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Changing air quality in the Greater Manchester conurbation

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ABSTRACT

The Greater Manchester region was the cradle of the Industrial Revolution and air pollution has been an inescapable consequence of industrial activity since the latter half of the 18th Century. Within the context of a historical perspective, the scale and nature of air pollution problems will be reviewed; trends in available data reported; major sources identified and effects upon humans; vegetation; buildings and other sensitive receptors considered. Air quality has improved and the changing nature of sources and pollutant mix is reported.

INTRODUCTION

The county of Greater Manchester covers some 1300 square kilometres of north west England, mostly draining into the catchment of the river Mersey. Hills forming the boundary of the Mersey catchment lie to the north, east, south east and north west. Altitude varies from *c*.30m a.s.l. in the west to more than 300m in the north east of the conurbation. The regional climate is affected by the Welsh Mountains which shelter it from moist south westerly winds. Hence the relatively dry nature of the area and low rainfall considering its proximity to the west coast [1]. Micro-climatological variation within the conurbation is related to altitude, topography, degree of industrialisation and distance from the sea. There is spatial variation in absolute rainfall amount [2] but this is not statistically significant.The long term mean rainfall is 875mm.

PAST AIR POLLUTION AND ITS CONTROL

As the cradle of the Industrial Revolution, air pollution has formed a component of the environment of Greater Manchester's citizens for more than 200 years. However, meaningful measurements of pollutants are limited and for a clear understanding of historical air pollution artistic representations, official reports and the views of travellers and writers are the only surrogates available. Manchester's population grew sevenfold in the 18th century and grew rapidly again in the 19th century in parallel with the growth in textile manufacture and the switch from water to steam power [3]. By 1795, four of the twenty-three cotton factories in Stockport were powered by steam engines [4]. By the start of the 19th century there were 52 spinning mills in Manchester, and 99 by 1830 when Manchester and Stockport between them contained half of all power looms in the country. As early as 1800 the Commissioners of Police in Manchester created a committee to attend to and report on nuisance [5]. The committee found that *'the increase of steam engines as well as smoak issuing from chimnies used over stoves, foundries, dressers, dyehouses and bakehouses are become a great nuisance to the town'* [5]. By the late 1830s the cotton industry had been joined by engineering, chemicals metal working. Carbolic acid was produced from coal tar near Bradford colliery from 1857 onwards, and from 1865 sulphuric acid and naphthalene were produced at Blackley. The air pollution experienced by the population of Manchester and its region in the middle of the 19th century is vividly reported in the writing of Engels [6] and in the comments of travellers such as Alexi de Tocqueville [7]. In the mid 1840s, the Manchester Board of Health described the area to the south of the city centre now occupied by Manchester Metropolitan University as being *'surrounded on every side by some of the largest factories of the town, whose chimneys vomit forth dense clouds of smoke which hang heavily over this insalubrious region'* [8]. In 1845 a Manchester cotton mill was observed to emit black smoke for 8 hours 52 minutes out of 9 hours, and of 500 factory premises visited by the Manchester Smoke Inspector in 1850, 300 were issued with notices or cautions [9]. Prentice [10] writing in 1850 commented that *'the volume of smoke which continually issue from chimneys and form a complete cloud over Manchester certainly make it less desirable as a place of residence than a place of business, and the enjoyment of the inhabitants would be greatly increased could they breathe a purer atmosphere and have a brighter and more frequent sight of the sun.'*

The atmospheric pollution also influenced the flora and fauna of the area. The dark melanic 'carbonaria' form of the peppered moth first being identified in 1848 [9] and the vegetation of the urban area was dominated by privet hedges and Manchester Poplar trees, the free living alga and the smog lichen. R.A. Smith [11,12] described the polluted atmosphere of the conurbation, commenting upon the effect of pollution on vegetation, brickwork, metalwork and textiles and made the first reliable measurements of air pollution. In so doing Smith identified and neologised 'acid rain', correctly identifying its urban-industrial origin. Smith [12] concluded that *'when the air has so much acid that two or three grains are found in a gallon of rain water, or forty parts per million, there is no hope for vegetation in a climate such as we have in the northern parts of the country.'* In his 1852 paper Smith [11] gave the first account of sulphur pollution in Greater Manchester from a detailed study of several sites within the conurbation. He noticed that *'all rain contained sulphuric acid as it approached the town'* and that in the rural areas to the south of Manchester *'carbonate of ammonia dominated in air, ammonium sulphate becoming dominant in the suburbs* *before the strong acid, H_2SO_4 became dominant in the centre'.* Schwela [13] calculated the pH of city centre rainfall measured by Smith [12] and estimated it to be pH 3.5. Smith [12] in his capacity as Alkali inspector of Great Britain noted in 1869 that *'the rain instantly reddens test papers in Manchester and where most soot is found there is more acidity'.* Smith identified sulphuric acid, principally due to coal combustion, as the cause of acidity in rain but also recognised the role of hydrochloric acid, itself due to both coal combustion and the action of sulphuric acid upon common salt in rainwater. Sulphate levels as high as Smith reported were common in British cities in the 1940s and 1950s [14]. Smith [12] also concluded that *'free acids are not found with certainty where combustion or manufacture are not the cause'.* Air washing techniques developed by Smith show total acid gases in March and December 1868 to lie in the range 527.8 (October 7th) to 9309.9 (November 20th) $\mu g\ m^{-3}$. The average sulphate concentration in rain in 1869 was 41.66 ppm and for 1870, 47.99 ppm. Total acid concentrations were 47.54 and 53.78 ppm respectively [12]. Pollution emanating in the conurbation was, of course, dispersed from the urban area to surrounding regions and this led to the virtual elimination of sensitive *sphagnum* moss species from the southern Pennines [15].

Local efforts to control air pollution continued throughout the 19th century [9]. In 1847 the Commissioners of Police in Manchester appointed a special inspector for the suppression of smoke nuisance [16]. The city of Salford passed a local act in 1862 to control the emission of black smoke and local citizens formed a Noxious Vapours Abatement Association in the late 19th century. By 1909 a Smoke Abatement Society was formed in Manchester, the catalyst for the Smoke Abatement League of Great Britain. By the onset of World War 1 deposit gauges were maintained at several sites in the conurbation to measure the fall of pollutants from the atmosphere and sulphur deposition rates of *c.*170 kg $ha^{-1}\ yr^{-1}$ were not uncommon [15]. Total deposited matter rates in some urban areas fell 50% between 1914 and 1927 but between 1929 and 1954 urban sulphate deposition rates did not change in the Greater Manchester area, city centre sites recording values twice that of suburban sites [15]. During the second world war air measurements of sulphur dioxide became more common in the conurbation and mean concentrations of 586 $\mu g\ m^{-3}$ were recorded in the centre of Manchester [15]. By 1952 the annual mean was 341 $\mu g\ m^{-3}$ in Manchester and over 400 $\mu g\ m^{-3}$ in Oldham. In 1949 deposited insoluble matter in Bradford, north Manchester, was recorded at 127 g m^{-2} per month [16]. The quality of the atmosphere in Greater Manchester during the first part of this century can be seen in the paintings of L.S. Lowry such as 'Coming from the Mill' (1930) and 'The Lake', (1937).

With the prevalence of soot particles in the air during the nineteenth and early twentieth century there was a high incidence of respiratory disease. In December 1930 with no fog there were 137 respiratory disease deaths in Manchester and Salford but in January 1931 Manchester and Salford were engulfed in a severe smog that persisted for 9 days during which 592 deaths from respiratory disease occurred [17]. Catastrophe is often the

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impetus for change and from this disaster emerged the concept of a smokeless zone, proposed by Charles Grandy of Manchester in 1934. Manchester City Council attempted to acquire the necessary powers to initiate a smokeless zone in 1938 but it was not until 1946 when the City acquired private powers to instigate a smokeless zone policy [9]. By 1952 104 acres (42 ha) of the city centre were smoke controlled. Other areas followed, Salford created its first smokeless zone in 1952 and Bolton in 1954. In 1952 London suffered a major air pollution episode which led to the 1956 Clean Air Act, and smokeless zones becoming a national policy. Even in 1962, several years after the 1956 Act, it was noted that, on the hills to the east of Manchester, *'at times the smoke can be seen crossing the summits in a shallow layer at ground level, and a fresh fall of snow may be heavily soiled in two hours'* [18].

CONTROL OF TRADITIONAL AIR POLLUTANTS

The programme of smoke control was finally completed in Manchester by 1985. By 1980 deposition of insoluble matter at Bradford, north Manchester had fallen to 21 g m^{-2} per month [16], less than 17% of the total recorded 31 years earlier. In Greater Manchester as a whole annual mean concentrations of smoke fell by 90% and SO_2 by 85%, between 1959 and 1984 clearly indicating the success of this policy. Perhaps more importantly the bronchitic death rate (an indicator of the health effect of air pollution) has reduced in step over this period [19]. Over time, the cause and composition of air pollution has changed in the urban areas of the UK. Concentrations of SO_2 and smoke have fallen whilst those of NOx have increased. The spatial dimension has altered, urban areas have lost many of their low level sources to green field sites and mobile sources have substituted for fixed point sources and emit along linear pollution corridors. The spatial scale of urban areas has increased and hence the spatial area over which pollutants are emitted has also grown. Shifts in diurnal and annual emission and concentration peaks have also occurred. Smoke and sulphur dioxide emissions were commonly at a maximum in winter but now there is a gradual levelling out in emissions throughout the year but with new peaks emerging in the spring/summer for nitrogen oxides and ozone. Diurnal emission patterns have also changed with vehicle related pollutant emissions being at a maximum at peak travel to work times whereas industrial emissions tend to reflect the working day.

CONTEMPORARY AIR QUALITY IN THE GREATER MANCHESTER REGION

Greater Manchester is one of the most important industrial and commercial regions of the UK. It has a diverse range of heavy and light engineering as well as increasingly important service, commercial and financial enterprises. The area has some 2.5 million people in ten administrative areas including the cities of Manchester and Salford and the Boroughs of Stockport, Oldham and Wigan. It is intersected and circled by major road and rail communication routes and its road network experiences heavy traffic flows. To the south of the conurbation lies Manchester Airport, the UK's third busiest. The conurbation thus provides a multiplicity of point, mobile and area sources of air pollution, the emission from which interact in complex ways with climatology. Additional pollution is provided by interchange of air masses with surrounding regions. Notable pollutant sources near to the conurbation include Merseyside and the coastal plain to the west where Fiddlers Ferry power station (coal fired, base load, 1800MW), Stanlow oil refinery and the petro-chemical complexes on the Mersey estuary are located.

A range of measurement networks have been operated in the conurbation to provide air quality data. Temporal data sets are available for smoke and SO_2 since 1959, lead from the 1970s and NOx since 1986 [20]. Such networks have generally been instigated at the wishes of local government and consequently lower cost measurement options have been utilised. The range of local initiatives began to be supplemented by central government towards the end of the 1980s. By the late 1980s the centre of the conurbation had been selected for establishment of an EC Directive national monitoring site for nitrogen dioxide. This was later augmented by a carbon monoxide analyser. To the west and east of the conurbation monitoring stations for ozone were also established. The major emission source for most of the pollutants of concern today is road transport [21].

Nitrogen dioxide

Nitrogen dioxide is measured on a continuous basis in Manchester city centre by the chemiluminescence method. In 1992 the annual mean concentration of NO_2 at Manchester city centre was 59 $\mu g\ m^{-3}$ with a data capture rate of 97%. The EC directive limit value was never exceeded; the 98 percentile of hourly values was 150 $\mu g\ m^{-3}$. However, both the 98 and 50 percentile guide values set by this directive were exceeded. The 50 percentile for this monitoring site was 54 $\mu g\ m^{-3}$. It is usual for the 50 percentile guide value for NO_2 to be exceeded in urban UK areas. The World Health Organisation one hour guideline was exceeded on four occasions with a maximum concentration of 708 $\mu g\ m^{-3}$ in December 1992. This high concentration occurred during winter anticyclonic conditions. The 24 hour guideline was exceeded twice during 1992 with a maximum concentration of 360 $\mu g\ m^{-3}$. In 1992 NO_2 concentrations were in the Department of Environment "very good" class for 7635 hours, in the "good" class for 760 hours , in the "poor" class for 92 hours and in the "very poor" class for 1 hour. Nitrogen dioxide is also monitored in the Greater Manchester region by diffusion tube samplers. This is a simple, passive technique which allows a wide spatial area to be monitored. Data are presented in Table 1 and discussed in Conlan *et al* [20].

Sulphur dioxide and smoke

Sulphur dioxide and smoke are monitored on a regular basis in the Manchester area at 10 sites as part of the UK Basic Urban Network and the EC Directive network using daily volumetric samplers and the British Standard black smoke method (see Table 2). Black smoke concentrations are below the trigger value at which the lower SO_2 limit values apply. EC

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limit values were not exceeded at any of these sites in the 1991/2 pollution year. However, the guide values were exceeded at a number of sites. The mean of daily values guideline over the annual period is set as a range (40 - 60 $\mu g\ m^{-3}$). The upper level was exceeded at the Manchester 21 and Trafford 1 sites and the lower level also exceeded at Eccles 6 and Manchester 11. The maximum daily guideline is also set as a range of 100 - 150 $\mu g\ m^{-3}$. The lower level was exceeded at all sites except Ashton-u-Lyne 8. The upper level was exceeded at all of the remaining sites with the exception of Manchester 11 and Middleton 3.

Ozone, Carbon Monoxide and Lead

Ozone is monitored on a continuous basis at Ladybower in the High Peak to the east and Glazebury in Cheshire to the west of Greater Manchester as part of the UK national ozone monitoring network. Ozone concentrations recorded at Glazebury in 1992 were in the Department of Environment's "very good" class for 7987 hours, in the "good" class for 146 hours, "poor" for 9 hours and in the "very poor" class for 0 hours of the year. Air quality at Ladybower was in the "very good" class for 4374 hours, in the "good" class for 92 hours, in the "poor" class for 3 hours and in the "very poor" class for 0 hours. Carbon monoxide is only measured continuously in Manchester city centre within the conurbation. Concentrations did not exceed WHO guideline concentrations in 1991 or 1992 (Table 3). Concentrations of lead in air are routinely measured in Greater Manchester. The annual average concentration at these sites is substantially lower than the EC limit value (Table 1).

Table 1 . Measurements of Nitrogen Dioxide and Lead in Air

Location	1992 Range of Nitrogen Dioxide Concentrations $\mu g\ m^{-3}$	1992 Range of Lead Concentrations $\mu g\ m^{-3}$
Bolton	23-70	0.06-0.12
Bury	40-53	n.a.
Manchester	31-83	0.09-0.10
Oldham	31-93	0.04-0.11
Rochdale	27-58	0.04-0.05
Salford	44-65	0.06-0.09
Stockport	17-46	n.a.
Tameside	28-64	0.04-0.18
Trafford	29-58	0.03-0.07
Wigan	49-55	0.04-0.07

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Table 2 1991/2 Sulphur dioxide and black smoke concentrations ($\mu g\ m^{-3}$)

Site	SO_2 Arithmetic Mean	SO_2 Maximum (day)	Smoke Arithmetic Mean	Smoke Maximum (day)
Ashton-u-Lyne	17	88	17	123
Bolton 24	36	184	15	164
Eccles 6	43	193	17	115
Farnworth 8	32	204	14	110
Manchester 11	42	143	25	190
Manchester 15	39	161	20	138
Manchester 21	64	259	16	152
Middleton 3	38	110	19	146
Oldham 13	34	162	13	161
Trafford 1	71	192	14	115

Table 3 Carbon Monoxide at Manchester city centre ($mg\ m^{-3}$)

Year	Mean	Max Hr	No Hours > 30	Max 8 Hr	No 8 Hours > 10
1991	1.0	10.0	0	4.2	0
1992	1.0	18.2	0	8.8	0

SUMMARY AND CONCLUSION

Air quality has been reviewed over a 250 year timescale. Data, impacts and control attempts have been discussed and the success in reducing emissions and concentrations of sulphur dioxide and smoke identified. Unfortunately there is a fragmented data set for a number of species due either to a change in measurement technique or a relocation of a measurement station. The range of contemporary air quality issues confronting the conurbation has been reviewed. The success of local government in the region in tackling past problems provides encouraging evidence for the ability of local communities to take control of their own atmospheric environment and to forge effective partnerships to effect change. Opportunities are now becoming available in the UK for local air quality management [22] which may enable this process to be repeated.

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