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Abstract

Medieval York was one of the largest and most important cities in England. The close confines of the city, the household and industrial waste, alongside the air and water pollution made this a city known for its pervasive smells, which at the time were considered to be a leading cause of disease. This paper aims to present the environmental context for disease combined with the human osteological record to reconstruct the pathoecology of medieval York. Combining archaeological and historical data, we gain insight into the interplay between medieval culture, disease, health, and the urban environment. It is clear that local authorities were concerned about urban pollution, and historical evidence demonstrates that legal measures were taken to remove or regulate some of the perceived causes of pollution. There is a demonstrable trend towards improving environmental conditions in York between the 11th and mid-16th century. However, it is likely that the extant socio-environmental conditions continued to contribute to morbidity, as evidenced by the prevalence of infection.

Keywords

Pollution; sinusitis; parasites; non-specific indicators of stress; urban environment; living conditions

1. Introduction

When one comes into a city to which he is a stranger, he ought to consider its situation, how it lies as to the winds and the rising of the sun; for its influence is not the same whether it lies to the north *or to the south, to the rising or to the setting sun. These things one ought to consider most attentively, and concerning the waters which the inhabitants use, whether they be marshy and soft, or hard and running from elevated and rocky situations, and then if saltish and unfit for cooking; and the ground, whether it be naked and deficient in water, or wooded and well-watered, and whether it lies in a hollow, confined situation, or is elevated and cold… From these things he must proceed to investigate everything else. For if one knows all these things well, or at least the greater part of them, he cannot miss knowing, when he comes into a strange city, either the diseases particular to the place, or the particular nature of the common diseases, so that he will not be in doubt as to the treatment of the diseases, or commit mistakes, as is likely to be the case provided one had not previously considered these matters.*

Hippocrates, *On Airs, Waters, and Places*, c. 400 B.C.

Urban environments afford microorganisms a wealth of opportunities, potentially militating against the health of their inhabitants. High concentrations of people live and interact together in relatively close confines, touching and breathing upon one another. The urban occupants as well as their food preparation and disposal methods, specialised crafts and industry generate prodigious quantities of waste, often with the potential for noxious environmental effects arising from the contamination of the surrounding air, land, and water and creating conditions which may lead to the proliferation of certain vertebrate and invertebrate species that facilitate the spread of disease. In short, cities and towns, even today, comprise environmental conditions that Laurie Garrett (1994) describes as *microbial heavens*, and perhaps more dramatically, has led John Cairns (ibid.) to perceive them as *graveyards of mankind*.

Medieval towns and cities are often depicted as dirty, filthy, and unsanitary environments (e.g. Melosi, 1981; Keene, 1982; Zupko and Laures, 1996). For example, T. P. Cooper (1912) wrote that "the thoroughfares and byways of towns and cities were loathsome and deep with offensive matter, and were a constant danger to health and life." However, Jørgensen (2010c) accuses some modern scholars of being too often presentist in their interpretation of the conditions in medieval towns. Jørgensen (2008a, b; 2010b, c), returning to the ideas of scholars such as Thorndike (1928) and Sabine (1933; 1934; 1937), adopts a more positive view of medieval urban environments, using city statutes for cleanliness to provide insight into what was seen as socially-acceptable behaviour. From this perspective, Thorndike (1928, p. 199) argues:

"If a society lived contentedly with the streets in a state of 100 per cent filth, this condition, however, shocking and deplorable it may seem to us, would evoke no remark or comment from contemporaries, and no records to prove the past existence of such a condition would come down to us. Most of the complaints that have come down to us from the past as to filthy and evil-smelling streets will be found to be applicable to abuses rather than normal usage, and to testify to the existence in public opinion of higher standards in such matters than the presence of the abuse itself would suggest."

Textual accounts and records from medieval city councils reveal three seemingly interconnected motivations concerning urban pollution: obstructions, proper moral behaviour, and disease (Jørgensen, 2008b; 2010b). Obstruction of roads and waterways had a direct impact on commerce and travel and was one of the principal nuisance violations under medieval English law, i.e. considered to be harmful or offensive to an individual or the public (Chew and Kellway, 1973). Jørgensen (2008b, p. 45) cites examples from Norwich's leet court of the 13th and 14th centuries: "Robert was fined for placing a muckheap in the street gutter in such a way that carts could not pass [and] Roger de Morley obstructed the king's highway with his muckheap". Flooding was another concern that stemmed from the obstruction of urban waterways. In 1421, Coventry's mayor issued a proclamation stating that "filthe, dong, and stonys" had made the River Sherbourne "stoppyd of his course" resulting in "dyuers perels... by floodys" (Harris, 1907-1913). Pollution concerns were also motivated by the idea that cleanliness was a part of civic pride and proper moral behaviour (Jørgensen, 2008b; 2010a). According to the Coventry leet, people who disposed of muck and other filth into gutters were "y'll-disposed persons... contrarie to all good rule of the Citee" (Harris, 1907-

1913). Finally, disease was an influential factor that generated interest in medieval urban pollution. The prevailing disease theory during the Middle Ages, and well into the 19th century, was the miasma theory, which claimed that disease was linked to the corruption of the air. The noxious vapours and strong odours that emanated from decomposing matter in contaminated water, fouled air, and unhygienic living conditions caused illness and could be identified by their bad smell (Cipolla, 1992). For example, the British Parliamentary statute of 1388 prohibited the deposition of "dung, offal, entrails and other ordure into ditches, rivers, waters, or other places" because it resulted in the putrefaction and infection of the air, causing "many illnesses and other intolerable diseases" (Luders *et al*., 1810-1828).

While textual accounts reveal that local authorities were concerned about urban pollution and taking both preventative and responsive actions for upkeep (cf. Jørgensen, 2010b), how successful were they? Keene (1982) acknowledges the efforts of municipal authorities and others to cope with the challenges of medieval sanitation as put forward in the textual accounts; however, he views their attempts as ineffective. Similarly, Zupko and Laures (1996) describe these efforts at cleanliness as "incomplete, sporadic, and sometimes misguided." Jørgensen (2008a, b; 2010a, b, c) assumes the stance that urban upkeep and cleanliness were challenges, as they are today, yet were issues that maintained a prominent position in medieval cityscapes. Further insight may be gleaned from Hall and Kenward's (in press) brief survey of the disposal of organic waste in York over a 2000 year period.

Pathoecology is the study of the intersection of the abiotic, biotic, and cultural environments of disease (Martinson *et al.*, 2003). These include abiotic or physical characteristics such as climate and the condition of the air, soil, and water, as well as biotic variables including the presence of pathogens, disease reservoirs, and intermediate hosts. Additionally, cultural factors are considered such as diet, crowding, hygiene, and sanitation. Presented here is a pathoecological reconstruction of the medieval city of York, northern England, between the 11th to the mid-16th centuries AD. Viewing the study area as a coupled human-environmental system, it is our aim to draw upon existing published and unpublished archaeological investigations in order to examine the interplay between the conditions in the urban environment and human health.

2. Study Area

The present-day city of York is located within the Vale of York at the confluence of the rivers Ouse and Foss, on a glacial morainic ridge. Bordered by the Pennines, the North York Moors and the Yorkshire Wolds, the Vale of York consists of a relatively flat area of fertile, arable land (Whyman and Howard, 2005). The city's principal commercial, maritime waterway, the River Ouse, winds through the heart of the city and connects York to the Humber River and the North Sea. The River Foss, meanwhile, meanders along the eastern side the city centre and is credited for creating marshy conditions and stagnant pools (Jørgensen, 2008b).

The geographical region encompassing the modern city of York has a lengthy history of human occupation. A substantial Early Mesolithic settlement (c. 9000 cal. BC) was present in the Vale of York (Conneller *et al*., 2012), and Mesolithic and Neolithic artefacts have also been recovered from the Heslington East site on the outskirts of the city of York (Ottaway, 2010). The material from the Heslington East site suggests that the area was being used from the Bronze Age (c. 2500 BC) through the early Roman Age, yielding evidence of roundhouses and field systems as well as a preserved human brain (Ottaway, 2010; O'Connor *et al*., 2011). Roman occupation began as early as 71 AD with the establishment of a 53 acre legionary fortress on the north-east bank of the River Ouse, and the civilian settlement *Eboracum* emerged nearby, spanning both sides of the Ouse (Addyman, 1989). During the Anglian period (AD 400-c. 866), the settlement is represented by two nuclei: firstly, near the former Roman fortress (e.g. Kenward *et al*., 1986), and secondly, to the south of the confluence of the rivers Ouse and Foss in the Fishergate area, which is where *Eoforwic* is believed to have been centred (Kemp, 1987). Following the capture of York by a Scandinavian army in AD 867, the primary focus of the settlement appears to have shifted to once again overlie the Roman town. Excavations throughout the Anglo-Scandinavian town of Jorvik suggest that it was an intensively occupied commercial (e.g. Bayley, 1992) and industrial (e.g. Kenward and Hall, 1995) centre. It is referred to in an Icelandic saga as *the dank demesne* (Tillott, 1961, p. 13), perhaps hinting at the presence of unsavoury and/or marshy conditions leading up to the Norman conquest of the city in 1068-1069 (Addyman, 1989).

York preceding the Conquest was an important social and economic centre. A monk of Ramsey and biographer of St Oswald, supposedly writing around 995-1005 AD, depicted the city as a metropolis with a population of 30,000, not including children and youths. However, an interpretation of the Domesday evidence puts forward a more conservative population estimate between 8,000 and 9,000 in 1066 (Tillot, 1961). York was considerably damaged during the Conquest and a substantial portion of the city was destroyed by fire (Tillot, 1961). Between 1068 and 1130, a considerable reorganisation/re-planning of the city took place, including: the erection of two castles on either side of the Ouse (one at Clifford's Tower and the other at Baile Hill)—wasting one of the city's seven shires in the process; the damming of the Foss to form the King's Fishpool and defend the eastern side of York—resulting in the destruction of two mills and arable land; the founding of the Abbey of St Mary and Holy Trinity Priory; and the extension of the walls to encompass the Walmgate area (Tillot, 1961; Addyman, 1989). In 1072, when Thomas of Bayeux assumed control of his diocese, he found York depopulated and wasted, and estimates based on the Domesday 1086 suggest a population no more than half of what it had been in 1066 (Tillot, 1961). However, by 1090, the city had begun to evince signs of recovery, and significant growth is suggested, for example, through the construction of new housing developments from the 12th century on (Jørgensen, 2010c). In the poll tax returns of 1377, the population was nearly 11,000, which ranked York second in size only to London (Tillot, 1961). Following the 14th century, the population of York began to wane (Jørgensen, 2010c). By the end of the 15th century, the population had declined to around 7,000 (Tillot, 1961), and in 1524-1525 was roughly 8,000 (Slack, 2000 cited in Jørgensen, 2010b). These estimates are reflected by the figure in the tax returns during the reign of Henry VIII (Tillot, 1961). This decline in population of York and other English provincial centres during this time has been attributed to a "conjunction of unparalleled underlying economic and demographic vulnerability with other severe short-term pressures", for example epidemics, poor harvests, and price inflation (Phythian-Adams, 1977).

3. Climate

The medieval period witnessed a climatic shift that would have had a significant impact on the living conditions at the time and have affected short-term agricultural production as well as the transmission of infection. With short-term variation, a general warming of northern Europe and the North Atlantic region began in the 9th century, and the 11th to the 14th century marked the warmest temperatures of the millennium (Lamb, 1995). During this warm period, the thermophilous nettlebug *Heterogaster urticae* (F.) has been regularly recorded from Anglo-Scandinavian deposits in York (e.g. Hall *et al*., 1983; Kenward and Hall, 1995; Kenward, 2000; Kenward *et al*., 2003), and has been argued to indicate local temperatures 1-2°C above those of the mid-20th century (Kenward, 2004). The so-called Medieval Warm Period is also supported by the presence other species of potential climatic-significance in the region, e.g. *Anthicus bifasciatus* (Rossi), *A. antherinus* (L.), *Acritus homoeopathicus* Woll., *Odocantha melanura* L., *Eurydema oleracea* (L.), *Coreus margiantus* L., *Cryptolestes duplicates* (Watl.), *Sehirus bicolor* L., and *Phymatodes testaceus* L. (see Kenward, 2004). The latest Post-Conquest record of the nettlebug in York appears to date to the later 14th century from the 17-21 Piccadilly site (Alldritt *et al*., 1991). Dinnin (1991; 1997) proposes that the disappearance of some taxa from the region during this period may be linked to the onset of the Little Ice Age (LIA), or at least climatic deterioration (see Wagner, 1997; Buckland and Wagner, 2001 for discussion of insects as indicators of the LIA).

Arguments on the alleged societal impact of the Medieval Warm Period and subsequent Little Ice Age have been rehearsed elsewhere (e.g. Dyer, 1989; Lamb, 1995; Roberts and Cox, 2003). The Medieval Warm Period heralded increased agricultural production and improved health and fertility (Roberts and Cox, 2003). Meanwhile, the climatic deterioration that began in the 14th century was marked by a downturn in temperatures, severe storms and floods (major floods were recorded in Yorkshire in 1315 (Radley and Simms, 1971), 1316, 1360 (Pugh, 1961), and 1564 (Whyman and Howard, 2005)), the depopulation of certain rural areas as well as harvest failures, food-shortages, and outbreaks of famine (notably the famines of 1315-1318 and 1437-1440) (Dyer, 1989). Certainly these climatic fluctuations would have at least partly affected health and disease during the period (see Duncan, 1994; Rawcliff, 1999; Roberts and Cox, 2003).

4. The Urban Environment and Disease

4.1 Air

In regards to his 1332 visit to York, King Edward III wrote of “the abominable smell abounding in the said city more than in any other city of the realm from dung and manure and other filth and dirt wherewith the streets and lanes are filled and obstructed”. For “the health of the inhabitants and of those coming to the present parliament” the king ordered the streets “to be cleansed from such filth... and to be kept clean” (Calendar of the Close Rolls). A similar complaint was recorded in relation to the Bootham area of York in 1298 where “the air was corrupted by pigsties and dunghills” (Tillot, 1961). Later in 1421, the city council’s concern of air quality is further evinced in its order to John Preston “to keep his property free from entrails and other filth causing foul smells” (Jørgensen, 2008b). While the condition of the land and water (as will be discussed below) were primary concerns of York’s authorities, the purity of the air, at least as it pertained to its smell, was a subject of medieval regulations (see Jørgensen, 2008b).

The most regulated industries—butchers, dyers, tanners, and skinners—also produced the largest quantities of odoriferous waste and environmental pollutants. Many of these industries were located in the city centre. For example, the street name Tanner Row can help provide evidence that tanning took place in the city centre to the southwest of the Ouse in the 14th century. Tanning and tawying were particularly pungent as well as slow processes—taking up to twelve months. The workers would prepare the hide by firstly encouraging the hair and flesh to rot with the aid of lime or urine. After the hair and flesh were removed, the hide, or leather, was de-limed and softened through immersion in either warm bird droppings or dog dung and treated in a concoction that consisted of urine or fermented barley or rye (Thomson, 1981; Cherry, 1991). Similarly, the preparation of linen involved the retting of flax and hemp, softening the fibre through bacterial action and consequently creating noxious effluent (see Walton, 1991; Robinson, 2003). The dyeing process may have also been unpleasant work, typically involving mordants such as alkalis, ferrous sulphate, and alum (Walton, 1991). The inhalation of industrial chemicals and by-products would have been a real risk, especially to the workers.

Interestingly, complaints against metalworking and similar smoke-producing industries appear rarely in the municipal accounts of York's authorities (Jørgensen, 2008b). This may be explained by Lay Poll Tax Returns of 1381, which suggests that many of these industries were located downwind of city either near the city walls or outside of the city (Bartlett, 1953 cited in Brimblecombe and Bowler, 1992). Although lead and pewter working as well as myriad processes involving mercury (see Homer, 1991) would have contaminated the air with heavy metals (Roberts and Cox, 2003; see Thackrah, 1832 for a discussion of health problems associated with the inhalation of metals prior to regulation of their usage), it was sources of odour which were the primary annoyances of the time, with the acrid smell of sea coal being notable. Sea coal was used in England from, at least, the early 13th century (Brimblecombe, 1976). However, it is first recorded as being burnt in York in 1371 (Brimblecombe and Bowler, 1992), and the remains of coal have been recovered from a 14th-15th century well at 22 Piccadilly (Carrot *et al.*, 1995b). In England, there appears to have been some concern about the effect of the burning of coal on health, and four commissions of enquiry were issued between 1285 and 1310 (Brimblecombe, 1975). The smoke from this new fuel was so objectionable that Queen Elizabeth I granted Dean Thornburgh of York a license in 1590 to attempt to purify the coal and free it from its offensive odour (Brimblecombe, 1987). In addition to coal, wood, charcoal, dung, peat, and crop residue were burned for domestic and industrial fuel. Biomass and coal smoke contain a number of pollutants and hazards such as: carbon monoxide, formaldehyde, nitrogen dioxide, particulate matter, polycyclic organic matter (e.g. benzo[*a*]pyrene, a carcinogen), and sulphur oxides (particularly coal) (Ezzati and Kammen, 2002). Hipkins and Watts (1996) estimated that harmful concentrations of smoke (5 mg/m^{-3}) and sulphur dioxide (10 mg/m^{-3}) would have been present in the centre of York between the 14^{th} and 17^{th} centuries.

While smell is no longer considered to detrimentally affect health, the inhalation of particulate, either pathogenic (e.g. *Mycobacterium tuberculosis* or fungal spores, e.g. farmer's lung) or non-pathogenic (e.g. stone particles which cause silicosis) does have deleterious effects. Indirect human skeletal evidence of air pollution can be found in changes to the maxillary sinuses, passages whose mucous membranes act to remove particulate from inhaled air (Roberts, 2007). The pollutants themselves, e.g. chemical or biological, cannot be identified, but the inflammatory changes, which can lead to new bone formation, can be observed. In York, the prevalence of sinusitis (maxillary and frontal sinuses) is 30% (Table 1), which is higher than the crude prevalence rate of 13% in Britain for this period (Roberts and Cox, 2003). However, a global study of maxillary sinusitis found a mean prevalence of 48.5% in urban-agricultural sites (Roberts, 2007). For York, the lower status sites of St. Helen-on-the-Walls and Fishergate House have the highest prevalence rates of 55% (although this could be as high as 72% based on Roberts 2007) and 49%, respectively (Holst, 2005). Pottery kilns were found associated with the site of Fishergate House (Spall and Toop, 2005), and it is therefore possible that airborne pollution from this industry was a causative factor (Roberts, 2007). The overall prevalence for York may reflect the combination of high levels of outdoor and indoor airborne particulate associated with fuel burning (Roberts, 2007), indoor damp or mould (Koskinen *et al*. 1999), alongside other factors, in particular, poor dental health such as apical periodontitis (Lu *et al*. 2012; Rege *et al*. 2012; Roberts, 2007).

Mycobacterium tuberculosis is an infectious disease spread between humans (and from animals to humans) via infected droplets or through drinking infected cow's milk. The bacterium can survive in infected droplets, particularly in dark conditions, for several months (Barnes, 2005). The dark, narrow streets, poor sanitation, and population density in York at this time would have made this an ideal environment for TB infection. Crude prevalence rates of definite cases of *Mycobacterium tuberculosis* support this. The British prevalence rate for definite cases of TB in this period is 0.88%, (Roberts and Cox, 2003). The prevalence at York is higher at 3%. However, the crude prevalence rates presented here alongside the non-specific nature of many of the skeletal changes and the fact that majority of those with TB do not develop skeletal changes (Steyn *et al*. 2013), means that the real rates of TB in medieval York are likely to have been higher.

4.2 Land

King Edward III provided some insight into the condition of York's urban landscape in 1332, where the streets were obstructed by filth and dung (Calendar of the Close Rolls). However, should this be taken to mean that York's residents would have been, at times, "ankle-deep in refuse" (Keene, 1982, p. 53)? Carrott *et al.* (1996a) assessed 12th-14th century deposits at the Merchant Adventure's Hall (perhaps accumulated from levelling or dumping). The recovered beetle and fly remains depict an environment that consisted of rather foul conditions, and the presence of *Trichuris* eggs may be further indication of human, or perhaps animal, faeces. Similar conditions were evidenced in contemporaneous deposits from the castle ditch at 1-2 Tower Street (Carrott *et al.*, 1995c), and an outdoor environment supporting large numbers of dung beetles was indicated from 11th-13th century material at Feasegate (Carrott *et al.*, 1998b). This evidence suggests that foul material, in certain parts of the city, was left exposed for at least a long enough period to begin to attract decomposer communities (see O'Connor, 2000).

However, around the beginning of the 14th century, evidence indicates a shift in waste disposal methods (Addyman, 1989). The unlined or wicker-lined pits, which were located behind the street fronts, were replaced by stone-lined latrines that could be cleaned or emptied (ibid). Furthermore, the York civic ordinances of 1301 comprised a requirement to construct four latrines in each of the city's four quarters (Prestwich, 1976), and in 1367, the council financed a public latrine house on the Ouse Bridge (Wilson and Mee, 2002). In 1371, the council outlawed the common practice of throwing dung in the streets and gutters for the rain to rinse away (Raine, 1940-1946 cited in Jørgensen, 2010c). To facilitate this, the council in the 15th century required that a dung cart be placed in every ward to carry waste to assigned disposal areas outside the walls, which in the first half of the 16th century, included a pit at Castle Mill, the Toft Green area, St. Leonard's landing, Hungate, and a plot outside of Monkbar gate (Raine, 1940-1946 cited in Jørgensen, 2010c). An evaluation of 16th century dated dumps at Carmelite Street (Hungate area) revealed the presence of insects associated with domestic and storage habitats as well as foul and dry decomposing matter (Carrott *et al*., 1991a), supporting its function as a waste disposal site. Contemporaneous deposits from nearby St. Saviourgate indicated very foul conditions and yielded several pit fills containing faeces (Carrott *et al.*, 1998a). In the mid-15th century, officers of the ward inspected the streets in the city to ensure that they were "clenely kepid and weekly sweped" (Attreed, 1991, pp. 353-354), and rather clean conditions appear to have been kept at The Bedern (Hall *et al*., 1993a, b, c). Clean conditions have also been evidenced for the interior of some medieval town houses, e.g. the Coffee Yard site (Robertson *et al.*, 1989).

The presence of human and animal faeces in the urban environment would have had a direct impact on the health of York's inhabitants—human and animal. The most common parasites encountered in York were the soil-transmitted helminths in the genera *Ascaris* (roundworms) and *Trichuris* (whipworms) (e.g. Jones, 1982; Carrott *et al.,*1995a; 1996a, b; 1997; Hall *et al.,* 2000b; Akeret *et al*., 2005b; Aylard, 2009). Unfortunately, many of these studies were conducted as evaluations, and the existing data precludes comparative quantitative assessments. These helminths are transmitted through the oral ingestion of eggs that were excreted in faeces (Mims *et al*., 1993), and their presence in archaeological contexts is typically perceived as reflecting poor hygiene and sanitation, i.e. faecally-contaminated environments. However, Jones (1985) has shown that parasite eggs in low frequencies are typical urban background fauna. Within an environment with inadequate disposal of faeces, the trichurid whipworms, in particular, would have been capable of parasitizing a wide range of human and animal hosts, e.g. domestic ruminants (*T. ovis*), pigs (*T. suis*), dogs *(T. vulpis*), cats (*T. campanula*), and rodents (*T. muris*).

The human whipworm, *Trichuris trichiura*, is the causative agent for human trichuriasis. Trichuriasis is commonly asymptomatic, but severe infections can lead to pathological symptoms including weight loss, dehydration, chronic diarrhoea, rectal prolapsus, growth retardation, and terminal anaemia (Mims *et al*., 1993). Adult *T. trichiura* worms can live in the human colon for between 6-8 years (Rey, 2001), and a female has the potential to lay up to 20,000 eggs per day. The eggs can remain viable in the soil for over a year (Burden *et al*., 1976). Adult human roundworms, *Ascaris lumbricoides*, live for approximately 2 years (Rey, 2001), and are estimated to lay 200,000 eggs per day (Reinhard, 1992). Brudastov *et al*. (1971) found *A. lumbricoides* eggs, which had been deposited in soil for 10 years, to be viable. Although light infestations are often asymptomatic, chronic infestations of roundworm (ascariasis) can cause severe respiratory distress, intestinal blockage, anaemia, and growth retardation (Mims *et al*., 1993). The eggs of *A. lumbricoides* are impossible to distinguish morphologically from the pig roundworm, *A. suum*, a species which can also cross-infect humans (Euzéby, 2002). Similarly, the pig whipworm *T. suis* also appears able to infest humans (Beer, 1976), and the size of its eggs overlap with *T. trichirura* (Thienpont *et al*., 1986). Today, the transmission of these species is favoured in areas where there is insufficient disposal of faeces, contamination of water supplies, and poor hygienic conditions (Mims *et al*., 1993), and similar corridors for transmission would have likely existed in medieval York. Additionally, Kenward and Large (1998) proposed that helminth eggs may have also been dispersed by insects, such as the housefly *Musca domestica* L. Protozoan oocysts can both survive and remain infective on the body surface of dung beetles for several months and are able to pass unaltered through the mouthparts and gastro-intestinal tracts of coprophagic coleopterans (Graczyk *et al*., 2005). Kenward and Hall (1995) have also discussed the role of non-biting flies, such as *M. domestica*, as causal agents of poliomyelitis and salmonellosis.

The conditions that existed within the urban living environment also supported communities of ectoparasites. A pre-Conquest gully fill from a building structure at 16-22 Coppergate yielded a range of lice: *Damalinia ovis* Shrank (sheep), *Haematopinus apri* Goureau (pig), *Felicola subrostratus* Nitzsch (cat), and *Pediculus humanus* L. (human). Samples analysed from the floor layers of the same building also revealed large numbers of human fleas, *Pulex irritans* L. (Kenward and Hall, 1995). At 62-68 Low Petergate, a 14th century dump/yard accumulation, potentially consisting in part of domestic ejectamenta, contained numerous lice, which were identified as probably *P. humanus*, as well as a single human flea (Hall *et al.*, 2003). Both species were also reported from a 15th century pit at The Stonebow, with beetle fauna interpreted as being representative of material derived from the inside of a human dwelling (Akeret *et al.,* 2005a). The presence of human ectoparasites probably reflects comparatively poor hygiene, e.g. the inability to regularly bathe or effectively wash clothing, rather than unsavoury living conditions. Evidence from deposits interpreted as house floors or as containing house floor sweepings tend to hint at clean and dry conditions within domestic buildings—although the use of rushes and/or other litter for flooring would have provided an ideal habitat for the larvae of fleas (see Kenward, 2009). Medieval documents also suggest that people were making efforts at pest control, not only of ectoparasites but also other species such as flies (see Busvine, 1976; King, accepted).

4.3 Water

During the medieval period, York's rivers served several functions and were of commercial, domestic, and industrial value. As such, the city council established ordinances to manage waste disposal into the waterways. For example, the council decreed that it was illegal to throw manure, household sweepings, or other filth into the rivers and eventually appointed a water bailiff to enforce these restrictions in the 1540s (see Sellers, 1912-1915; Raine, 1942-1950). Jørgensen

(2008b; 2010b) reviews the efforts of the local government to regulate pollution and cleanse the rivers.

York's waterways were already showing evidence of pollution by the early 11th century. Certain freshwater fish, i.e. barbel, burbot, and grayling, require well-oxygenated water with relatively little suspended sediment. These species became less frequent in the Foss-Ouse system from the mid-10th century and were absent from the record by the Norman Conquest (O'Connor, 2004). Similarly, the period indicates a decline in the freshwater bivalves *Unio tumidus* and an increase in the prevalence of *U. pictorum*, a species that is more tolerant of silty, poorly oxygenated water (ibid.). Geochemical analyses of alluvial deposits from the Ouse River-side North Street site in York show elevated lead concentrations in 9th-11th and 13th centuries, suggesting contamination of the water system by heavy metals (Hudson-Edwards and Macklin, 1999). However, cores collected from the North Street site, dated between the 11th-13th centuries, also yielded two individuals of *Oulimnius* sp., beetles typically associated with clean flowing water (Dainton *et al.*, 1992), and the riffle beetle *Macronychus quadrituberculatus* was recovered from 1-9 Micklegate (Kenward and Hall, 2000b). The presence of these species may indicate an improvement in water conditions in the Ouse following the Anglo-Scandinavian Period.

Sites intimately associated with the rivers and the King's Fishpool reveal some indication of domestic and industrial dumping. Borehole samples from 12th-14th century contexts at Palmer Lane, in association with the fishpool, yielded an assortment of grain pests, dry-material decomposers, and human and dog fleas—components that probably originated from the inside of a building—alongside water beetles and *Daphnia* ephippia (Carrott *et al.*, 1992b), implying the dumping of domestic material into still or slow-moving water. Similarly, deposits from the Garden Place site, contemporaneous to the early stages of the fishpool, contained flora and fauna of anthropogenic and natural origin (Carrott *et al.*, 1990). Following the mid-14th century, there may be some evidence to suggest a decrease in aquatic dumping in the area—although deposition of waste material along the river's edge likely still occurred as waste disposal or attempts to revet the river. In addition to aquatic biota, only small numbers of terrestrial fauna were recovered from 14th-15th century silt deposits at 84 Piccadilly (Carrott *et al*., 1991c). Furthermore, 14th-16th century material from nearby 38 Piccadilly provided evidence of aquatic invertebrates, including ostracods, cladocerans, aquatic molluscs, *Cristatella* statoblasts, and aquatic beetles and bugs, with some terrestrial (background) biota (Carrott *et al,* 1992a).

Several medieval industries would have exploited the urban waterways. Both the tanning and textile industries required substantial amounts of water and produced large quantities of effluent (Cherry, 1991; Walton, 1991), with resulting washwater contaminated with chemicals, blood, fats, lime, faeces, etc. Along the Ouse, the tanning industry was located upstream near the outskirts of city (e.g. Tanner Row). However, the city council barred the tanners from washing their skins in this area—instructing the tanners not to cast, lie, or wash limed skins or leather in the water upstream of the Pudding Holes (Sellers, 1912-1915). The area referred to as the Pudding Holes was a stretch of water between the Friar's Minor and the King's Staith, where water was used for brewing and baking and butchers washed entrails for use in black pudding (Sellers, 1912-1915; Raine, 1955; Jørgensen, 2010b).

Butchery was also a source of pollution. Jørgensen (2010b) details a sequence of complaints and proclamations that were issued between 1371 and 1380 concerning the casting of offal and refuse from slaughtered beasts into the Ouse and which involved York's butchers, the Friars Minor, the king, and York's authorities. The friars claimed that "the air in their church [was] poisoned by the stench there generated (referring to the butchery waste which had accumulated near the friary walls and in the Ouse) as well as around the altars where the Lord's body is daily ministered as in other their houses, and flies and other vermin are thereby bred and enter their church and houses" (Jørgensen, 2008b, p. 132). Following the 1380 order from the king, the butchers appear to have relocated their waste disposal to The Marsh, a region of swampy terrain near the Foss River and the King's Pool, close to St. John Hungate (Jørgensen, 2008b). In 1524, the Hungate area was officially designated as the appropriate disposal location for residents of the Walmgate suburb (Jørgensen, 2008b).

The Foss River may have also been used for tanning and textile production. Textile-working and tanning may have occurred upstream at Layerthorpe Bridge (Hall *et al.,* 2000a). Waterside and riverine deposits yielded large numbers of the hide beetle *Trox scaber* L. along with the remains of bark, bark beetles, and foul organic decomposer beetle species, which comprise a species group later put forward by Hall and Kenward (2003) as a potential indicator of tanning waste. The remains of flax (*Linum usitatissimum* L.), which is used in retting, were recovered from early Post-Conquest deposits at the site. Additionally, the recovery of the sheep ked *Melophagus ovinus* L., an ectoparasite of sheep, may indicate the processing of wool (Hall *et al*., 2000a). A number of dye plants were also recovered from the site (ibid.). The chemicals and other waste from these industries may have been carried down river towards the city centre. Evidence of runoff from the Layerthorpe site or from other industrial sites exploiting the Foss may be indicated by the recovery of *M. ovinus* and *L. usitatissimum* from the Adams Hydraulics II site (Carrott *et al*., 1991b). However, the aquatic beetles and *Daphnia* eggs, which were recovered from the site, imply conditions with still or slow moving water (ibid.).

The city council tried to regulate the pollution of its waterways. For example, in 1428, the authorities instructed butchers to dispose of their waste at a particular location along the Ouse where men of the nearby villages could arrive with their boats in order to collect the "dung, filthy nuisances, fluids and intestines to cultivate and prepare their land" (Sellers, 1912-1915, p. 2:70). In the mid-16th century, the council organised physical cleansing operations to clear waste and debris from the Ouse (Jørgensen, 2010b), and merchants were ordered to supply one labourer to help clean the Ouse during a workday (Raine, 1942-1950). However, direct dumping into the rivers was not the only source of water pollution, and runoff from the streets and waterfront sites would have contributed to their contamination.

No direct skeletal evidence for water-borne disease can be found at these sites. Diseases associated with diarrhoea tend to kill their victims quickly and, unless other diseases associated with skeletal changes were also present, any individuals killed by such quick acting pathogens would appear well based on their skeleton. This effect is called the “osteological paradox” (Wood *et al*., 1992). While macroscopic skeletal analysis cannot identify these diseases, it may be possible in the future to identify them biochemically, e.g. using enzyme-linked immunosorbent assays (ELISAs). Similar methods have been used to diagnose enteric protozoan parasites, such as *Entamoeba histolytica* and *Giardia duodendalis* which are known to cause dysentery, from other medieval period sites in Europe (cf. Mitchell *et al*., 2008; Bartošová *et al*., 2011). Unfortunately, these methods have yet to be employed in York. Water may have also acted as a compartment for the transmission of other infectious agents. For example, the ova of intestinal parasites were recovered from deposits associated with a 14th-15th century well at 22 Piccadilly (Carrott *et al*., 1995b).

5. Shared Spaces: Zoonoses and Vectors

The conditions that existed within the medieval urban environment put humans at risk of exposure to a range of diseases; prevalent among these were pathogens transmitted through interaction with animals and invertebrates. Throughout the period, animals were being kept in the city. An ordinance dated to 1301 stated that “no one shall keep pigs which go into the streets by day or night” (Prestwich, 1976, p. 16). Similar ordinances are issued throughout the 14th century and into the mid-16th century (see Jørgensen, 2008b, pp. 91-92). At the end of the 15th century, the city council decreed that no swine were to be kept in the city or suburbs in sties, houses or other places, and was repeated in the mid-16th century, this time ordering with all urban livestock to be removed from the city before a visit by King Henry VIII (Jørgensen, 2008b).

The co-habitation of the urban environment with livestock and other animals also created an issue of waste disposal, and secondary evidence of stable manure (via associated invertebrate and plant taxa) has been suggested for a number of sites in York through the 14th century (see Kenward, 2009). These include 11th-12th century pits at Skeldergate (Jaques *et al*., 2000), 12th-14th century surface deposits from Swinegate (Carrott *et al*., 1994), and a 14th c. fill collected from a timber lined pit at 41-49 Walmgate (Jaques *et al*., 2001). The deposition of faeces and other organic refuse in the urban environment would have attracted a specialised community related to decomposers and scavengers, such as flies, rats, and ravens (O'Connor, 2000; see also Kenward, 1997).

5.1 Echinococcosis

Echinococcosis is caused by the hydatid worms of the genus *Echinococcus.* For the hydatid *E. granulosus*, the definitive hosts are canids. During its life cycle, eggs are passed with faeces for ingestion by an intermediate host, typically sheep, goat, pigs, cattle, and horses. However, humans are viable intermediate hosts if they ingest an embryonated egg. In the small intestine of the intermediate hosts, the eggs hatch. Penetrating the intestinal wall, the larvae migrate into various organs, especially the liver, lungs, and brain, where they develop into cysts. The canids become infected upon ingesting the organs that harbour the cyst (Eckeret *et al*., 2002). In York, only one parasite cyst, identified as probably *Echinococcus* sp., has been found in association with a human skeleton (Tucker, nd). The skeleton was from the cemetery (11th - 14th century) associated with the church of St. Stephen's near Piccadilly (Tucker, nd), and may indicate the presence of dogs in the community. This is further supported by the recovery of the dog flea *Ctenocephalides canis* (Curtis) from medieval contexts in York (Carrott *et al*., 1992b; Carrott *et al*., 1994; Hall *et al*., 1993c). Moreover, bone-rich concretions, which may reflect the presence of dog coprolites, have been recovered, e.g. 14th century deposits at 41-49 Walmgate (Hall *et al.* 2002). The presence of dogs and thus their faeces within the urban environment would have created the opportunity for infection, and the role of dog faeces in the tanning process would have provided a second compartment for the spread of the eggs via the waterways.

5.2 Dicrocoeliasis

Dicrocoelium dendriticum, the lancet fluke, is a common parasite of grazing ruminants, such as sheep. However, it can infect horses, pigs, rodents, lagomorphs, and, more rarely, humans. It has a complex life cycle which requires the presence of two intermediate hosts to develop, i.e. a land snail and then an ant. Adult worms lay eggs which are shed into the environment with the host's faeces. The embryonated lancet fluke's eggs are ingested by a terrestrial snail (e.g. *Cionella lubrica*, *Achantinidae*, and *Streptaxidae*), hatch, and replicate larvae which are in turn deposited back into the environment in slime balls. After the infected slime ball is ingested by an ant (especially *Formica* sp.), the parasite influences the ant's behaviour to favour accidental ingestion along with vegetation by a definitive host (Dittmar and Steyn, 2004; Samaila *et al*., 2009). The principal clinical symptoms of dicrocoeliasis occur in the bile duct and liver with diarrhoea, weight loss, and anaemia occurring in some cases with severe infection (Markell *et al*., 1992; Cengiz *et al*., 2010). While eggs of *D. dendriticum* have been noted in a 10th century pit from 28-9 High Ousegate (Habraken and King, unpublished), the species has yet to be recovered from Post-Conquest sites in York. Also notably absent from York is the common liver fluke, *Fasciola hepatica*, which is another parasite of ruminants that occasionally infects humans through the ingestion of contaminated aquatic plants and/or fresh water. The potential absence of these two species of fluke in Post-Conquest York may indicate that ruminants, such as sheep and cattle, were not grazed or potentially kept for lengthy periods within the city centre—a possibility which may also explain the absence of the cow louse *Damalina bovis* L. during the period.

5.3 The Plague

The plague initially reached York in 1349 (Kenward 2009). While commonly referred to today as the Black Death, Busvine (1976) argues that this name may be a mistranslation of *pestis atra* or *atra mors*, where *atra* means dreadful rather than black. The bacterium *Yersina pestis* is believed to have been the causative agent for the epidemic (ibid.). *Y. pestis* is primarily a rodent and rabbit pathogen but can spread to humans and other animals through direct contact with contaminated fluid or tissue, infectious droplets, or through the bite on an infected flea. Additionally, cats and other carnivores can become infected by eating other infected animals (Salyers and Whitt, 2001). Cats, in particular, are susceptible to contracting the plague and can spread it to humans via air-borne droplets (e.g. Doll *et al*., 1994).

While the rat flea *Xenopsylla cheopis* L. has been identified as a primary vector (Hinnebusch, 2005), there are no archaeological records of the flea from Britain. The rodent fleas *Nosopsyllus fasciatus* (Bosc.) and *Ctenophthalmus nobilis* (Roths.) have been recovered from York (e.g. Kenward and Hall, 1995), and *N. fasciatus* is capable of transmitting the plague (Audouin-Rouzeau, 2003). Similarly, the dog flea *Ctenocephalides canis* is able to spread the plague to humans, and the human flea *Pulex irritans* L. can be a plague vector, albeit an inefficient one (Gratz, 1999). Single individuals of *C. canis* have been noted in Post-Conquest contexts in York (Carrott *et al*., 1992b; Carrott *et al*., 1994; Hall *et al*., 1993c). The human flea appears relatively regularly in York following the Norman Conquest. For example, single specimens have been recovered from 84 Piccadilly (Carrott *et al*., 1991c), 12th-14th century deposits at the Merchants Adventures' Hall (Carrott *et al*., 1996a), a 12th-14th century dump at Palmer Lane (Carrott *et al*., 1992b), and 17-21 Piccadilly (Alldritt *et al*., 1991). Moreover, Hall *et al.* (1993a, b, c) reported a few records of *P. irritans* in 14th century pits from The Bedern. *P. irritans* is a promiscuous flea and will feed on a range of hosts, including humans, canids, felids, rats, and swine (Jellison and Kohls, 1936). Although the perceived primary vector *X. cheopis* has yet to be recovered from medieval archaeological contexts in York, the urban environment fostered a number of reservoirs and vectors capable of transmitting *Y. pestis*.

5.4 Hymenolepsiasis

Hymenolepsiasis is primarily caused by the dwarf tapeworm *Hymenolepis nana*. The eggs are immediately infective to humans, via ingestion, upon being shed into the environment with faeces. The embryonated eggs can survive up to 10 days in the external environment. However, the life cycle of *H. nana* can also involve an intermediate host where the dwarf tapeworm may undergo larval development. Grain beetles, especially *Tenebrio* and *Tribolium* spp., and various fleas, notably *Pulex irritans* and *Nosopsyllus fasciatus*, are common intermediate hosts. Copraphagous insects can also be intermediate hosts (Roberts and Janovy, 2000). *H. nana* may then infect humans and rats upon ingestion of the intermediate host. Hymenolepsiasis is often asymptomatic but can cause diarrhoea and sleep disturbances (Wittner and Tanowitz, 2006). In York, the eggs of *Hymenolepis* sp. have been recovered from medieval pit fills at The Bedern (Hall *et al*., 1993a, b, c) as well as Anglo-Scandinavian deposits from 118-126 Walmgate (Kenward and Hall, 2000a) and the NCP car park site, Skeldergate (Habraken and King, unpublished). As with other pathogens which are dependent on faecal-oral transmission, the presence of *Hymenolepis* in medieval York may have been fostered by poor hygiene, inadequate waste disposal, and contaminated food and water. Moreover, rodents and insects would have been capable of promoting the cycle of the tapeworm as well as facilitating its spread and transmission. Interestingly, the available evidence suggests that dwarf tapeworm was not widespread in the community during the Post-Conquest period, having only been identified from The Bedern (Hall *et al*., 1993a, b, c).

5.5 Diphyllobothriasis

The broad fish tapeworm *Diphyllobothrium latum* is the infectious agent of diphyllobothriasis. The eggs of *D. latum* have been recorded in 10th century cess pits at 28-9 High Ousegate, York (Habraken and King, unpublished). Diphyllobothriasis can cause diarrhoea, anaemia, bone formation anomalies, and vitamin B12 deficiency. The eggs of the broad fish tapeworm are released during defecation. If released into water, the parasite is passed through the food chain from low-trophic level freshwater crustaceans to a second intermediate host, typically a small, crustacean-eating fish, and finally to fish-eating mammals, e.g. felids, canids, and bears (White *et al*., 2006). Humans can acquire the parasite by eating raw or undercooked marine or freshwater fish, which may provide insight into diet and food preparation methods. Similarly, the life cycle of the species requires the defecated eggs to be deposited into water, potentially evidencing an intersection between waste disposal and water systems. The remains of the broad fish tapeworm have yet to be recovered from Post-Conquest sites in York. If the species was not present during this period, its absence may be an indication that York's inhabitants were consuming fish that was prepared in a way that killed the parasites and/or that the city's sewage was not contaminating the waterways—at least not the same water systems which they were fishing. Isotopic analyses of the Fishergate and All Saints communities show that a transition to a marine diet occurred during the 11th-12th centuries and that the population was consuming notable amounts of marine fish by the later Middle Ages (Müldner and Richards, 2007a, b).

6. Non-Specific Skeletal Evidence

The parasitic burden, discussed above, is, apart from the one case of *Echinoccocus* (Turner, n.d.), not possible to evidence directly from the skeletal remains. The secondary effects of these parasites, namely anaemia and, in the case of diphylobothriasis, vitamin B12 deficiency, alongside generalised high pathogen load have been linked to the prevalence of porotic hyperostosis found at the lower status cemetery of St. Helen-on-the-Walls (Grauer, 1993). Cribra orbitalia is more commonly reported than porotic hyperostosis in British collections and has also been linked to anaemia. Recently this association has been called into question (Walker *et al*., 2009), but in Britain it has been found to be associated with *Plasmodium vivax* malaria, which is transmitted by *Anopheles* mosquitoes (Gowland and Western, 2012). Although York was not likely to have been a malarial hotspot (ibid.), its marshy conditions, particularly near the Foss, as well as the presence of stagnant water in urban pits and pools hosted a community of nematoceran flies (the suborder containing midges and mosquitoes) (Kenward 2009). Although not identified to species, the remains of nematoceran flies have been recovered from sites in York, and Culicidae (the family containing mosquitoes) have been observed but not recorded (Kenward 2009). The presence of anaemia-causing parasites (the endoparasites discussed above) could be one of the reasons for the high prevalence of cribra orbitalia, which was found to be almost double (Table 1) the British average for the late medieval period of 11% (Roberts and Cox, 2003).

Further evidence of the effect of the environmental risk factors discussed above, may be seen in other non-specific indicators of infection and inflammation. Periostitis, which manifests as new bone formation on the outer surface of bones, is caused by inflammation of the periosteum due to either infection or trauma (Weston, 2009). York's average rate of 26% (Table 1) is higher than the crude prevalence rate for Britain of 14.1% (Robert and Cox, 2003). A systematic study of periostitis at St. Helen-on-the-Walls found that it increased in frequency with age (Grauer, 1993). Thus, the risk of having periostitis is cumulative during life, and factors previously discussed, e.g. anaemia and parasite load, as well as infections such as endemic treponematosis (e.g. diseases caused by spirochetes of the genus *Treponema* and which include syphilis), would, alongside localised trauma, have been causal agents in York. One definite case of syphilis is known from this period in York and was found at St. Helen-on-the-Walls (Dawes and Magilton, 1980). This likely reflects human-to-human contact.

Osteomyelitis, a non-specific infection of the bone or its marrow, can be evidenced, skeletally, from the presence of a cloaca, a drain for purulent material (Roberts and Manchester, 2005). It is often associated with a localised infection that has been spread via the blood stream, e.g. tonsillitis or other ear, nose, throat, and chest infections (ibid.). This was as common in York (1%, see Table 1) as in the rest of Britain (crude prevalence rate of 0.8%) (Roberts and Cox, 2003). Early stages of osteomyelitis, i.e. thickening of the bone without a cloaca may have been seen in 10 cases of osteitis at Fishergate House (Holst, 2005). Some of these cases were associated with fractures and may be an indication of bacteria, probably environmental in origin, entering the body via broken skin.

The overall poor health, as evidenced above, is supported by the slightly shorter overall stature of the individuals at York than the British mean for this period. Mean male stature in Britain was 171 cm and for females, 159 cm (Robert and Cox, 2003). At York, mean male stature was 170 cm (but is equal to the mean 171 cm if the lowest mean stature of 167 cm, more than two standard deviations lower than the average, at the site of Jewbury is excluded, see Table 1). Female mean stature was 157.6 cm. It is possible that the similarity of York's male mean to the British average is due to economic migration of men into York from the surrounding countryside, this is, in part supported by the isotopic evidence (Müldner and Richards, 2007a, b). It could also be an effect of a longer growing period for males than females, allowing for catch-up growth after a period of stress (Bogin, 1988).

Due to the long use of many of the cemeteries, it is not possible to determine the effects of short-term environmental change on human health due to legislative changes or local planning. Only two of the cemeteries discussed are tightly chronologically bound, Jewbury (c. 1175 to 1290) and St. Stephen's (11th to 14th century), whereas the other cemeteries span the time frame of this study (or extend beyond it in either direction). St. Andrew's Fishergate is multi-period, with period 4 spanning the late 10th to 12th centuries and period 6 ranging from 1195 to the later 16th century. The early period sites of Jewbury and St. Stephens have lower rates of sinusitis than average, which could be a reflection of the lack of sea coal being burnt during this period, as discussed above. Jewbury also has the lowest prevalence of periostitis and the shortest statures, so these low rates of infection may reflect the osteological paradox (Wood *et al.* 1992). St. Andrew's Fishergate demonstrates a halving of the prevalence of cribra orbitalia from the early to the late phase of the site. This is possibly linked to the status of the site changing as opposed to environmental changes, because the other early sites reflect a lower prevalence of cribra orbitalia. The two cemeteries associated with religious orders, Clementhorpe and St. Andrew's Fishergate, do not stand out as being different to the other York sites (excepting the prevalence of cribra orbitalia), but this could be a result of the limited comparable data in the original reports. Therefore, it is difficult to make generalised statements regarding short-term environmental changes in York. What is clear from the osteological evidence is that the population of York had high rates of diseases associated with air pollution and living in close proximity to humans and other animals, and these appear, based on the best currently available evidence, to be higher than the rest of Britain at this time. Combined with other evidence it seems clear that the local environment had a detrimental effect on human health.

7. Conclusions

The medieval city of York harboured and cultivated a diverse community of organisms, which intersected with each other as well as the conditions comprising the urban environment. The interplay between these characteristics would have had an impact on the emergence and distribution of pathogenic organisms as well as the proliferation of potentially detrimental abiotic factors. A concentrated synthesis of data pertaining to York's medieval period between the 11th and mid-16th centuries risks potentially placing undue emphasis on conditions which may have gone unnoticed or have been of minor concern to the community at the time.

However, the textual accounts of contemporaneous civil authorities reveal that certain conditions were considered unacceptable and that regulations were set forth in order to attempt to maintain a *clean* urban environment (see Jørgensen 2008a, b; 2010a, b, c). Certainly, the recovery of *Oulimnius* sp. from North Street (Dainton *et al.*, 1992) and *Macronychus quadrituberculatus* from 1-9 Micklegate (Kenward and Hall, 2000b) suggests an improvement of aspects of the urban environment, at least pertaining to the water, following the Norman Conquest. While other cultural factors, e.g. food preparation and the importance of marine fishing, likely played a role, the management of the urban waterways may have also contributed to the potential absence of the parasite *Diphyllobothrium latum* at this time.

Following the advent of coal burning in the city in the later 14th century, the quality of the air appears to have deteriorated (Brimblecombe and Bowler, 1992). Smoke and chemicals resulting from metal-working and other industries would have polluted the air and have had an impact on human health, e.g. sinusitis. Harmful levels of smoke and sulphur dioxide seem to have been in the city centre following the 14th century (Hipkins and Watts, 1996). Despite this, textual accounts hint that the medieval urban reforms were primarily concerned with managing the contamination of the air evidenced by foul or strong odours, and regulations targeted industries such as tanning that produced odoriferous waste (Jørgensen, 2008a, b; 2010a, b, c).

The conditions of the terrestrial urban landscape seem to exhibit a similar, albeit slightly later, trend to the waterways. During the early part of this period, certain areas of the city appear to have had fairly foul conditions, e.g. 11th-14th century deposits from the Swinegate area (Carrott *et al.*, 1994), and 11th-13th century yard surfaces and pits at 44-45 Parliament Street (Carrott *et al.*, 1995a). Starting in the 14th century, waste disposal methods began to change, and regulations were implemented to facilitate the transfer of human and animal refuse to designated disposal areas, often on the outskirts of the city (Addyman, 1989; Jørgensen, 2010c). The excreta disposal pattern was fairly erratic in the pre-14th century medieval urban environment in comparison to the defined isolated dumps and cleanable stone latrines of the later period. This governance of refuse disposal likely had a pronounced impact on the health of York's inhabitants, particularly in respect to infectious parasites. Faecal-borne helminths have been regularly recovered from sites in York throughout this period, mostly in small numbers where quantitative or semi-quantitative results were reported. However, from contexts dating from the 14th century on, the records of faecal-borne parasites appear to be mostly limited to pits and dumps, e.g. 14th and 15th century pit fills from 62-68 Low Petergate (Akeret *et al.*, 2005b).

The evidence suggests a gradual trend towards greater urban environmental cleanliness following the Norman Conquest. However, the negative impact on human health, when compared to the rest of Britain, of the extant socio-environmental conditions is obvious. While the direct evidence of parasites and disease vectors cannot be directly translated to the osteological record, future biochemical and biomolecular research may be able to detect direct evidence of immunological response to these diseases or the casual agents themselves. Furthermore, it is possible, with appropriate archaeological methods, to recover evidence of intestinal parasites from grave soils, but so far this has been rarely undertaken in Britain. Through employment of these methods, it may be possible to obtain direct evidence of individuals affected by the environmental diseases discussed above.

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Table 1. Osteological data for York obtained from original skeletal reports except where explicitly stated. All refers to adults, including un-sexed adults and sub-adults.

Site	**Sex**	Mean stature		Infection (not specified)			Periostitis			Sinusitis			TB			Cribra orbitalia		
		n	(cm)	affected	n	%	affected	n	%	affected	n	%	affected	n	ɔerts and	affected	n	%
	Females	34	156	11	62	18.0%												
	Males	18	173	4	31	13.0%												
Clementhorpe	All			15	127	11.8%												
	Females	42	159				32		60.0%	20		31.0%				6	53	11.3%
Fishergate	Males	48	170				34		60.0%	18		34.5%				8	57	14.0%
House	All						102		42.0%	58		48.5%				49	244	20.1%
Fishergate, St.	Females		158													6	11	54.5%
Andrews Period	Males		172													7	26	26.9%
4	All																	43.1%
Fishergate, St.	Females		159													5	20	25.0%
Andrews Period	Males		171													9	69	13.0%
6	All																	21.0%
	Females						13	67	19.4%				0					35.5%
Fishergate, St.	Males						41	179	22.9%				4					16.8%
Andrews (all)	All														1.50%			30.3%
	Females		156				22	107	20.6%							19	107	17.8%
	Males		167				14	131	10.7%							16	122	13.1%
Jewbury	All						56	323	17.3%	28	90	31.1%	6		1.50%	73	322	22.7%
	Females	34	158															
	Males	37	172															
St Stephen's	All						33		28.5%	13		11.0%				11		9.3%
	Females		157															
St. Helen-on-the-	Males		169															
Walls[1]	All						21		22.2%			55.0%			0.50%	6		
Total	Mean					11.8%%			27.0%			30.0%			1.2%			20.6%

1. St. Helen-on-the-Walls sinusitis was not in the original report, three different prevalence rates are reported in the literature ranging from 7.9% (Keeping, 2000), 55% (Holst, 2005) to 71.93% (Roberts, 2007) the decision was made to use the data from Holst to calculate a mean because this fits closest with the remaining data. 21 cases of periostitis and osteoitis were reported at this site, with the prevalence of 22.2% obtained from Holst (2005) because this was not provided in the original report.