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Industry, environment and health through 200 years in Manchester

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Abstract

The Manchester urban area evolved rapidly in the early 19th century from a series of small towns to a major industrial conurbation with huge material flows and worldwide trade connections. A combination of the availability of nearby coalfields, canals, and free trade, which encouraged entrepreneurial enterprise, made Manchester into the 'shock' city of the industrial revolution. Rapid nucleated urban growth associated with industrialisation throughout the 19th century involved an exponential growth in materials transfers and in waste flows. The 20th century suburban dispersal of residential and industrial growth led to further increase in the impact of the urban metabolism, especially in terms of mass: distance of materials movement. The current post-industrial phase in Greater Manchester has to cope with the environmental and social legacies of its industrial past and with growing per capita materials consumption and increases in number of households despite a nearly static population of around 2.5 million. Changes in material flows, land usage and river morphology in Greater Manchester over the past 200 years have reflected changing technologies, industry, economics, social expectations and environmental legislation. Manchester had the first passenger railway, the first inter-basin domestic water transfer in the UK, the first urban smokeless zones and was part of a pioneering land reclamation partnership in the 1970s. Even so, the environmental legacy of industrial material flows constantly presents new challenges, from the cost of reclaiming contaminated brownfield sites to finding destinations for today's urban waste.

Keywords: Manchester UK; Environmental history; Housing and health; River pollution; Air pollution

1. Introduction

1.1. The place of Manchester in urban environmental history

Urban growth is about the occupation of land and the assimilation and transformation of natural resources. From the earliest urban markets to the modern world cities, urban development is associated with the bringing of natural products together, their re-distribution, re-combination, and their eventual disposal. Although urban environments might be those furthest removed from nature, urbanisation increases the dependence of our culture on natural resources (Gulick, 1958). From the time of the European mediaeval cities

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when great finance houses like the Fuggers and Medicis had their agents everywhere from Milan to Antwerp, goods have been transferred from distant sources to the warehouses and trading floors of urban centres (Jardine, 1996). This turnover of materials can be discussed as trade (Pirenne, 1925), conspicuous consumption (Jardine, 1996), urban metabolism (Wolman, 1965), urban ecosystem dynamics (Douglas, 1983) or ecological footprints (Rees, 1992). In the nineteenth and twentieth centuries, the scale of this turnover increased enormously. Not only did both the world population and the total urban population multiply many times, but conspicuous consumption became the occupation of a huge new city-dwelling middle class, transforming distant landscapes and creating new, more local demands for food, water, building materials, and waste disposal sites. The vision, flexibility and dynamism of local authorities, urban elites and reforming and campaigning individuals or groups often governed responses to these demands.

Manchester and its surrounding towns joined this urban expansion in the second half of the 18th century when technological innovation made factory production of textiles possible. It faced the problems associated with concentrated industry earlier than most places and has subsequently responded to a great series of issues at the heart of the relationship between society and environment, particularly the unplanned consequences of materials flows. Manchester was an urban prototype: the first of a new generation of huge industrial cities created in the Western world in the two centuries after 1750 (Rodgers, 1987). Manchester pioneered many industrial activities, particularly through an unfettered, entrepreneurial, commercial sector, but also made early progress in health and environmental improvements (Appendix A). Political action and local campaigning spirit was such that a strong social framework developed. Powerful voices of reform, particularly public health doctors such as Percival and Ferriar, led to the worst impacts of uncontrolled industrial waste discharges being modified and mollified from 1830 onwards (Brockington, 1958).

As the place where the rapidly accelerating processes of machine manufacturing and urbanisation first converged to create the modern industrial city, Manchester was bound to attract widespread attention. The British establishment viewed Manchester as a kind of experiment, seeing the city as both an indication of what economic progress really was, and as a warning on the environmental and social problems that went with such progress. There was no escaping the paradox of this major experiment with capitalism: great economic wealth amid mounting social and environmental problems (a paradox since replicated elsewhere many times over). De Tocqueville (1958) succinctly characterised it in 1835 as a foul drain from which the greatest stream of industry flows to fertilise the whole world. From this filthy sewer pure gold flows'. All too often, responses to problems were short-term expedients, such as some of the early efforts of private water supply companies. Even the great infrastructure works on water supply dams, sewers, bridges and hospitals between 1850 and 1900 could not last forever, and Greater Manchester has faced a massive re-investment in infrastructure renewal since 1975. With some 2.58 million people living in the 1287 km^2 of Greater Manchester County in 2001, the heart of the urban core, made up of the inner cities of Manchester and Salford and part of the Borough of Trafford, had approximately 0.5 million inhabitants (Fig. 1). After nearly a century of increasing industrial problems, especially those associated with decline of textile trades—the result of foreign competition and technological obsolescence—Greater Manchester is now experiencing an economic regeneration and image make-over in an attempt to recapture some of the extraordinary vitality and unique influence that made it the 'shock city' of the industrial revolution (Briggs, 1968). This paper tests the hypothesis that the human consequences of, and responses to, urban environmental issues are not simple cause, effect and technological fix situations, but the scene of constant adjustment, re-appraisal, response to changing attitudes and new technologies. Solutions that were once deemed to be inadequate are re-examined as needs, ideas and technologies change. Environmental expenditure recurs as the chemicals causing pollution alter and land use and land cover changes occur.

1.2. The growth of the greater Manchester area before 1850

Until the second half of the 18th century, the settlements of Manchester and Salford had strayed little from their medieval core at the confluence of the Irk and Irwell (Fig. 1). The beginnings of mechanisation of the long-established wool and linen textile industry in the late 18th century changed all that. International trade dominated by cotton became the business of the city. Massive imports of cotton, imported mainly from the southeastern USA, were spun and woven into cloth in the local region and then distributed to an ever expanding market at home and abroad. By 1835, 90% of the British cotton industry was concentrated in and around Manchester and goods manufactured out of cotton amounted to 51% of all British exports. By 1853, the British cotton industry supplied 45% of the total world consumption of cotton cloth (Farnie, 1979). The humid climate and soft local river water were ideal for cotton manufacture. Local coal for the new steam-driven machinery was supplied by river and, after 1764, by canal to hundreds of mills. Following the Bridgewater canal, Manchester enterprise fostered the world's first passenger railway, to Liverpool in 1830. A labour force of skilled, semi-skilled and unskilled workers was drawn from a steadily widening area. A complex, ever-changing pattern of residential, industrial and commercial settlement had begun. The pace of exploitation of the surrounding countryside for materials expanded.

This industrial dynamism led to a remarkable growth of population: in Manchester township alone, from nearly 77 000 people in 1801 to over 316 000 in 1851. Only 45% of the 401 000 inhabitants of Manchester–Salford at mid-century had been born locally, barely 1% came from abroad, with the remainder being drawn from other parts of the British Isles (Fig. 2a). Both business and employment opportunities attracted a wide variety of migrants, from the Sephardi Jews from the

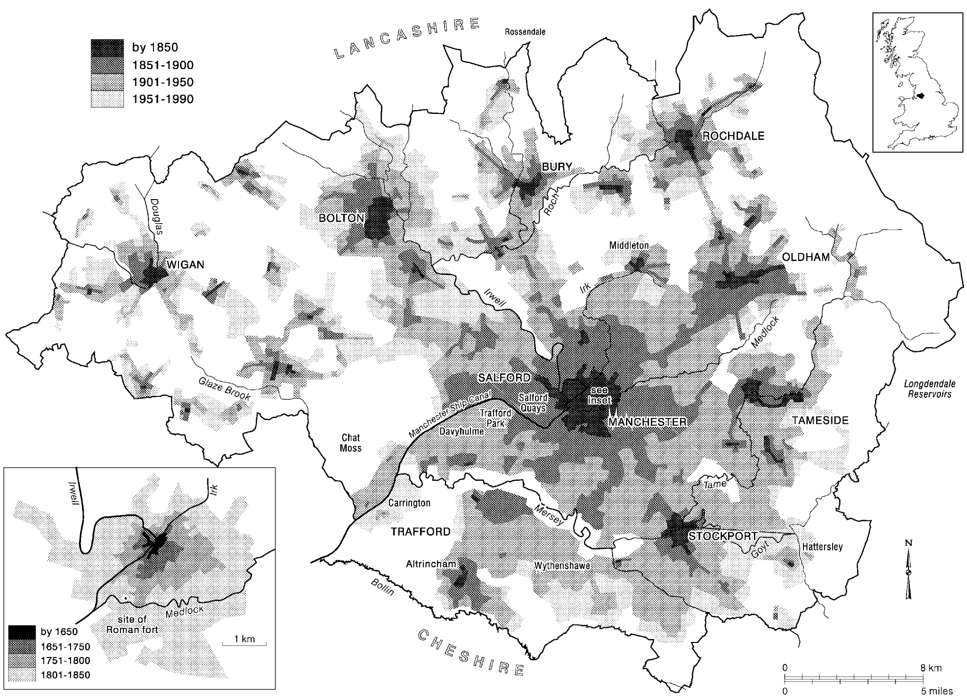

Fig. 1. Growth of the built-up areas of Greater Manchester. (Compiled by Graham Bowden, University of Manchester, from various sources).

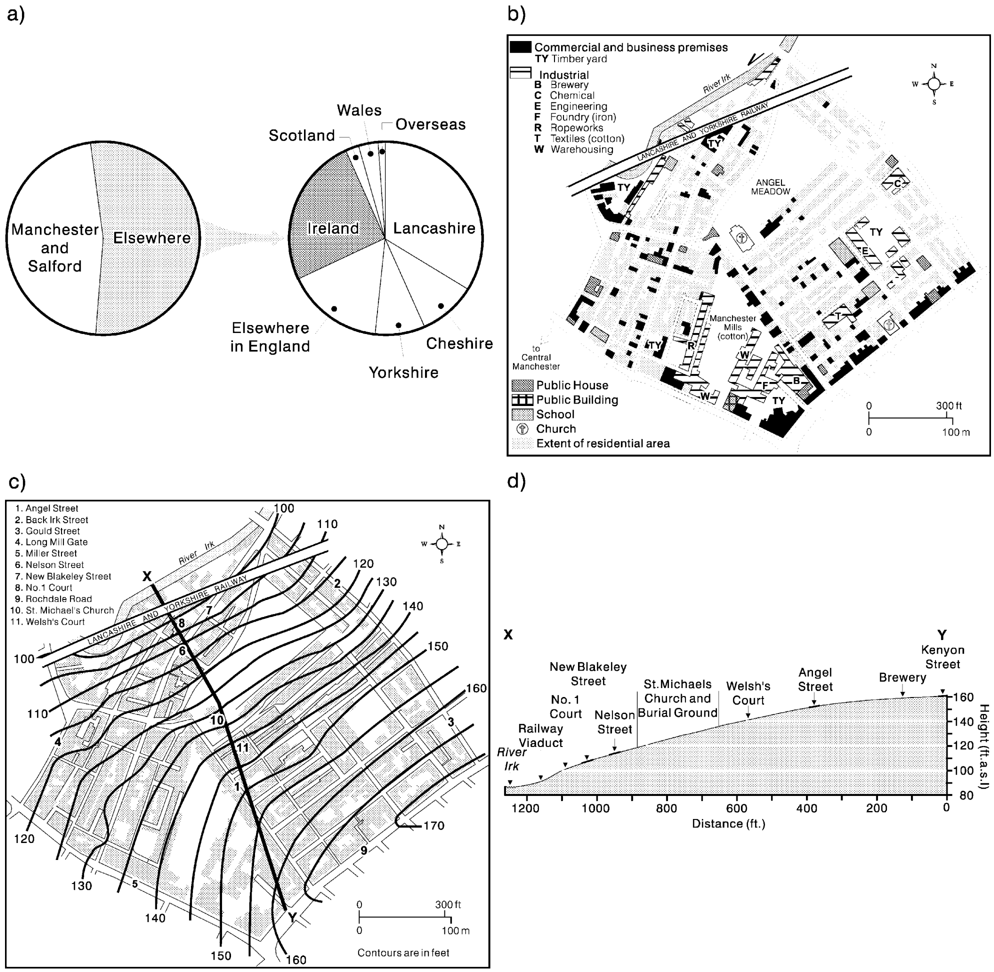

Fig. 2. Migrants in Manchester: (a) the places of origin of the population of Manchester–Salford in 1851, and the Irish-dominated settlement of Angel Meadow in Manchester showing (b) the crowding of houses between the river, the railway and factories, with (c) and (d) the fall of the ground towards the River Irk. (Sources: Census Returns 1851; Busteed and Hodgson, 1994).

Middle East and the German industrialists who engaged in cotton broking, banking and manufacturing, to the Irish who formed the largest and most exotic element in the population and whose navvies built the canals and railways. This was paralleled in the mid-20th century by the arrival of Commonwealth country immigrants, from the African Asian entrepreneurs and Indian professionals to the Bangladeshi textile workers.

1.3. Rapid growth and land use change after 1850

Greater Manchester's population rose to 2 149 000 by 1901. The built-up area expanded greatly (Fig. 1) following the building of local railways, such as the Bolton to Salford in 1838 and the Manchester South Junction and Altrincham in 1849; introduction of horse buses from 1850 and horse drawn trams after the passing of the Tramways Act in 1870 (Gray, 1996). High densities were particularly prevalent in inner areas surrounding an increasingly 'dead heart' of the city. After 1840, city centre houses were demol-ished to make way for commercial properties, railway passenger and goods stations and warehouse complexes. By 1901 the resident population of central Manchester was only 30 000, one-third that of 1851. However, salients of urban growth linked Manchester to a ring of agricultural and industrial villages, especially to the south and west, and to often fiercely independent cotton-manufacturing towns to the north and east, such as Bolton, Bury, Rochdale, Oldham, Ashton and Stockport.

Manchester diversified while continuing, through its Royal Exchange, to be the commercial and financial nucleus of the cotton trade. Machinery of all types was manufactured and exported, including textile machinery, steam engines and locomotives, armaments, and machine tools. The dominance of cotton in the trade from Manchester fell in the late 19th century as the products of manufacturing and engineering grew in importance. Gradually the sourcing of raw materials and food supplies expanded to all parts of the world. Apples from North America came through Liverpool early in the 19th century (Scola, 1992), but by the end of the century food was coming from America, Africa, Asia and Australasia (Appendix B).

The commercial expansion was not a continuous boom. Both economic downturns and cotton famines affected the city, but at the end of the 19th century, the local economy was given a great boost by the opening of the Manchester Ship Canal in 1894. The Canal not only dramatically reduced transport costs, but also transformed Manchester into the third port in the country by 1917, with a throughput of 3.84 million tons (Farnie, 1980). Alongside the docks, at Trafford Park, the first and still the largest industrial estate in Britain was developed. Ultimately up to 75 000 people worked in factories at Trafford Park. The construction of the 57 km long Ship Canal involved total materials flows of the order of 82 Mt. The gravel for the concrete used came from the southern end of Walney Island, some 80 km up the coast from Ellesmere Port, the seaward terminus of the canal (Sherlock, 1922). The 19th century thus witnessed a vast expansion, not merely in the built-up urban area but also of the impact of Manchester's activities and demands, both on the adjacent countryside and on distant ecosystems that supplied food and raw materials and were themselves transformed by the machinery and other goods exported from Manchester.

1.4. 20th Century changes

Population densities decreased with the outward movement of population, but the total number of people in the conurbation changed little. Since 1961 the Greater Manchester population has been virtually stable, with the low rate of natural increase being entirely offset by net out-migration. Gross out-migration has been partly counterbalanced by in-migrants, the 1991 census showing that 11.9% of the City of Manchester population was born outside UK, compared with 6.1% in Greater Manchester as a whole.

By the last third of the 20th century, Greater Manchester faced the decaying legacy of the precocious growth of its urban fabric a century earlier. Even though there had been extensive rebuilding of housing around 1900, further slum clearance had to be carried out after 1955. Demolition of some 90 000 dwellings between 1957 and 1976 in the City of Manchester alone involved some 2.16 million m^3 of rubble. In addition to the huge expansion of suburbs in the 1930s (Fig. 1), smaller households created a demand for yet more housing units, which was met both by infill and greenfield site development. Manchester City Council built 23 500 new dwellings, including multi-storey flats on 22 overspill sites, the largest of which were Langley (Middleton) (4700 dwellings) and Hattersley (4150 dwellings on 1.94 km^2).

Modern industrial location shows a contrast between the old surviving 19th century industries and the new early 21st century activities. The old industries, including some chemical plants subject to the EC Seveso directive on high risk chemical installations, are in traditional locations alongside canals and former railways, often surrounded by housing. The new activities are scattered over a wide range of industrial estates, some on brownfield sites, others in greenfield locations close to motorways and other major traffic routes.

Economic activity close to the core-city has some stability with a broad range of service industries, financial activities and three higher education institutions. The important service function of the city centre has been developed and reinforced since 1945. Just outside it, however, the inner city has become a severely deprived area, containing many disadvantaged and ethnically mixed communities with poor job and health prospects.

In 2001 the conurbation consists of a central city area, broadly defined as inner Manchester and Salford, and an outer girdle of substantial towns such as Bolton and Altrincham plus numerous lesser towns and industrial villages. While patches of green separate parts of the area, the whole zone has virtually continuous development (Fig. 1), with greenfield sites still being infilled for new leisure, shopping and road developments. Ten local authorities now separately administer their own sections of the conurbation (Fig. 3), coming together as the Association of Greater Manchester Authorities (AGMA) to look at some planning and environmental concerns. Although, the administrative structure is far less complex than in 1888, there are still many difficulties in developing and carrying out environmental policies covering the whole conurbation.

2. Housing, health and sanitary reform

Despite expectations to the contrary, a sizeable proportion of the immigrant 19th century Greater Manchester workforce often had only casual, low paid work and lived in overcrowded, damp, poorly lit and inadequately ventilated accommodation (most notoriously back-to-backs, court dwellings and cellars) with little sanitation (privies often shared by 20–30 families, sometimes many more), an inadequate water supply, and high rates of disease and mortality. Engels (1845) described wretchedness of life in Little Ireland, a district of

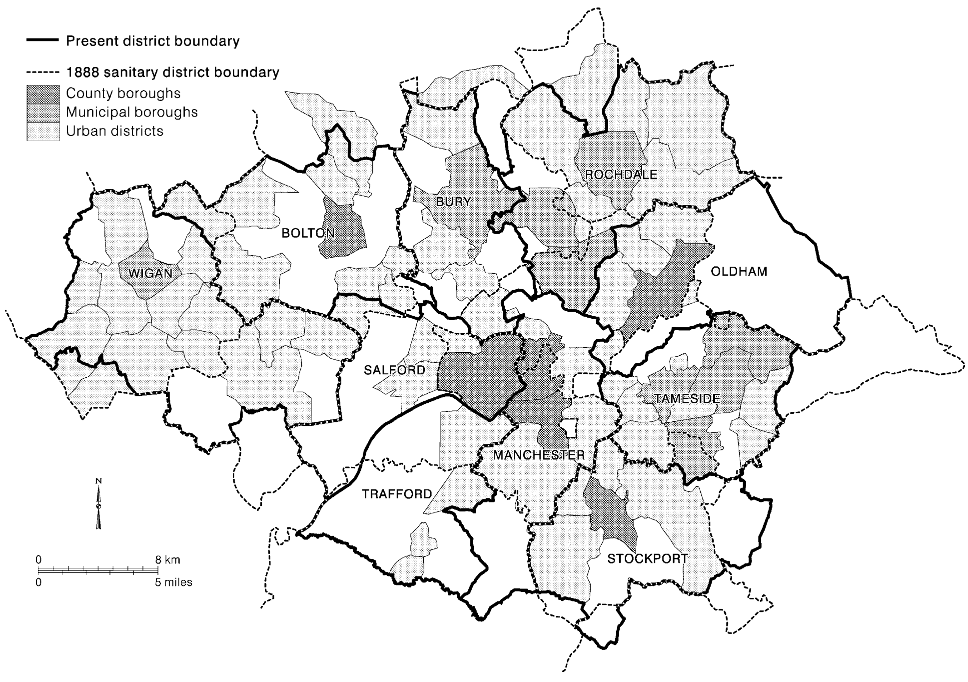

Fig. 3. Maps of local authority areas in 1888 and 1990 showing the complexity of 19th century local government. Manchester took over many adjacent local authorities, especially those that wished to be joined to the Longdendale water supply, while new urban authorities were created out of the rural districts (the white areas within the modern county boundary on the map). The 10 Metropolitan Districts and Greater Manchester County were created in 1974, but the County Council was abolished in 1986. (Compiled from 1888 Sanitary District Boundary Map and 1995 County Boundary Map).

dense Irish settlement in the 1820s and 1830s, thus:

"A horde of ragged women and children swarm about here, as filthy as the swine that thrive upon the garbage heaps and in the puddles."

The worst conditions were in low-lying dwellings surrounded by factories, mills, railway lines and viaducts, and which were also liable to flooding from polluted rivers. Although these archetypal, classic slums were not confined to Manchester, they were more widespread than in most other industrialising British towns and cities of the time. For example, the streets and homes in the lower levels of the Irish-dominated district of Angel Meadow (Busteed and Hodgson, 1994) built on sloping ground (Fig. 2b–d) suffered accumulations of effluent from the upper levels, and flooding from the Irk, polluted by the dumping of personal and industrial waste. Hence, at a sitting of the Court Leet on 14 April 1837, the owner of a chemical factory in Angel Meadow was fined for releasing naphtha into the river.

"By reason of which large quantities of obnoxious and unwholesome smell, stenches and effluvia did… issue from said River into and upon the dwelling houses of divers of His Majesty's liege subjects"' (Court Leet Records, Vol. 12, 1887).

Despite inadequate understanding of the causes and spread of disease, the association between ill-health and poor living conditions soon became evident. The first local campaigning group in Britain for health improvements came about in 1796, when typhus among cotton-mill employees led public-spirited Manchester physicians to organise an ad hoc health board (Porter, 1997). This 1796 report by The Manchester Board of Health pointed out that cotton factories were a hot-bed of epidemics and that the lives of children working in them were ruined by the contaminating surroundings of their early years (Chapman, 1904). The 1831–1832 pandemic of cholera prompted actions such as those of Kay (1832), whose ideas were taken up by Chadwick (1842) in recommending reform of housing, provision of clean water and efficient disposal of household rubbish and sewage. These sanitary reformers skilfully appealed not only to humanitarian considerations but also to other growing political and economic anxieties in the host population. Sanitary reform was seen as a way both of maintaining the efficiency of the labour force and of quelling the 'revolutionary' activities or 'rioting propensities' of the working class people who formed three-quarters of the population (Love, 1842).

Lack of political will, finance, and understanding of public health made efforts to improve the household situation patchy in time and space. Even less was done about reducing industrial emissions lest the economic growth of Manchester be impaired. The diversity of small local authorities (Freeman, 1959) obsessed with keeping local rates (council taxes) low and reluctant to co-operate with their neighbours (Fig. 3) made collaboration in reform on such key issues as water supply and drainage difficult. Efforts concentrated on improving housing, sanitary arrangements and water supply, culminating in having taps and water closets (WCs) in every dwelling. Progress was relatively slow and uneven. Manchester Borough Council was ahead of national legislation in passing local acts regulating housing conditions. Most cellar dwellings had gone by 1874 and nearly all the unhealthy, poorly ventilated, back-to-back houses had disappeared by 1915 (McKechnie, 1915).

Infant mortality in Manchester in 1798 may have been as high as 300 per 1000 live births. Smallpox was a major killer of young children until 1800. Percival introduced vaccination, and in the 1820s and 1830s whooping cough became the most serious cause of death of infants under 1 year. Respiratory diseases amongst cotton workers were exacerbated by the dusty and damp conditions in the cotton mills and were the most significant form of death in the 1850s by a fairly substantial margin (Fig. 4) (Fleischman, 1985). Not until the beginning of the 20th century was it realised that dust and particles of cotton, particularly prevalent in card rooms, should be extracted without first contaminating the atmosphere. The injection of steam to facilitate weaving sized warp threads made from short-staple cotton yarns was common, and maximum limits of humidity at given temperatures and the maximum proportion of carbon dioxide in humidified weaving sheds

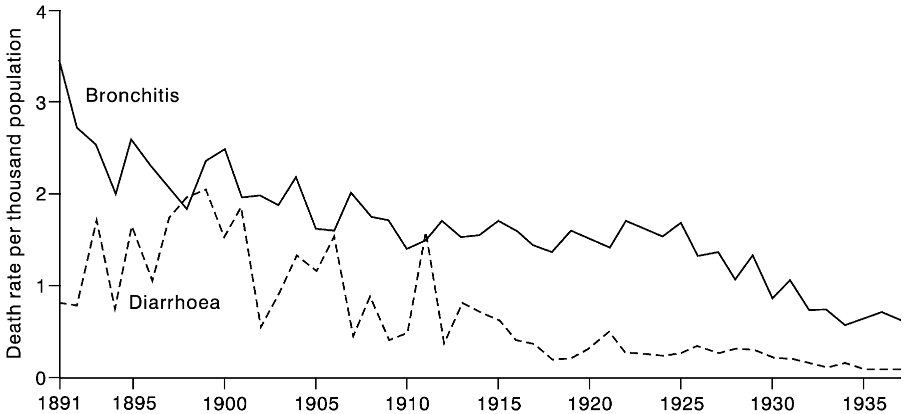

Fig. 4. Deaths from Bronchitis and Diarrhoea in Manchester 1891–1938.

were not imposed until the Cotton Cloth Factories Act of 1889. In 1890, the infantile death rate for the offspring of cotton workers and labourers in Blackburn was 252 per 1000 births compared with 160 for the offspring of all other parents (Cruickshank, 1981).

From the middle of the 19th century until the 1910s diarrhoea, which reached its peak during hot, dry summers, was the greatest single cause of infant mortality, showing wide variations in its impact from year to year (Fig. 4) (Newsholme, 1899). Milk purchased from street vendors quickly went sour and infants often died through lack of understanding of the causes of gastric problems (Pooley and Pooley, 1984). The transfer from breast-feeding to cows milk was reflected in a shift from a winter to summer peak in infant deaths (Huck, 1997). In Manchester after 1851 a relatively small proportionate fall in infant mortality occurred (Fig. 5) but it rose again in the 1890s, due to increased diarrhoea, perhaps because contaminated food, frequently blamed for infant deaths, was being replaced by equally contaminated tinned or fresh milk (Beaver, 1973; Pooley and Pooley, 1984).

General improvements of the urban environment in the 19th century made a major contribution to the decline in infant mortality (Fig. 5) (Woods, 1991; Porter 1997), arguing that changing public opinion, the efforts of medical officers of health, better drinking water and sewerage, slum clearance, the success of cleanliness campaigns and many individual small improvements, such as dustbins with lids to keep out flies, lead to a better urban environment. In Manchester, despite reforms and public activity, the real reductions in mortality did not occur until the end of the 19th century, with infant mortality falling only after 1900 and diarrhoea as a cause of death declining significantly after 1916. Pooley and Pooley (1984) emphasised that the acute poverty of many Victorian city dwellers inevitably led to malnutrition and inadequate accommodation that progressively reduced resistance and increased exposure to disease. This relationship between health, poverty and living environment was re-echoed in the late 20th century in the 1980 Black Report, *Inequalities in Health*, that showed that in 1971 the death rate among adult males in social class V (unskilled workers) was nearly twice that of adult men in social class I (professional workers) (Porter, 1997). In 1950 a baby in social class IV or V was twice as likely to die before attaining the age of 12 months than a baby in social class I (Carr-Saunders et al., 1958).

Vigorous Local Authority attempts to improve sanitation were spatially discrete in their coverage. Nearly a third of the houses in the city lacked sanitation in 1868 (Pooley and Pooley, 1984). Earth closets and privies increased the risks of cholera, typhoid and gastric tract diseases. Elsewhere, untreated drainage running directly into rivers from suburban WCs aggravated severe river pollution problems. In the 1870s cesspits in

Manchester began to be replaced with night soil collection from pail closets (ironically called Dolly Vardens after a nationally known perfume!). Only after 1890 did a waterborne system of sewage disposal and treatment come into operation in Manchester and start to reduce the incidence of typhoid.

Collection of night soil and horse manure from the city by scavengers in carts created a disposal problem, and Manchester Corporation purchased large parts of the desolate wet area of Chat Moss, across which Stephenson had such difficulty building the Liverpool to Manchester Railway in 1829 (Burton, 1980). The drainage and reclamation of such mosslands around Manchester (Shimwell, 1985) were seen as providing rich soil for growing vegetables and potatoes to supply the city. The organic waste from the city helped to improve the land (Kear, 1991). It was carried out of town along newly constructed turnpikes, canals and railways which had sidings into the newly drained mosslands, bringing the wastes out and taking farm produce back to town, thus overcoming a sanitation and health problem. The disposal of sewage became linked with transportation and food production for the people and livestock of the 19th century city.

With the construction of bye-law housing in the late 19th century, water-borne sewerage was installed in all new housing areas. Each municipality had its own treatment works until the City of Manchester built the large works at Davyhulme in 1896. This expansion set up a new form of organic waste: sewage sludge. This was originally taken by barge down the Manchester Ship Canal to be dumped in a defined area of the Irish Sea. When this ceased in 1998, Greater Manchester's people were producing about 77 500 tonnes of dry sewage per annum, of which 45 600 tonnes required disposal. The sewage sludge is now dewatered at Davyhulme and piped as a cake containing approximately 27% dry solids to a new processing plant at Shell Green, Widnes. This plant copes with up to 240 000 tonnes of dry sludge annually, including that from Merseyside and Warrington. Approximately, 50% of the dry matter is incinerated and 50% is disposed of on to arable land and in reclamation projects, being mixed with colliery spoil for use in landscaping schemes (Belshaw, 2000). Now, once again, Manchester's organic wastes are being dumped on farmland and helping to feed the city's people.

A reliable pure water supply was critical for public health and the WC system. Although Manchester Corporation took direct control of the city's supply in 1851, and despite the completion of reservoir schemes in Longdendale in 1850s and Thirlmere in 1890s, distribution of pure water remained very uneven throughout the 19th century. Despite exhortations from reformers, most central-city courts and terraces did not have their own in-house water supply but relied on standpipe in yard or end street for most of the 19th century. Around 1900, it was not unusual to find

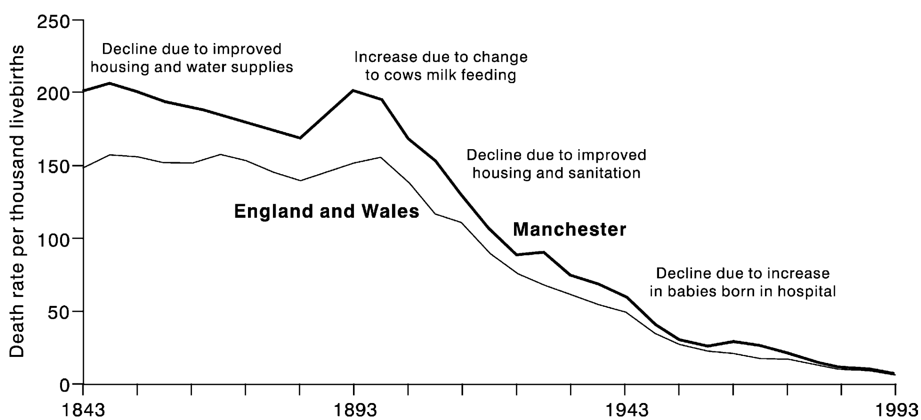

Fig. 5. Infant mortality in England and Wales and in Manchester 1843–1993.

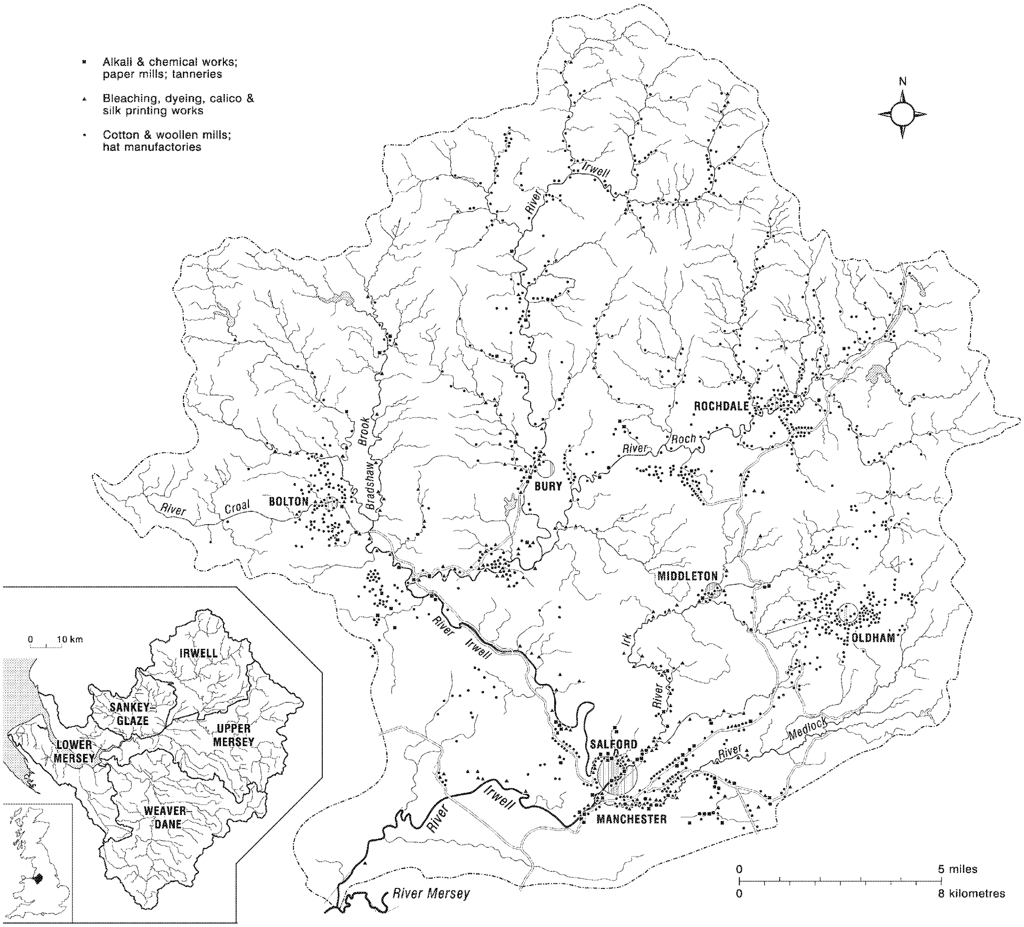

Fig. 6. Location of mills, works and factories close to the River Irwell and its tributaries in 1869, showing the general occurrence of dyeworks and chemical factories adjacent to rivers, although cotton mills are more widely distributed across the landscape. (Source: Rivers Pollution Commission, 1870).

one tap in a yard supplying 20 or 30 houses (McKechnie, 1915). Standpipe supplies both increased the possibility of infection as water from them stood around the house in containers for several hours, and encouraged the use of less pure alternative supplies obtainable closer to hand. Despite relatively pure water being readily available in middle-class suburban areas, most working-class districts were forced to endure inadequate supply. The increased use of water and the expansion of the built up areas added to the existing materials flows to rivers and to water quality problems.

3. River pollution

For 200 years the rivers of Greater Manchester presented a sorry record of deterioration in quality. While the major rivers rise on the peat covered moorlands of the plateau of the Pennines, local streams draining the plains around the core city are now almost buried beneath concrete and brick. The most intractable pollution stories come from the Irwell and its tributaries, the Croal, Irk and Medlock.

During the 19th century increasing industrialisation led to many mills, works and factories directly discharging many pollutants, including ashes and cinders, into rivers (Fig. 6). Notable cases were the upper reaches of the Irwell where, before 1870, half the capacity of the channel was lost by dumped coal and furnace deposits and cinders from domestic fireplaces (Fig. 7). The silt in the river below Salford built up so much that whereas vessels of 1.5 m draught reached the wharves in 1840, by 1860 vessels of 1 m draught had difficulties, and at the lowest flows no vessels could pass (Gray, 1993). Around 1870, Salford township took upstream townships to court for dumping ashes and debris in the river and causing this problem. Serious flood problems, which became increasingly damaging after 1850, led to many flood alleviation scheme proposals, including one to build a tunnel from Adelphi, upstream of the City Centre, to the river near Weaste, downstream of the city.

Drains were developed in phases: (i) culverting of water courses and street drains to 1820, (ii) local sewerage systems 1792–1880 and (iii) intercepting sewers in two stages 1886–1898 (including Davyhulme Treatment works with treated effluent ultimately returned to the recently built Ship Canal) and 1910–1973 (to provide additional capacity with extension of the built-up area). During the 19th century, the drainage system received ever increasing amounts of varied, and uncontrolled, discharges; including liquids containing many dissolved substances and much solid waste including ashes and cinders from houses and factories.

The consequences of this are evocatively described by the 1870 Rivers Pollution Commission Report, a direct response to local and national concerns about the foul rivers:

"When taking samples at Throstlenest Weir, below Manchester, at 05:00 h on July 21, 1869, we saw the whole water of the River *Irwell*, there 46 yards wide, caked over with a thick scum of dirty froth, looking like a solid, sooty crusted surface. Through this scum, here and there, at intervals of six and eight yards, heavy bursts of bubbles were continually breaking evidently rising from the bottom; and wherever a yard or two of the scum was cleared away, the whole surface was seen simmering and sparkling with a continual effervescence of smaller bubbles rising from various depths in the midst of the water, showing that the whole river was fermenting and generating gas. The air was filled with the stench of this gaseous emanation many yards away. The temperature of the water was 76 F, and that of the air 54 F."

Even the Manchester Ship Canal became polluted virtually as soon as it was completed, both from the already heavily contaminated River Irwell, the major source of water to the canal, and from the 519 out-falls of sewage and industrial effluent which feed into it (Fan, 1996). As early as

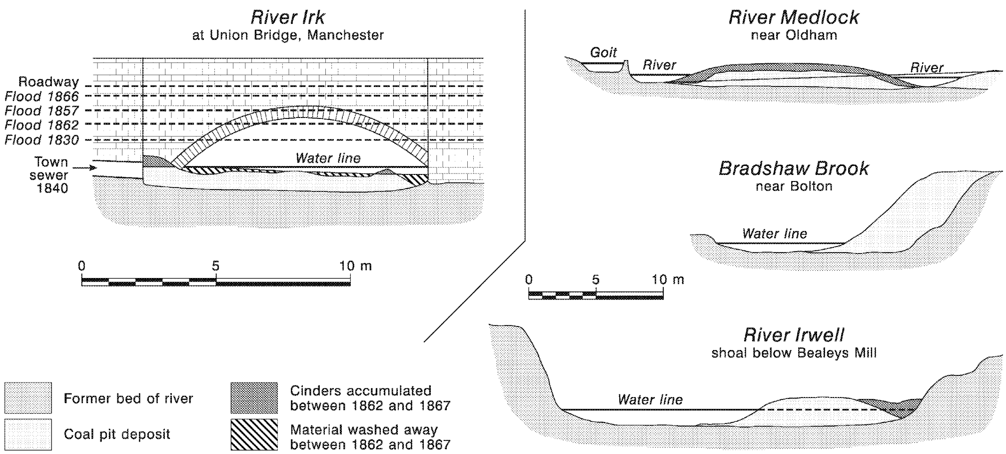

Fig. 7. Mid-19th century changes to river channels due to the dumping of cinders and other wastes, as described by the Royal Commission on Rivers, 1870. Note particularly how siltation of the Irk at Union Bridge had buried the outlet of the town sewer at least 1 m below a mass of debris. (Source: Rivers Pollution Commission, 1870).

1896, complaints of pollution during summer droughts led to the creation of a Port Sanitary Authority (Farnie, 1980).

The Eighth Report of the Royal Commission on Sewage Disposal (1912) defined the standards for sewage works effluents as 20 mg l^{-1} of BOD and 30 mg l^{-1} suspended solids (Tebbutt, 1992). Limits were imposed on what factories and homes could discharge; licensed discharges were established, and gradual regulation was imposed. By 1940, every local authority had its own sewage treatment plant on the banks of a river.

Reduction in industrial discharges (through a gradual decline in number of sources) and the move from steam to diesel and natural gas power helped lower pollutant loads, but these were countered by an expansion in number of residences and in the per capita use of water and chemicals, such as detergents. Increased water discharges to sewers meant more overflows from combined sewers during storm events. In addition, increasing farm effluent, especially from pig farms where effluent from one pig is equivalent to that from five humans, led to many small streams being heavily polluted. In 1985 Manchester had 97 combined stormwater sewage overflows discharging into the Medlock, which means that even in small rainfall events untreated sewerage entered the river. Since 1985, the national urban pollution management programme in which North West Water, the local water and sewerage company, has taken the lead, has set out to intercept most of these overflow sources and to create large new storm water storage tanks from which the effluent during overflows is far less oxygen demanding than from the original outfalls.

River water quality management has involved major expense since 1974. Much of the 19th century sewage system has been rebuilt, treatment plants have been upgraded, and most small sewage treatment plants have been eliminated, with interceptor sewers taking wastes to major stations such as the Davyhulme treatment works. River water quality has improved considerably in the last decade of the 20th century (Fig. 8a) and local fishermen now take edible trout out of the River Mersey on the south of the City of Manchester.

4. Air pollution

While water-borne diseases were eased by the sanitary reform measures of 19th century, progress on those related to air pollution, especially bronchitis and other respiratory ailments, was virtually non-existent before 1900. By the 1880s Manchester had acquired an unenviable reputation for dirt, smoke and gloom. Many reformist individuals and groups, such as the Manchester and Salford Noxious Vapours Abatement Association (NVAA), warned of the dangers from chemical pollutants (from alkali works), and more especially smoke from coal burning both at industrial sites and in domestic hearths. Nevertheless, the prevailing and often dominant view was that smoke pollution was a necessary and harmless corollary of ‘progress’. Total freedom from smoke pollution was still regarded by many an utopian goal and those who pressed for abatement were often dismissed as irksome, interfering, do-gooders: ‘amiable and unpractical faddists’. Reform efforts were preoccupied with industrial pollutants, but had limited impact. Some tightening of existing regulations was achieved by the NVAA, for example, in the Alkali & Works Regulation Act in 1881 (Mosley, 1996). However, these pioneering efforts paved the way for succeeding generations, which placed Manchester at the forefront of air pollution abatement.

In the first decade of the 20th century, as part of the great expansion of manufacturing in Trafford Park, a steelworks, further chemical industries and electric power stations were built, beginning a period of concentrated point-source emissions which did not end until the late 1980s and early 1990s with the closure of the last four power stations in the county. The other great SO_2 source was the railway whose network reached its greatest density by 1910.

With new ideas about housing and healthy lifestyles, Manchester and Salford pioneered smoke control measures. The 1930s saw a campaign for clean air and smokeless zones (led by Charles Gandy, a Manchester barrister and chairman of the National Smoke Abatement Society, whose headquarters were in Manchester). At this time suburban housing development occurred

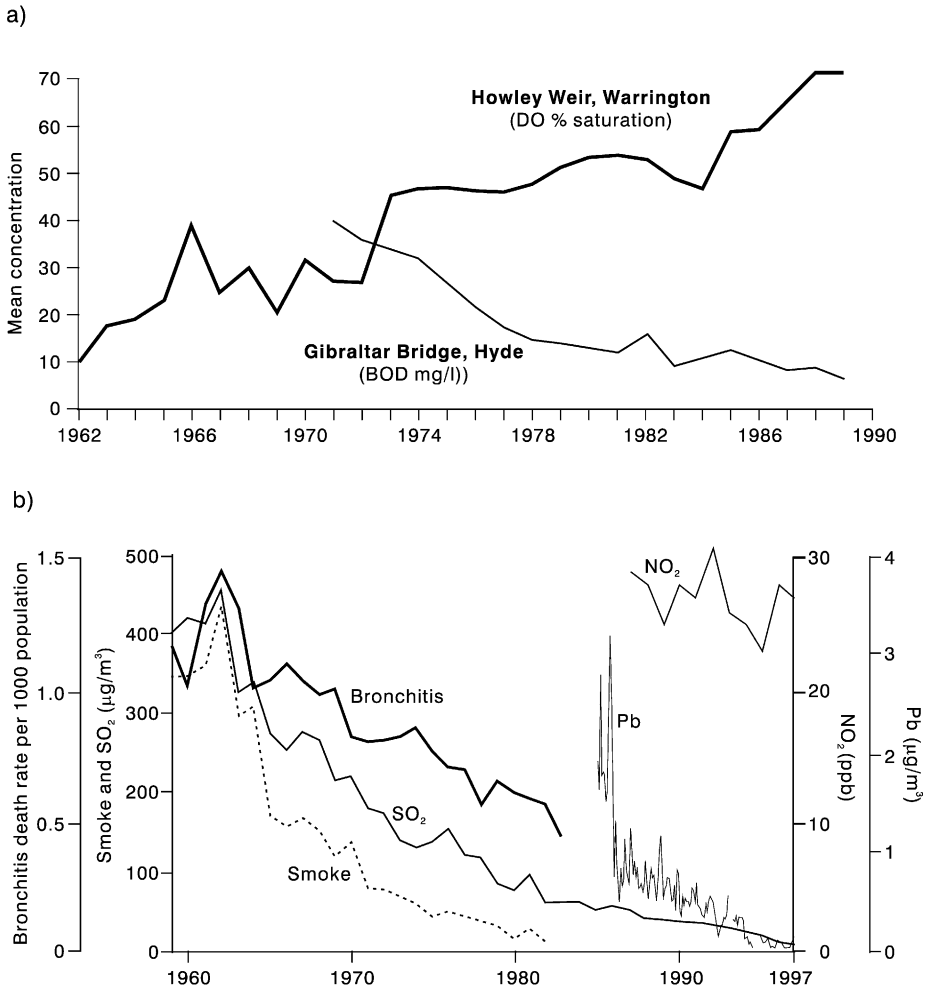

Fig. 8. Reductions in air and water pollution: (a) Improvement in the oxygen content of rivers, both upstream of the city at Hyde and downstream of Great Manchester at Warrington since 1960; (b) falls in SO_2 and smoke in the air at Manchester Town Hall, deaths from bronchitis; lead in the air at the side of the M56 in Wythenshawe; the recent record of annual average NO_2 in the air in Piccadilly Gardens in Manchester City Centre. (Compiled from data supplied by North West Water, The Medical Officer of Healthand Manchester City Council).

rapidly (Fig. 1), linked to centres of employment by motor buses. Both private and local government public housing in 'garden city style' estates covered many km^2 of south Lancashire and north-east Cheshire farmland around the city. One of the most enterprising ventures was Wythenshawe, Manchester's own 'garden town', described as "perhaps the most ambitious programme of civic restructuring that any British city has ever undertaken" (Kidd, 1993). Nevertheless, in 1959 Manchester still had 68 000 'grossly unfit' houses without the basic amenities, which had become standard in modern private and Corporation homes since 1919. This 'healthier' housing still relied on coal for heating, but the chimney density was less than in the older inner city areas.

Permission to establish the first smokeless zones in the City Centre was obtained just as World War II started in 1939. After the war in 1946, Manchester became the first UK local authority to obtain powers (under Manchester Corporation Act) to establish 'smokeless zones'. Salford and

Bolton obtained similar powers soon after, and the first smokeless zone came into effect in Salford in 1949. Well before the 1956 National Clean Air Act, the local governments of the Greater Manchester area had effectively set the pace by dealing with a local problem which was in reality a national menace, as the great London smog of December 1952 showed to every politician in the Houses of Parliament at Westminster. Over the 25 years after 1955 the pollution due to smoke and SO_2 declined markedly. From the early 1960s onwards the reduced levels of smoke and SO_2 are clearly reflected in the reduction in deaths from bronchitis (Fig. 8b). Between 1945 and 1969, winter sunshine increased by about 50% in the city centre (Wood et al., 1974) with a further 20% improvement between 1969 and 1975 (Tout, 1979).

For Greater Manchester as a whole, the process was virtually completed by 1990, save for a few mining communities where the traditional right of miners to receive free coal supplies remained socially important. This achievement of cleaner air was greatly helped by the decline of heavy manufacturing industry and the substitution of electricity, gas and oil for coal burning and steam power. For the whole of Britain it was fortunate that natural gas from the North Sea basin became available at the time of implementation of the clean air legislation.

The improvements locally were assisted, not only by industrial change, but also by the policy requiring new plants to install tall chimneys to expel whatever emissions occurred high into the atmosphere. The chimney built at the Shell (now Montell) petrochemical works in the 1970s at Carrington in the western part of Greater Manchester is a good example of the planning authority insisting upon a higher chimney than originally proposed (Wood, 1976). Yet these chimneys only shifted the emission problem elsewhere. Ejected into the prevailing westerly airstream, the emissions were carried over the already abnormally acidic Pennine moors of the centre of northern England, across Yorkshire and the North Sea to Scandinavia where they contributed to the acidification of lake waters that caused such concern in the 1970s.

Furthermore, other new and expanding technologies brought new air pollution problems to Greater Manchester. In the 1960s, high octane 'anti-knock' petrol was hailed as a revolution in motor car engine efficiency. A decade later, concern was raised about the impacts of lead emissions on health, especially that of children in schools close to traffic routes. Once again, public campaigning led to political pressure which saw the introduction of lead-free petrol in 1986 and, later, a differential tax on leaded and lead-free petrol. The technical adoption of catalytic converters was a further step in reducing motor vehicle emissions. The data for St. Thomas School, near the M56 motorway in Wythenshawe, show a dramatic decline from the high levels prevalent in 1986 (Fig. 8b). In the city centre increased traffic caused a gradual increase in lead in airborne dust that peaked in 1989. Traffic emissions, as indicated by lead in roadside soils and vegetation, tend to be higher where vehicles stand at traffic lights than elsewhere along major roads. Increased congestion in the future could again lead to more pollution, even though emissions from individual vehicles are being reduced.

In 1999, the greatest concern about air pollution in Greater Manchester is over suspended particulate matter (SPM) and oxides of nitrogen (NO_x). Particulates are associated with diesel powered vehicles, NO_x with both diesel and petrol vehicles. They are of particular concern because of their ability to intensify asthmatic conditions among those already susceptible to asthma. Severe episodes of high particulate concentration can occur locally under still, calm, anticyclonic weather conditions. The annual average NO_2 concentration in the city centre has varied little since measurements began in 1987 (Fig. 8b), but they exceed the EC Directive's recommended annual mean of 21 ppb. However, the more serious annual 98th percentile of hourly means has remained below the Directive's compulsory limit of 105 ppb save in 1992 and 1994 when cold, anticyclonic conditions caused NO_2 levels to exceed the guidelines during two 48 h periods.

Thus air pollution problems have changed over time. Public pressure and the determination of key individuals helped to propel the change, but technological changes and resource substitution also played their part. Now local authorities are recognising the need to reduce the use of motor vehicles. The re-introduction of trams to the city centre and their replacement of trains on two suburban rail routes have taken 2.5 million car journeys a year off the city streets. Proposals to operate road charging trials and to charge for workplace parking are actively being discussed by some councils. The tramway is being extended with new fixed rail lines, but not as rapidly as many advocates wish. Provision of bicycle lanes and bicycle parking facilities is proceeding, but cyclists find the separation of bicycles and traffic totally inadequate.

The battle against air pollution in Manchester has thus seen a combination of campaigning by individuals and pressure groups, some grassroots, but others combining medical, business and legal expertise. Conscious of the mistaken perceptions of some people, both in southern England and beyond, that Manchester is a grimy unattractive city, the Manchester and District Chamber of Commerce and the wider North West Business leadership have established environment or sustainability teams and have projected ideas of a 'Green and Pleasant Region'. Yet, at the same time, new foci for traffic movements, such as major sporting facilities and shopping centres (like Bolton's Reebok Stadium and the Trafford Centre), have opened on the fringes of the major nuclei of population within Greater Manchester. Despite pollution reduction measures, everything that encourages extra vehicle movements adds to atmospheric emissions.

5. Discussion and conclusions

Every effort to make the city more prosperous, healthier and more attractive to residents leads to new environmental pressures. Some materials flows have gone almost full circle. In addition to the return to disposal of organic wastes to the land, there is the use of methane gas from landfills to generate electricity for the local grid and, in particular, the highly successful re-introduction in 1992 of trams to the city centre streets 43 years after they last ran there. The modern trams have cut out some 2.5 million car journeys a year. The innovation characteristic of Manchester for the last 200 years is seen in many of its environmental solutions, from the technology used to keep the waters of the redeveloped former docks at Salford Quays clean, to the efforts being made to ensure the widespread use of low-floor, easy access, cleaner emission buses throughout the city. The rejuvenation of the city centre has seen former warehouses converted to apartments, student residences and office blocks, thus avoiding some of the materials flows of bricks and concrete for new buildings. Elsewhere in the county, much brownfield, old industrial land has been re-used, but, in 1999, 3217 ha remain to be tackled. Many of these brownfield sites still contain the legacy of their industrial use, for example, coal gas purification plants which produced gas that substituted the burning of coal and made a major contributed to the reduction in atmospheric SO_2. Most of these plants closed down as soon as natural gas from the North Sea became available in the 1970s after being operative for anything up to 100 years or more. Some of the chemical time bombs of hydrocarbon and heavy metal contaminated land from these plants are still requiring remediation.

Yet, innovative initiatives are now starting to tackle the regeneration of derelict land and some of the old urban landfills in a manner which will enable them to become a part of urban greenspace corridors. Within the urbanised areas of Greater Manchester and Liverpool there are some 1060 ha of derelict and neglected closed landfill sites (Roome et al., 1999). Initially, these older landfill sites were located at the edge of the cities and towns, but with urban growth many of these sites which were once on the urban fringe have now closed and are surrounded by settlements. Within Greater Manchester alone, there are over 900 closed landfill sites and many have the potential for re-development as community woodland, but the availability of soils and soil making materials is crucial in advancing their regeneration (Rawlinson et al., 1999). Trials are now taking place on the suitability as landfill cover of the 120 000–150 000 tonnes per annum of soil-making material which can be produced from domestic and commercial waste by the Greater Manchester Waste Authority. Thus, an initiative able to close a material's flow circle is starting to evolve—waste which would have increased land dereliction is being transformed in to a product which potentially will enhance land regeneration, environmental regulations permitting.

Containerisation and changing trading patterns led to the closure of the Port of Manchester in 1977. Since 1984 this whole area has been in the process of being redeveloped as a desirable waterside location for modern offices, housing units and leisure pursuits. Following a rigorous risk assessment, the water quality is also being improved to a level compatible with these new uses.

The dock areas cut off from the river flow contain 3–4 m of contaminated sediments, a chemical time bomb from 80 years of environmental neglect. These sediments are heavily contaminated and removal would be both costly and unsafe. The solution is the isolation of the docks from the flowing water in the canal and treatment of the largely anoxic water by permanent aeration and by bio-manipulation.

Sediments in the semi-closed turning area and in the upper reaches of the canal also contain high levels of heavy metals and over 75% organic material which has a BOD value of up to 3000 mg/l, and was classified by the NRA (now the Environment Agency) as 'bad' (Fan, 1996). Oxygen injection equipment designed to improve the water quality to 'good' by an improvement in BOD of 75% over the next 20–25 years came on stream in 2001. It is estimated that the quality of the water will have returned to 'poor' by 2005 and to 'fair' by 2010.

Innovation in Manchester continues to evoke new materials flows and environmental impacts. The highly successful international airport has built a second runway involving the excavation and deposition or disposal on site of 2.36 million m^3 of material, the import, by a temporary railway, of 1.3 Mtonnes of stone and a total materials shift of the order of 6.3 Mtonnes (AMEC-Tarmac Joint Venture, 1999). The impact of this was felt not only in the stone quarries of the Peak District, but will also affect the global atmosphere, as the contrails of the larger number of aircraft flying into Manchester each add to the greenhouse gases.

The aircraft emissions may be seen, along with the sewage sludge disposal and the emissions from tall chimneys, as Greater Manchester imposing its wastes from materials flows on other environments, thereby extending its ecological footprint. Even the major part of the solid waste flows goes to sites outside the county boundary. Of arisings of 7.7 Mtonnes per year, some 1.5 Mtonnes are sent to landfills within Greater Manchester, a small part is incinerated and the remainder, after pulverisation and compaction, goes to sites outside the county (Bell, 1997), 600 tonnes per day being sent by rail to old iron ore mines 110 km away in Lincolnshire.

These examples show that Manchester has had to cope with the failures of its past systems and renew the successes. Managing materials flows in a city like Manchester is not simply a question of putting in infrastructure and systems and allowing them to run forever. The message is not just one of adopting an ecological risk-control strategy (Cantlon and Koenig, 1999), but also one of constant renewal and change. Most of Manchester's Victorian sewers, bridges, dams and hospitals have been renewed, refurbished or replaced. The engineering costs involved illustrate how sustainable management of materials flows requires both infrastructure investment and political and economic commitment to long-term care and maintenance. Often changes are prompted by a crisis, made possible by the availability of new technology, encouraged by subsidies, stimulated by entrepreneurship or professional and community pressure groups, and made possible because there is some political will. The example of infrastructure renewal confirms the hypothesis that responses to urban environmental issues are not simple cause, effect and technological fix situations, but the scene of constant adjustment, re-appraisal, response to changing attitudes and new technologies. Removal of small inefficient waste water treatment plants and the development of tertiary treatment at the remaining large plants, together with new ways of managing storm sewer overflow, illustrate technological adaptation to new public values and perceptions of the benefits of clean rivers and the reduction of health risks. So often, Manchester has led other cities—as the first industrial city, the pioneer of free trade, the owner of the first Major British inter-basin transfer urban water supply and the initiator of smokeless zones. These responses to needs and crises have not been driven by market forces alone, but have been driven by ideas of social and environmental improvement, by the recognition that there must be a better way of doing things. Manchester now recognises the need to think globally, but act locally, to create a high quality living and working environment with as small an ecological footprint on other ecosystems as possible. This is not easy, as consumer demands lead to the supply of food, goods, and materials from ever widening, more distant sources, and many recycling and reuse options for waste and old industrial materials are constrained by legislation and perceptions aimed at reducing health hazards and environmental contamination. One way forward, which contains broad-brush estimates for materials flows for Greater Manchester, has been set out by Ravetz (2000). This goal of greater sustainability is far from being achieved, but awareness and appreciation of materials flows and their impacts will help to get closer to it.

Appendix A. List of key events in the evolution of modern Manchester

1752	Royal Infirmary established
1761	Bridgewater Canal, the first industrial canal in the UK, opened as far as Stretford
1789	Construction of first steam engine used in manufacture of cotton
1790	Power looms introduced into Manchester
1791	House rented near Salford Bridge for a lying-in hospital
1796	Board of Health established in Manchester by Percival and Ferriar (a result of a typhus epidemic: the first local health pressure group in England and Wales) and House of Recovery set up.
1804	Rochdale Canal completed through central Manchester
1807	Gas first supplied to the City
1809	Manchester and Salford Waterworks Company founded
1814	Manchester Institution for Curing of Diseases of the Eye founded
1817	Manchester Gas Works established
1825	Manchester Medical School founded by Thomas Turner
1828	Ancoats Hospital opened as Ardwick and Ancoats Dispensary
1829	General Dispensary for Children established in Back King Street
1830	Liverpool and Manchester Railway opened-the world's first passenger railway
1832	Major cholera outbreak
1833	Manchester Statistical Association founded District Provident Society providing relief in cases of sickness and convalescence established in Manchester
1834	New Poor Law Act
1838	Incorporation of the City of Manchester Bolton to Salford Railway opened
1842	Manchester and Birmingham Railway opened
1843	Royal Commission on the Health of Towns Gas Undertaking became Manchester Corporation Gas Works
1844	Metropolitan Health of Towns Association established Manchester Police Regulation Act (included powers related to sanitation)
1846	Common Lodging Houses Act First two parks, Philip's Park and Queen's Park presented to the City
1847	City Corporation obtained Act to acquire the works of the Manchester and Salford Waterworks Corporation and to develop Longdendale reservoirs
1848	British Public Health Act (required setting up of local Boards of Health responsible for sanitary supervision, drainage and water supply among other matters)
1849	Manchester South Junction and Altrincham Railway opened

1850 Manchester Clinical Hospital established
1851 First UK inter-basin water supply transfer from Longdendale to the city
1852 Manchester and Salford Sanitary Association founded
1854 Withington hospital built as Withington Workhouse (Chorlton Union)
1856 The lying-in hospital, after several temporary locations, moved to Quay Street as 'St. Mary's Hospital and Dispensary for the diseases of Women and also for the diseases of children under 6 years of age'
1858 Local Government Act (permitted compulsory purchase for sanitary purposes)
1863 River Medlock Improvement Committee appointed by City Council
1866 Sanitary Act (gave local authorities powers to provide clean water supplies and regulate tenements)
1867 Vaccination Act (increased penalties for failure to vaccinate infants) Manchester Southern and Maternity Hospital for Women opened in Chorlton-on-Medlock Diseases of the Eye Institution became Manchester Royal Eye Hospital
1868 First medical officer of health for the City of Manchester appointed
1870 Tramways Act
1871 Alkali &c Regulated Works Act
1873 Children's Hospital at Pendlebury opened
1875 Public Health Act (required appointment of a medical office of health to every sanitary district in England and Wales)
1876 Manchester and Salford NVAA founded
1893 Electricity first supplied to the City centre
1894 Water supply from Thirlmere inaugurated Manchester Ship Canal opened
1904 Manchester Southern and Maternity Hospital for Women merged with St. Mary's Hospital
1911 Town Planning Committee appointed by Manchester City Council Ford opened factory in Trafford Park to make Model-T cars
1915 Booth Hall Children's Hospital opened in north Manchester
1912 Air Pollution Advisory Board established by Manchester City Council
1920 Royal Manchester Eye Hospital moved to Oxford Road
1925 Manchester Committee on Cancer formed
1926 Manchester and District Regional Smoke Abatement Committee formed
1929 Barton Aerodrome opened-the first municipal airport in the UK
1938 Ringway Airport (now Manchester International Airport) opened, replacing Barton Aerodrome
1949 First smokeless zone in UK comes into effect in Salford
1956 UK Clean Air Act
1971 New buildings for St, Mary's hospital opened on Hathersage Road
1990 Greater Manchester smokeless zone designations virtually completed
1995 Upgrading of water quality in River Mersey permits return of fish

Appendix B. Manchester's sources of supply and destinations of exports

Date	Trading partner countries	Nature of imports	Nature of exports
c1800	Ireland, Netherlands, Spain, Italy, Germany, Turkish empire, India, China, Japan, South and Central America, West Indies, Mexico	Raw cotton, banking and insurance	Cotton goods
1800–1850	Ireland, Netherlands, Spain, Portugal, Italy, Germany, Turkish empire, India, China, Japan, South and Central America, West Indies, Mexico, USA	Raw cotton, livestock, apples, oranges	Cotton goods, machine tools, made-up textiles
1851–1900	Ireland, Netherlands, Spain, Italy, Germany, Turkish empire, India, China, Japan, South and Central America, West Indies, Mexico, USA, Australia, New Zealand, Canada, South Africa	Raw cotton, livestock, apples, oranges, food products, industrial raw materials, wood	Cotton goods, machine tools, made-up textiles, locomotives and railway carriages
1901–1915	(*Regular steamship services from the Port of Manchester to*): Canada, USA, Brazil, India, Persian Gulf states, Australia, New Zealand, Egypt, Syria, Italy, Spain, Denmark, Sweden, Russia, Netherlands and France	Raw cotton, fruit, livestock, meat, food products, industrial raw materials, wood, grain	Cotton goods, woollen goods, jute, linen, silk, steam and gas engines, boiler, textile and electrical and other machinery, chemicals, iron, steel, and copper, India rubber and other goods
1929	(*Regular steamship services from the Port of Manchester to*): Canada, USA, Brazil, India, Persian Gulf states, Australia, New Zealand, Egypt, Syria, Italy, Spain, Denmark, Sweden, Russia	Oil and spirit, timber, grain, fruit, cotton, wool, frozen meat, tea, sugar, provisions, starch, glucose, leather, manufactured iron, ores, nitrates, copper, tobacco and wood pulp	Cotton and woollen goods, yarns, machinery, locomotives, implements, tools, hardware, earthenware, paper-making materials, chemicals, coal, salt and pitch
2001	*Direct airline services from Manchester Airport to:* Canada, USA, Egypt, United Arab Emirates, Pakistan, India, Malaysia, Singapore, Hong Kong, Mauritius, Ireland, Canary Islands, Spain, Portugal, Malta, Israel, Turkey, Cyprus, Croatia, Slovenia, Czech Republic, Italy, France, Switzerland, Austria, Germany, Belgium, Luxembourg, Netherlands, Poland, Finland, Sweden, Norway *Regular shipping links through the Port of Manchester*: France, Spain	*Through the Ship Canal upper reaches*: bulk chemicals, LPG and products; petroleum products and chemicals; maize, grain	*Through the Ship Canal upper reaches*: scrap metals, cement products; chemicals

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