



19th century London dust-yards: A case study in closed-loop resource efficiency

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ARTICLE INFO

Article history:

Accepted 25 October 2008

Available online 1 January 2009

ABSTRACT

The material recovery methods used by dust-yards in early 19th century London, England and the conditions that led to their development, success and decline are reported. The overall system developed in response to the market value of constituents of municipal waste, and particularly the high coal ash content of household 'dust'. The emergence of lucrative markets for 'soil' and 'breeze' products encouraged dust-contractors to recover effectively 100% of the residual wastes remaining after readily saleable items and materials had been removed by the thriving informal sector. Contracting dust collection to the private sector allowed parishes to keep the streets relatively clean, without the need to develop institutional capacity, and for a period this also generated useful income. The dust-yard system is, therefore, an early example of organised, municipal-wide solid waste management, and also of public–private sector participation. The dust-yard system had been working successfully for more than 50 years before the Public Health Acts of 1848 and 1875, and was thus important in facilitating a relatively smooth transition to an institutionalised, municipally-run solid waste management system in England. The dust-yards can be seen as early precursors of modern materials recycling facilities (MRFs) and mechanical–biological treatment (MBT) plants; however, it must be emphasised that dust-yards operated without any of the environmental and occupational health considerations that are indispensable today. In addition, there are analogies between dust-yards and informal sector recycling systems currently operating in many developing countries.

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1. Introduction

There is a common misconception that resource efficiency is a recent phenomenon, when extensive organised reuse and recycling of waste materials has occurred for many centuries (Woodward, 1985; Strasser, 2000; Cooper, 2006). Early waste and resource management have received systematic attention in the US (Melosi, 1981; Tarr, 1996; Melosi, 2000; Miller, 2000; Louis, 2004), but less so in Europe. For instance, Ratcliffe (1992) reported on socio-economic aspects of waste picking and marginality; Herbert (1998) referred to elements of 19th century waste management; and Cooper (2006) described aspects of the 19th and early 20th century waste recovery from an urban environmental history perspective. Resource efficiency is also increasingly attracting interest within the field of urban environmental history (Schott et al., 2005).

Many studies have identified the origin of systematically organised, municipality-wide, solid waste management systems as arising from the sanitation movement of the second half of the 19th century (Gandy, 1994). However, in London, England, an often overlooked, but highly effective and organised, system appears to date back much earlier to the end of the 18th century. This was

not driven by public health concerns, but by the resource value of household waste or 'dust', which had a high content of coal ash and was in demand by the brick industry and for agricultural applications. In response to this, London parishes began to let contracts, effectively granting an exclusive franchise for private contractors to collect and treat waste in 'dust-yards' from where separated materials were sold for various end-uses. The market peaked around the 1820s and was in decline by the 1850s, when the sanitation movement began to have an impact.

This paper reports on the dust-yards operating in the 19th century London, which have so far been discussed only in the context of English literature (Dickens, 1864; Sucksmith, 1973). The dust-yards provide an early example of organised municipal solid waste management. This research has primarily used published documents, both historic and contemporary, with some use of archival material. The inherent methodological limitations should be recognised: these include the paucity of sources, lack of serial data and the ideological bias of some of the available sources (White, 1985; Ratcliffe, 1992; Green, 1995; Joshi, 1998). The investigation reports on the material recovery methods used by dust-yards; the conditions that led to their development, success and decline; their contribution to the emergence of 'systematic' municipal solid waste management; and their contemporary relevance for waste management in the 21st century.

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2. Dust-yards as a material recovery system

The municipal solid waste management system in London during the late 18th and early 19th century had several component parts. The first was an extensive, largely informal sector which collected both clean, source-separated materials and scavenged materials from the streets, including anything that had a ready market. The sector included both itinerant or street buyers and street finders (Velis, 2004). There were many specialist groups, focusing either on particular locations (e.g., dredger men, sewer-hunters, mud larks) or on materials (e.g., rag-and-bone men, 'pure' collectors), each of which was described in fascinating detail by Mayhew (1862). 'Pure' was dog waste, which was used at that time in the leather tanning industry. Similarly, largely informal systems existed in other European cities: for example, in Paris the 'chiffonniers' recycled anything of value from the solid waste (Paulian, 1896; Ratcliffe, 1992; Lieberherr-Gardioli, 1996). In both London (Mayhew, 1862) and Paris (Reid, 1991; Barles, 2007), parallel systems recovered 'night-soil' (human excreta) for use as a fertiliser.

The other major component of the system focused on the 'residual' household waste, and in some cases also on the commercial waste (collectively 'dust'), together with street sweepings, which were managed through a series of semi-formal contracts granted by the parishes. The three basic elements managed by the dust-contractors were 'dust' collection, processing in the dust-yards, and product transport and trade. This component, which we have labeled as 'the dust-yard system' and which appears to have been more specific to London, is the focus of the current paper.

Household waste was collected by 'dust-men' (Guy, 1848; Horne, 1850; Mayhew, 1862). The waste was placed by householders in holes called dust-pits, ash-pits or dust-holes. The collection crew typically included two dust-men using a horse-drawn cart. One of the dust-men filled the baskets ('filler') by shovelling from the dust-pit. The other would carry the basket to the cart ('carrier'), emptying it and returning for the next one. The type of cart employed was a high-walled container that required the use of a ladder. Carrying and unloading a full basket demanded high physical strength due to the high density of ash. The process was repeated until the cart was full, when it returned to the dust-yard, where they 'shooted' the content on a 'dust-heap' (or 'lay-stall') before proceeding on another collection round. A network of dust-yards existed around London. These were mainly situated along the River

Thames and canals, often in what were then London suburbs (Mayhew, 1862).

The dust-yards were material recovery facilities that used manual sorting and sieving to produce secondary raw materials (Fig. 1). The sorting process was performed by women, children and older men, who were often related to the dust-men (Guy, 1848; Greenwood, 1874; Gordon, 1890). Mayhew (1862) mentioned a case of four consecutive generations of dust-women working at the same yard. The 'feeders' (or 'fillers-in') were boys or men who shovelled the material onto iron sieves which were held by 'sifters', who were women, girls ('dust-women') and old men. Sifters forcefully moved the sieves back and forth, striking it against an outer protective leather apron. The sieve underflow constituted the 'soil' and the oversize material was the 'breeze'. Other salvageable items were recovered by manually removing them from the dust-heap before shovelling the mixed material onto each sieve (Mayhew, 1862; Uncle, 1895), or they were separated on the sieve (Greenwood, 1874; Hobhouse, 1900). All the separated marketable materials or re-usable constituents were stored in separate piles. The 'soil' and 'breeze' were loaded onto carts, and were conveyed to nearby barges on the River Thames or canals.

The dust-yards are of particular interest today because they were highly effective and constituted a 'closed-loop' system. Quantitative data from the early part of the 19th century are not available, but Fig. 2 shows the distribution of products recovered from a semi-mechanised dust-yard operating in Paddington in 1886 (Gordon, 1890). This shows that more than half the waste was coal ash recovered as 'soil', with a further 30% recovered as 'breeze' and cinders. These were the most important and lucrative products. 'Soil' was sold as a soil improver/fertiliser and as a raw material for brick-making, where it was mixed with clay and 'breeze', to provide energy for the process. These and other recovered materials from the dust-yards are listed in Table 1, which also summarises potential end-uses.

The whole dust-yard system was driven by the 'dust-trade'. The strong commercial demand for 'soil' and 'breeze' was the primary driver for the development of such a sophisticated, well-organised and labour intensive materials recovery system. The dust-yards were sited to serve the waste collection areas, but also to minimise the distance to the River Thames or canal wharfs, where the loads of 'soil' and 'breeze' could be transported by barge to their end users in the surrounding counties.



VIEW OF A DUST YARD.
(From a Sketch taken on the spot.)

Fig. 1. The sifting process at a dust-yard in the 19th century London. (Mayhew, 1862).

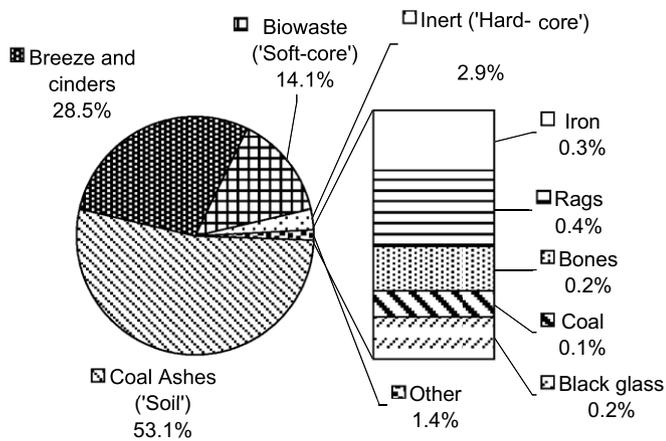


Fig. 2. Mass balance (wt.%), for materials recovered from a semi-mechanised dust-yard in Paddington, London, in 1886 (Velis (2004), using data from Gordon (1890)).

3. Markets/uses for recovered products

3.1. 'Soil' and 'breeze' use in bricks

There is little information on market values and volumes of the main products derived from the dust-yards. London grew rapidly from a population of 1.1 million (M) in 1801, to 1.6 M in 1821 and had reached 2.7 M by 1851 (Ball and Sunderland, 2001). This

led to an increased demand for raw materials for bricks. By the early 19th century, most local materials for the production of the typical yellow London 'stock' brick had been exhausted (Allinson, 2003). Coal ashes and 'soil' were attractive substitutes for clay, at least until the 'lower Oxford clay' (or 'shaley clay') began to be used after 1880 (Hillier, 1981). 'Soil' did not need extraction, had low moisture content, and was available in powdered form, sieved, and in large quantities almost all-year round. The development of the system of canals in the late 18th century allowed the proliferation of brick-fields along their banks: London was described in 1811 as being surrounded by a "ring of fire" (Allinson, 2003). Production of bricks rapidly increased until 1825, and then declined slightly until 1832 before slowly increasing again until 1847 (Cairncross and Weber, 1956; Sheppard et al., 1979).

The high demand of raw materials for bricks led to high prices for 'dust'. The first known indication of the positive value for 'dust' produced out of household waste can be tracked back to 1767 in Portsmouth (Webb, 1906). International trade further contributed to increased prices, and in 1814–1815 'soil' was shipped as far as Moscow, which was being rebuilt after the fire of 14 September 1812 (Webb and Webb, 1922). The London market could not be satisfied by local production, and 'soil' was regularly shipped to London from Newcastle and other ports in the North of England. The peak price for 'dust' is reported to have been between £0.75–1.0 per chaldron (1.3 m³) (Mayhew, 1862), and this approximates to £45–60 per m³ at 2008 prices (using data from O'Donoghue et al. (2004)).

There was a sufficient demand from the brick-making industry for sifted 'dust' products until around 1840, and this market outlet

Table 1
Main recoverable fractions from London 19th century dust-yards and their end-uses.

Waste constituent	Description (including pre-processing)	End-user/buyer and use
'Soil'	Fine coal ash fraction	<ul style="list-style-type: none"> 'Manure', especially for clover² or for "breaking up a marshy heathy soil at its first cultivation"² – also, mixed with road sweepings⁴ (see also 'soft-core' below)
'Breeze'	Small partly unburned or charred items of coal	<ul style="list-style-type: none"> Secondary raw material, mixed with clay, for brick-making^{2,4} Brickworks, for burning bricks^{1,2,4} Sold to builders, for mixing in mortar⁴ Laundresses, braziers, for use as a fuel¹ Sold for energy content¹
Cinders	Larger partly unburned or charred coal items	
Coal	Fragments of unconsumed coal	
'Soft-ware' or 'Soft-core'	All vegetable and animal matter ¹ ; e.g., kitchen leftovers such as bread scraps. 'Soft-core' gained the meaning of street sweepings as well ⁵ .	<ul style="list-style-type: none"> 'Manure' for ploughed land, wheat, and barley¹ In-feed for poultry and pigs², e.g., bread scraps³
'Hard-ware' or 'Hard-core'	Inert material, such as broken pottery, pans, earth ware, oyster-shells, etc ¹	<ul style="list-style-type: none"> Sold to builders, for sinking foundations² Some used as in-fill for road making,^{1,3} e.g., old bricks² Oyster-shells ground for use as a fertiliser⁵ Sold to Swedish manufacturers of emery paper^{6,a} Fat and marrow sold to soap-boilers;¹ glue-makers⁵ Crushed bones used as fertiliser¹ Sold to middlemen, e.g., junk-stores² Hop-manure^{1,3} Paper-making^{1,3} Papermaking^{5,6} Low quality grades shipped to Germany⁵ Prussian-blue manufacturers² Making fires for colouring fine steel³ Solder sold separately (most valuable⁵) Detached pieces of tin sold to be melted up with old iron
Glass		
Bones	Pre-processing: first, fat and marrow was boiled out, and then the bones were crushed	
Rags	Woollen rags White linen rags	
Paper and board	Sorted manually into quality categories and bundled into trusses	
Boots and shoes		
Tin and iron	Suitable items pre-processed, by heating to melt the solder, which was collected in a receiver through a grated base (items included ⁵ meat and biscuit tins ⁴ , cans, old buckets, rusty saucepans etc) Remains of tin and iron vessels (reusable items would have been removed long before the waste reached the dust-yards)	
Brass and lead		<ul style="list-style-type: none"> Sold to trunk makers for "clamping the corners of their trunks"⁴ etc, or for making 'copperas'^{2,b} Sold to be melted up separately, or in the mixture of ores
Coins and articles of jewelry	Either pocketed off-hand by the first finder ¹ , or handed to the 'supervisor', and/or saved and proceeds equally distributed to the sifters ³	<ul style="list-style-type: none"> Jewellery sold primarily to the Jewish community²

Adapted from: Velis (2004).

References: 1. Horne (1850); 2. Mayhew (1862); 3. Greenwood (1874); 4. Thomson and Smith (1877); 5. Gordon (1890); 6. Hobhouse (1900).

^a A variety of the mineral corundum, that can be crushed and used as an abrasive for polishing hard surfaces.

^b Also ferrous sulphate: a white or pale green salt containing iron, oxygen, and sulphur. It occurs naturally as the mineral copperas, and is used in inks, tanning, and in the treatment of iron-deficient anaemia.

existed at least until the 1890s. Around 1890 approximately ten barges per day, each carrying 70 tonnes of mixed 'soil' and 'breeze', were travelling to brickworks from the dust-yard at the City of London alone (Gordon, 1890); and cinders were still sought in the 'dust' ('Jas Jakson' study circle of the Birmingham corporation salvage department, 1929).

However, the price of 'soil' for brick-making had fallen by 1850 (Mayhew, 1862) and remained low during the following decades (Webb and Webb, 1922). This was due both to changes in the brick-making industry, including competition from new raw materials such as high calorific value 'Oxford clay', new technologies and financing opportunities (Cox, 1979), and to the increased supply of dust. The population of London had reached 6.5 M by 1901 and 'dust' production before then was reported to have exceeded the demand of the entire brick-making industry in England (Gordon, 1890).

3.2. Fertiliser and land-improver uses

The fine coal ash fraction or 'soil' was also used as a fertiliser and soil improver, and this was at least as important as the brick outlet. Increased demand for waste materials with nutrient value was evident from around 1750 (Webb and Webb, 1922), which again may be attributed to rapidly increasing urban populations, who needed to be fed. Demand may have been stimulated further by the introduction of the 'Corn Laws' in 1815, which taxed imported grain and thus increased the price of home-produced cereals (Vamplew, 1980). Dust-derived 'soil' was in competition with night-soil and slaughterhouse waste, all of which were transported by barge to neighbouring agricultural areas (e.g., the market gardening area around Barking Town (London Borough of Barking and Dagenham, 2007)). However, the agricultural market was significantly reduced by the 1850s, a reason cited by Mayhew (1862) was changes in land use, notably from cultivated to pasture land, following the 1846 repeal of the 'Corn Laws' (Brawley, 2006). Later in the 19th century, 'soft-core' (a mix of street sweepings and organic household waste) was a more desirable commodity than 'soil' derived from dust, due to the high horse manure content (Gordon, 1890). Other recycled materials used as fertilisers/land-improvers included bones and animal-origin rags, both recovered by 'rag-and-bone' men (Velis, 2004).

4. Institutional aspects

4.1. Contractual agreements between London parishes and dust-contractors

The accumulation of wastes in the streets caused problems in London and in other cities for centuries. The main issues were that putrefying waste was malodorous and it caused physical obstruction of streets (Melosi, 2000). Industrialisation escalated the problem by significantly increasing the urban population and, therefore, the waste quantities. The Westminster Pavement Act of 1762 transferred the responsibility to clean, pave and light the road in front of houses from the home-owner to the local municipal authority (Inwood, 2000).

The rise in value of 'dust' at the end of the 18th century occurred, when the City of London and other metropolitan 'parishes' were struggling to meet these new legal responsibilities. As a result, they began to let contracts that granted an exclusive franchise to private contractors to collect household waste or 'dust' and to sweep the streets in particular districts.

Officers of the parish or district came to an agreement with 'dust-contractors' for the collection and removal of household waste, including street cleansing in certain cases. Dust-contractors

would bid for the yearly rights to collect and manage the household waste, submitting offers to the authorities on an arranged date each year. Mayhew (1862) listed around 180 parishes in 1850, which were further subdivided into districts, each with separate waste collection contracts. There were estimated to be approximately 90 dust-contractors as many served more than one district.

The contract was awarded primarily on the basis of price (Mayhew, 1862); there is no evidence that other criteria, such as service performance, were directly considered. Contractors were paying for the right to collect 'dust'. The duties of dust-contractors for the City of London specified the types of waste to be collected, the area covered and the frequency of collection (Sewer's Office, 1837).

Bidding was a capital intensive activity, and dust-contractors were people with significant wealth. They needed capital to bid, horses, carts, land to use as a dust-yard and the necessary materials processing equipment. While the contract was between the parish and the dust-contractor, multiple sub-letting was common (Mayhew, 1862). Dust-contractors would sub-contract activities to a master dust-man or form a partnership with others in possession of suitable equipment. However, such arrangements did not appear in the official contract. Operations in the dust-yards were supervised by a 'hill-man/woman', who reported to the dust-contractor.

Issues arose from the implementation of the contracts. The quality of the service was often dependent on dust-men receiving tips, a practice strongly disapproved of by the parishes, as refusal to tip often resulted in poor service (Thomson and Smith, 1877). As a result, areas such as Bethnal Green, that were not particularly affluent, tended to receive poor service and this caused waste to accumulate (Gavin, 1848). Dust-yards were often perceived by residents as a nuisance and this resulted in their gradual re-location to the outer London suburbs of the time (Mayhew, 1862). An inquiry into dust-yards in 1848 led by William Augustus Guy, a prominent physician, medical statistician and academic of the time, did not find them to be a threat to occupational or neighbourhood health (Guy, 1848); however, it suggested they should be placed along river/canal banks and be properly supervised.

At the peak of the dust-trade, between approximately 1790–1850, 'running' or 'flying' dust-men appeared (Mayhew, 1862; Thomson and Smith, 1877). These were not registered with a dust-contractor or authorised by the parishes/districts, and they often provided collection services to households that were not adequately serviced by official contractors. They were also reported to raid 'dust-holes' at night. This illegal informal sector activity was problematic as it often resulted in subsequent fly-tipping of unwanted waste. Those caught were fined or imprisoned by 'inspectors of nuisance' (Thomson and Smith, 1877), who were responsible for imposing the relevant law (Sewer's Office, 1837).

4.2. The economics of 'dust' collection

The evolution of the financial agreements between dust-contractors and London parishes/districts provides evidence of the rise and fall of the 'dust' trade. Between 1790 and 1850, dust-contractors often paid for the right to collect 'dust' (Fig. 3) on the basis that revenue from the dust-yard products would provide a healthy profit (Gavin, 1848; Mayhew, 1862; Gordon, 1890; Webb and Webb, 1922). For example, the parish of St. Margaret's in Westminster paid £150 to its waste collection contractor in 1799, but was paid £150 in 1801 and £625 in 1825. In 1796, the Marylebone parish charged a contractor £1050 for the right to remove the waste from the streets, and this increased to £2350 in 1803. The City of London obtained £5000 in 1846 "for liberty to clear away the dirt

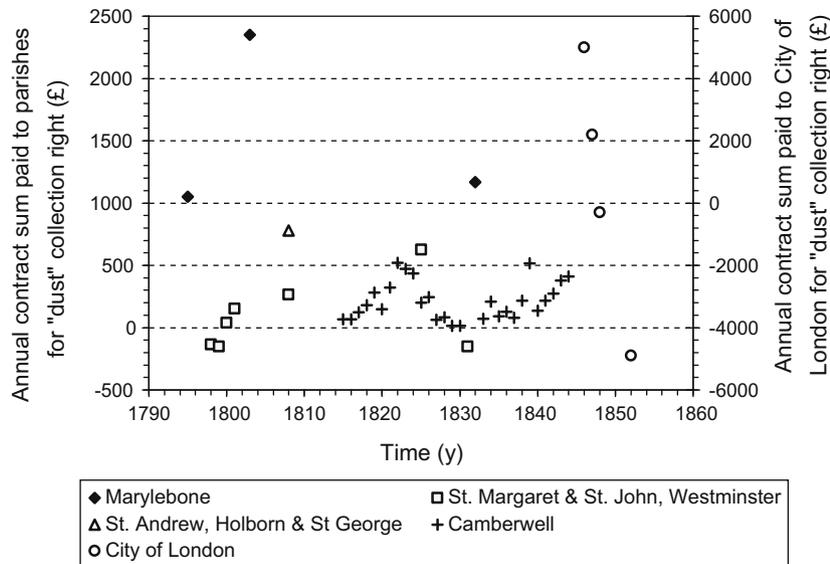


Fig. 3. The value of some London contracts for 'dust' collection from 1790 to 1850. A positive value shows that the dust-contractors were paying the parishes/districts for the right to collect and use the household waste. The values for the City of London are plotted on a secondary axis (right) as they are much higher (the population serviced was much greater). Values are not corrected for the changing time value of money. (Adapted from: Velis, 2004.)

from the streets and the dust from the bins and houses in that district" (Mayhew, 1862).

Inwood (2000) suggested that the peak in dust value occurred before the 1830s, as did Webb and Webb (1922). The evidence as compiled in Fig. 3 suggests that 'dust' maintained a value high enough to cover the cost of waste management (collection, street cleansing, treatment and transport for recovery) until around 1850. Later in the century, waste management had clearly become a net cost to the parishes. For example, in 1878 in Kensington parish the overall cost of waste collection and street cleansing was £34,000, while the income from 'dust' had fallen to £2318 and was effectively zero by 1886 (Gordon, 1890). In Islington, the overall waste management costs were £21,000, and the revenue from 'dust' was low and decreasing: £852 in 1885 and £121 in 1888. For the City of London, the revenue from both street sweepings and household 'dust' was approximately £3750, while the overall cleaning cost was £30,000 in 1890 (Gordon, 1890).

5. Dust-yards and the emergence of modern waste management

The dramatic fall in the value of 'dust' around 1850 coincided with the emergence of the sanitation movement (Duffy, 1992; La Berge, 1992; Porter, 1999; Melosi, 2000). The core belief of the 'sanitary idea' was that certain environmental conditions were the cause of disease, especially for deadly epidemics such as cholera. The scientific rationale was however largely erroneous, based on the 'filth' (or 'miasmatic') theory which postulated that odours emanating from decaying organic matter were responsible for the spread of disease. The rapid removal of waste from streets before excessive biodegradation was therefore seen as necessary (Tarr, 1996; Melosi, 2000). The first Sanitation Commission in London in its "Sanitary Report" highlighted a clear link between infectious diseases such as cholera and poor sanitation conditions (Chadwick, 1842). This led directly to the 1848 Public Health Act, which gave all local authorities the power to provide a waste collection service. This was eventually replaced by the 1875 Public Health Act, which required householders to keep their waste in a 'movable receptacle' and put an obligation on local authorities to empty this receptacle at least once a week.

Similar public health legislation in other countries laid the foundation of 'systematic waste management', organised formally on a

municipality-wide basis. It could be argued that there was little further progress until the 1970s, when environmental legislation brought in controls on waste disposal practices (Wilson, 2007).

During the 1850s, London parishes had to pay increasingly large sums to continue with their private waste collection contracts, due to the collapse in demand for dust-derived products. At the same time they were under pressure to take formal responsibility for waste collection and street cleaning on public health grounds. The existence of the dust-yard system for solid waste management, which had successfully been collecting household waste and sweeping the streets for more than 50 years, allowed them to move smoothly to a municipally-organised system.

The sudden rise in the net cost of the old system due to the collapse in the market value of dust required a decision on whether the primary collection, treatment and final disposal of the increasing quantities of waste should continue to be contracted to the private sector or would be provided by organisations owned by the local authorities. The parishes gradually started "collecting their own dust" (Mayhew, 1862), realising the emergent public responsibility for waste through the public sector. In 1850, only one parish (Bermondsey) was collecting 'dust' (Mayhew, 1862). By 1890, this had changed significantly and the public sector was increasingly undertaking activities that had previously been provided by dust-contractors. Over this transitional period, many different types of contractual agreements existed between the private and public sector (Gordon, 1890; Hobhouse, 1900): delivering waste management services by either the private or public sector was a widely debated issue at the time.

Fig. 4 summarises the major events and changes that occurred, which are relevant to the rise, evolution and decline of the dust-yards.

6. Analogies with and lessons for 21st century waste management

6.1. Dust-yards as precursors of MRF/MBT plants

The dust-yards of the early 19th century were highly efficient, labour intensive material separation systems, from which almost all outputs were marketable. Over the decades, increasingly the dust-yards transformed into integrated waste/resource manage-

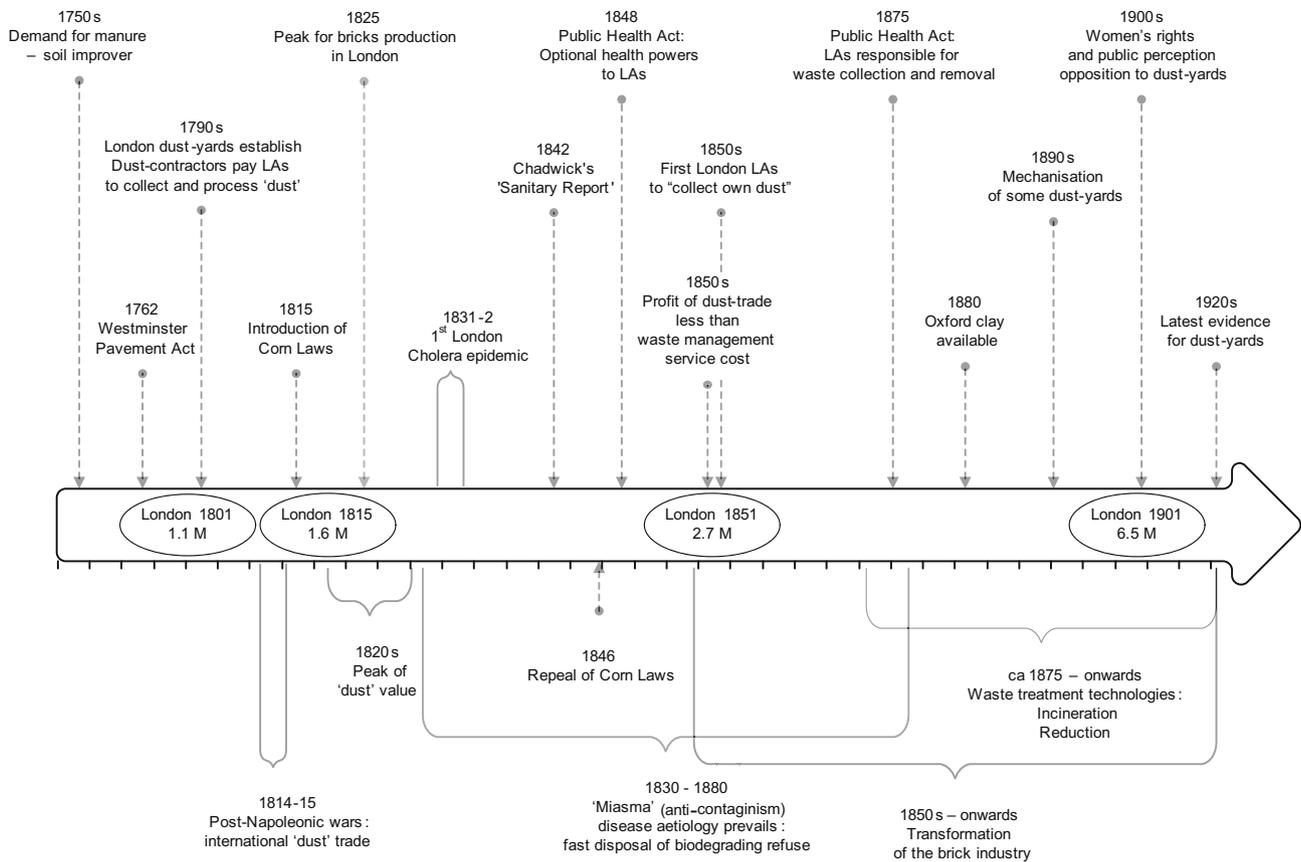


Fig. 4. Evolution of the dust-yards of London: timeline of related landmark events and periods. The timeline length is not proportional to time periods. LAs: local authorities. London population in millions (M). (Adapted from: Velis, 2004).

ment facilities, hosting the first mechanised treatment of municipal wastes. In 1867, the site on the banks of the Regent canal included a covered storage area for gathering bulk quantities of secondary materials, a wash-house and drying room for the recovery of rags, and a furnace for the combustion of non-recoverable items (Greenwood, 1867). Examples of discarded materials that could not be used were worn-out oil cloths, old bonnet-boxes and cocoa-nut matting.

As the public sector gradually took over service delivery from 1850s onwards, the function of the dust-yards changed. For example, by 1890 the 'dust-yard' of the City of London had become a centralised treatment facility on the south bank of the River Thames that enabled loading of separated fractions onto barges; unmarketable residual fractions after the separation process were treated on site in a waste 'destructor' (a batch-fed incinerator, but without any attempt at emissions control) (Gordon, 1890). Other dust-yards shipped out (transferred) the residual waste to open dump (uncontrolled 'landfill') sites outside London.

In some cases, the dust-yard process had become semi-mechanised (Gordon, 1890; Hobhouse, 1900), as for example the Paddington site, for which data are given in Fig. 2. Such dust-yards applied mechanical separation for the first time in solid waste management: the focus was on separating out what we would call today a 'fine fraction', 'aggregates' and a 'residual fraction' concentrating potentially salvageable items which required further manual sorting. The necessary screening machinery had already been used in industry sectors such as coal, ore, salt and agriculture (Meinel, 2008).

Dust-yards were sites managing waste material flows and re-introducing them into the resource cycle. They can be viewed as

early materials recycling facilities that were taking mixed waste as feedstock (cf 'dirty' MRFs). There are also similarities in the function of outputs with modern mechanical–biological treatment (MBT) plants: the 'soil' can be compared to a compost-like output (CLO), while the 'breeze' was used as a solid recovered fuel (SRF). However, today's MRFs and MBTs have to separate much more complicated inputs and use much more sophisticated equipment. As with modern MBT plants, the economic viability of the dust-yards depended critically on the availability of market outlets for these two major product streams.

6.2. Similarities with the informal sector in developing countries

The waste management system in early 19th century London had significant similarities with informal sector collection and recycling systems operating today in many developing country cities (Medina, 2000; Wilson et al., 2006; Wilson, 2007).

A widely studied modern informal sector example is the Wahiya-Zabbaleen of Cairo (Velis, 2004; Fahmi and Sutton, 2006). Their operations are analogous in some respects to the semi-formal dust-yards of 19th century London. The Zabbaleen provide a collection service to householders for mixed waste, which is then hand sorted to remove recyclable material. The remaining largely organic fraction is fed to pigs, with composting of the residues resulting in the highest recycling rates (84%) anywhere in the world (Waste and SKAT, 2007). In both systems, the development of waste collection and recovery was a private sector response to an opportunity to generate either a livelihood for relatively poor workers or a profit for the dust-contractors (or indeed both). Both systems extracted residual value present in waste by segregating initially heteroge-

neous waste to provide homogeneous secondary raw materials. They relied solely on the value of the recovered products, achieved very high recycling rates and operated at little or no direct cost to the local authorities. Both used low-technology, but operated with high effectiveness due to their use of manual sorting.

6.3. Zero waste

Many non-governmental organisations (NGOs) regard 'zero-waste' as the ultimate goal of 21st century waste management, combining high recycling rates for clean, source segregated materials with effective and efficient utilisation of the residual wastes (Institute for Public Policy and Research and Green Alliance, 2006). There is much debate as to whether this aspirational target is indeed desirable or achievable (Ragossnig, 2006; Ignatenko et al., 2007).

The 'dust-yard' waste management system in London in the early 19th century is one example that has approached this modern goal; it could be described as an example of 'closed-loop', city-wide industrial symbiosis. Similarly to modern industrial symbiosis cases, development of the dust-yard system was driven by its financial attractiveness (Erkman, 1997), and took advantage of the flexibility of private initiative and the facilitating conditions in cities (Desrochers, 2001). The success of the dust-yards owed much to the juxtaposition of favourable market conditions, caused partly by rapid population growth which also increased the supply of 'dust', and the availability of local markets close to the city. For a period supply and demand were in balance, while the system also met what is now called the proximity principle.

It is clear that under appropriate socio-economic conditions, market-driven, for profit informal and semi-formal recycling systems can operate for substantial periods with minimal public sector intervention, given profitable outlets exist for the secondary raw materials (Velis, 2004). However, markets are critical, and one lesson is that, in order to achieve very high recycling rates, there must be marketable uses for the bulk content of the residual waste.

However, it must be pointed out that the dust-yard system achieved 'zero-waste' under very poor conditions of environmental protection and public/occupational health when viewed according to the 21st century standards. Modern concerns over the environmental appropriateness of the recycled secondary raw material, such as leaching of potentially harmful trace elements, were also not an issue at the time.

6.4. Private sector participation and lessons for developing country cities

When the markets for dust collapsed, the parishes began to pay the private sector to provide a service, which coincided with new legal responsibilities being placed on them under the Public Health Acts. The main objective moved from that of making money from the resource value in the waste to that of getting the waste out from under foot in order to protect public health. In London, this resulted in service delivery gradually being taken over by the public sector as they sought to be more in control, a situation which remained for the next 100 years, until the introduction of compulsory competitive tendering for local authority services in the 1980s (Wilson, 2007). The position has to some extent now come full circle, with most services now being provided again by the private sector, on the grounds that they can deliver the service more cost-effectively.

There is an important lesson here, particularly for developing country cities which are often under pressure from international development agencies to introduce private sector participation (PSP) as a pre-condition for financial assistance in improving their

current public sector waste collection and disposal systems. Simply involving the private sector is not a pancea for all ills. The 19th century dust-yards were a private sector system, poorly regulated and overseen by the state, which was gradually replaced by a public sector system with the aspirations of (1) overcoming the cost and service performance limitations of a largely market-based system and (2) improving public health in the form of fast disposal of rapidly increasing waste arisings. In modern PSP contracts, the responsibility for providing the service remains with the municipality, but the service is delivered by the private sector under a contract which places strict obligations on the contractor, and sets out clearly the performance indicators, monitoring procedures and sanctions for non-compliance. Comprehensive guidance on how to make PSPs work in developing countries is available (Cointreau et al., 2000; Coad, 2005).

PSP is generally advocated in developing country cities as a means of 'modernising' inefficient, public sector collection and disposal systems. It is ironic that a casualty of such modernisation can be the existing, entirely private sector, informal, market-based recycling system, which is often achieving high recycling rates (Wilson et al., in press). It can be argued that the replacement of the PSP dust-yard system in London with a public sector system resulted, *inter alia*, in a gradual decline in recycling rates, from effectively 100% before 1850, to well below 10% by the 1980s; much effort over the last 10 years has brought recycling rates in the UK back over 30%.

Hence, another lesson from the dust-yards is that, when 'modernising' a city's waste management system, great care is needed not to impact negatively on existing recycling systems. Trying to integrate these two approaches, to achieve a true 'public-private sector partnership', including the existing informal as well as the formal private sector, while moving towards a modern waste management system, remains an elusive but highly desirable goal. At a time when many countries are struggling to achieve the millennium development goals and halve poverty by 2015, protecting the livelihoods of poor workers is important, while at the same time striving to improve their working conditions and eliminate child labour (Wilson et al., in press).

Concerns about unhygienic working conditions and exploitation of women and children were raised in later 19th century London, by 1867 (Greenwood, 1867) and increasingly by later commentators (Rowe, 1880; Greenwood, 1883; Hobhouse, 1900), and were one factor in the eventual demise of the dust-yards. In the longer term, a combination of increasing standards of living and of occupational health and safety may also reduce the role of informal sector recycling in developing country cities, but that transition is likely to take a number of decades.

7. Conclusions

This paper has drawn attention to the dust-yards operating in London mainly during the first half of the 19th century, which have been rather a forgotten chapter in the history of solid waste management. Further, more detailed research by urban environmental historians is recommended, making more use of local archival sources than was possible in this work.

The dust-yard system was an early example of a semi-formal, systematic, municipality-wide approach to waste management. The high coal ash content of household 'dust', and the emergence of markets for 'soil' and 'breeze' products, encouraged dust-contractors to recover a significant proportion of the residual wastes. Contracting 'dust' collections and street sweeping to the private sector allowed parishes to keep streets relatively clean without having to develop institutional capacity. The dust-yard system, dating back before 1800, thus had an important role in the

transition to institutionalised, municipally-run solid waste management systems, following the Public Health Acts of 1848 and 1875.

Public–private sector participation currently has an important role in the delivery of waste management services in many countries. Similar arrangements existed in 19th century London; its subsequent replacement by municipal, public sector systems, does draw attention to the short-comings of a purely market-based system when it is loosely regulated and monitored, sustainable markets for recovered materials cannot be guaranteed, and public health considerations mandate the provision of a municipality-wide collection and disposal system.

The management of material flows by the dust-yards was broadly similar to the production of secondary raw materials in modern MRF and MBT facilities, although dust-yards operated without any environmental and occupational health considerations. In addition, there are similarities between 19th century London dust-yards and informal sector recycling systems currently operating in developing countries. When combined with the thriving informal sector which separated saleable items at source, the dust-yard system was resource-efficient, and an example of closed-loop industrial symbiosis that has contemporary relevance to 21st century waste managers.

Acknowledgements

We would like to thank Peter Ager, former Director of Cleansing Services for the City of London, for sharing archived historic documents compiled over 20 years by a previous Director, Tony Crellin.

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