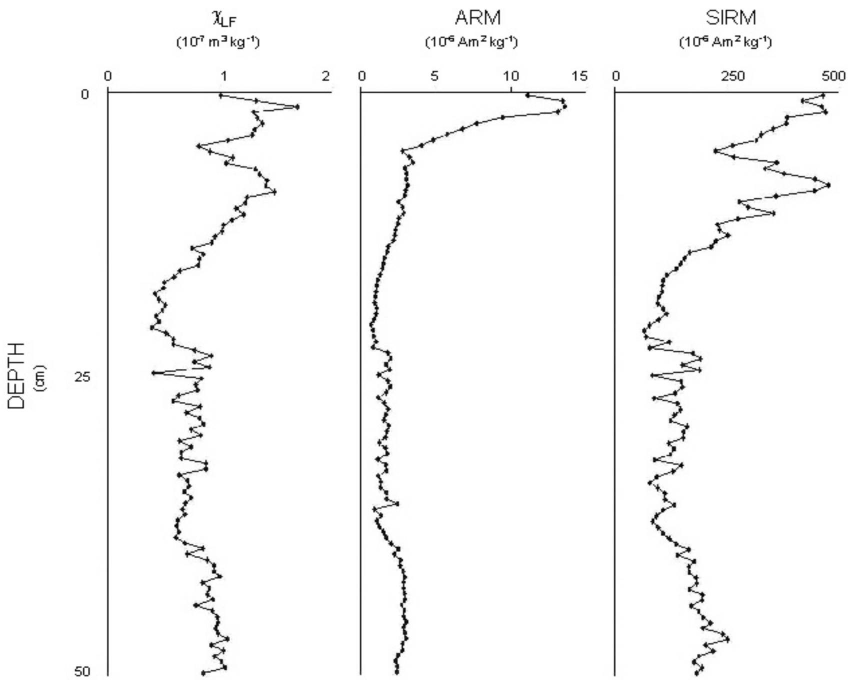

Figure 2: Magnetic profile data for Daresbury Delph Pond.

It is noteworthy to mention that similar pollution profiles have been identified in south Merseyside [12], suggesting that both urban lakes retain a regional pollution signal. If the stratigraphy dates for the south Merseyside work (unpublished ^{210}Pb) are similar to this case study, then the lower pollution episode occurred at circa. 1850, a time of boom industrial activity in the Halton area. The decline in values, recorded above this point in the core, is probably attributable to the reduction in pollution concentrations after the introduction of the Alkaline Acts (1863), which encouraged safer and less wasteful techniques to be introduced by the chemical industry. With this timeframe in mind, it is probable that the upper peak is attributable to the introduction and increased use of modern road vehicles, especially as the site is adjacent to two major regional transport networks. However, these interpretations require further analytical testing [17].

6 Ongoing and proposed future work

By combining these preliminary magnetic results with further analyses (i.e. laser-diffraction, x-ray fluorescence and spheroidal carbonaceous particle counts, together with radiometric dating), a more detailed record of atmospheric pollution change over the past *ca*. 250 years will be achievable. Subsequently, pollution profiles will be compared with archive health records. This will be accomplished in tandem with consultants from the Halton Public Health team and hopefully will reveal some interesting correlations between pollution episodes and disease patterns.

7 Conclusions

In an area dominated by the chemical industry for more than 150 years the Halton Health Project [8] has highlighted the need for a consideration of the historical impact of atmospheric pollution on local populations. While there is much work currently being done on the contemporary monitoring of atmospheric pollution (in particular with regards to disease patterns) and significant research into the health and social histories, there is no research focussing upon its temporal nature. If we are to gain a clearer understanding of the relationship between human health and atmospheric pollution the temporal dimension must be considered. This research, coupled with the work in South Merseyside [12], establishes an important initial, sedimentary record of atmospheric pollution that can be used as the basis for further work and demonstrates clearly, the importance of small, anthropogenic, urban lakes to the local community as well as to research in environmental science. The work therefore has begun to fulfil the need highlighted by public health organisations [8] by producing the first coherent archive of historical atmospheric pollution for Halton itself.

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