WASTE AND CITY FORM: RECONSIDERING THE MEDIEVAL STRATEGY

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ABSTRACT

This paper argues that "new" sustainable technologies being used to manage human waste—composting toilets, bioremediation, and biodigestion—are essentially reviving the medieval strategy of waste management: containment and reuse of waste, as opposed to the modern strategy of dilution and evacuation. This debate should not occur in a vacuum, uninformed by the motivations for, and history of, the development of the modern system. Therefore, this paper more closely examines the medieval system, which closely linked waste and agricultural production. It then considers the transformation to the modern system, using the design of Leonardo da Vinci's city of Romorantin as a case study. It is argued that this transformation was largely predicated on now-delegitimized miasmic theory, which held foul or corrupt air to be the cause of disease, and that it precipitated larger changes in the urban environment. In light of this historical view it is suggested that contemporary sustainable technologies imply larger changes in the form of human settlement, and that the nature of these changes must be explored further.

KEYWORDS

sustainability, waste management, sewage, Leonardo DaVinci, Romorantin, composting toilets, bioremediation, biodigestion

INTRODUCTION

The management of human waste is an essential component of urban sustainability. The new systems of waste management being advanced by proponents of sustainability aim to reduce the environmental impact of waste by conferring value to it and reusing it—in the words of William McDonough, by eliminating the concept of waste. This paper argues that such systems are not new at all, but rather represent a revival of the medieval strategy of containment and reuse of waste, rather than the modern strategy of dilution and evacuation.[1] The sustainability debate would benefit from a reexamination of the historic processes that shaped the modern system now being challenged—that made the re-use of waste a radical idea. This paper examines the medieval system and the reasons for its elimination. It then considers the transformation to the modern system, using the design of Leonardo da Vinci's ideal city of Romorantin as a case study. This transformation had important implications for urban form, ultimately allowing greater density and scale, and decoupling food production from the city's organic output. Finally, the paper will consider the implications of the "new" sustainable strategies of waste management in light of this historical view.

Sustainable waste management strategies share a proclivity for the reuse of human waste. New systems being advanced to manage human waste include composting toilets, biodigesters, and bioremediation systems. Composting toilets contain waste and decompose it aerobically, producing compost—a "rich mud" that can be used as fertilizer. Biodigestion systems decompose waste in an anaerobic environment, creating methane-laden "biogas" that can be burned for heating and/or electricity generation, as well as organic matter that can be used as fertilizer. Bioremediation can take several forms: artificial wetlands and "ecological machines" are the most common. Both treat wastewater biologically through a series of vegetative filters: plants consume the waste and excrete clean water, and the plants themselves can be composted or used as food for livestock or aquaculture.[2] The degree of mechanization these systems

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exhibit is loosely related to density: relatively passive systems such as artificial wetlands require greater land area than their more mechanical counterparts. All of the systems, however, tend to be *decentralized*—at the scale of a building or neighborhood rather than an entire city—and are typically located within human settlement in order to facilitate the utilization of the valuable end products: fertilizer, methane, clean water, and/or food. Thus the strategy of waste management they represent is substantially similar to the medieval strategy of *containment and reuse* of waste.

This revival passes unrecognized. As Dominique Laporte describes, the use of fecal matter is a contentious issue: "The investment of waste—particularly human waste—with value is consistently marked by a feigned oblivion of recent practices. It is offered as a discovery, or better yet a rediscovery, of ancient models" (Laporte 1978/1993, 31). In the discourse of sustainability, the use of waste is cast as a discovery of natural principles: legitimacy is sought through objective science. The strategy, however, is not new: it was standard practice throughout Europe as recently as the nineteenth century. An understanding of this system and the reasons for its demise are essential for an informed discussion, and reveal important considerations regarding sustainable waste management in relation to city form.

THE MEDIEVAL STRATEGY: CONTAINMENT & REUSE

As Lewis Mumford (1938) describes, the composition of waste in the medieval city was almost exclusively organic. Aside from a small amount of glass, metals, and other byproducts, most waste consisted of food scraps, human waste, and offals, and was therefore biodegradable. There was little distinction between types of waste: human excrement and garbage were treated similarly (Mumford 1938, 46). In rural settlements, waste was applied directly to the land as fertilizer (Gibson and Farrar 1974, 249). In denser settlements this strategy was not feasible, and city residents disposed of waste in one of two ways: they dumped it onto the unpaved city streets, or contained it in cesspits at the lower level of buildings (Singman 1999, 188). One of three things subsequently happened to it. Much of what ended upon the street was eaten by the pigs and other livestock that freely

FIGURE 1. Florence in 1493. Despite what appears to be a dense urban fabric, there is open land within the city walls as well as immediately beyond, and the overall scale of the city is relatively small.

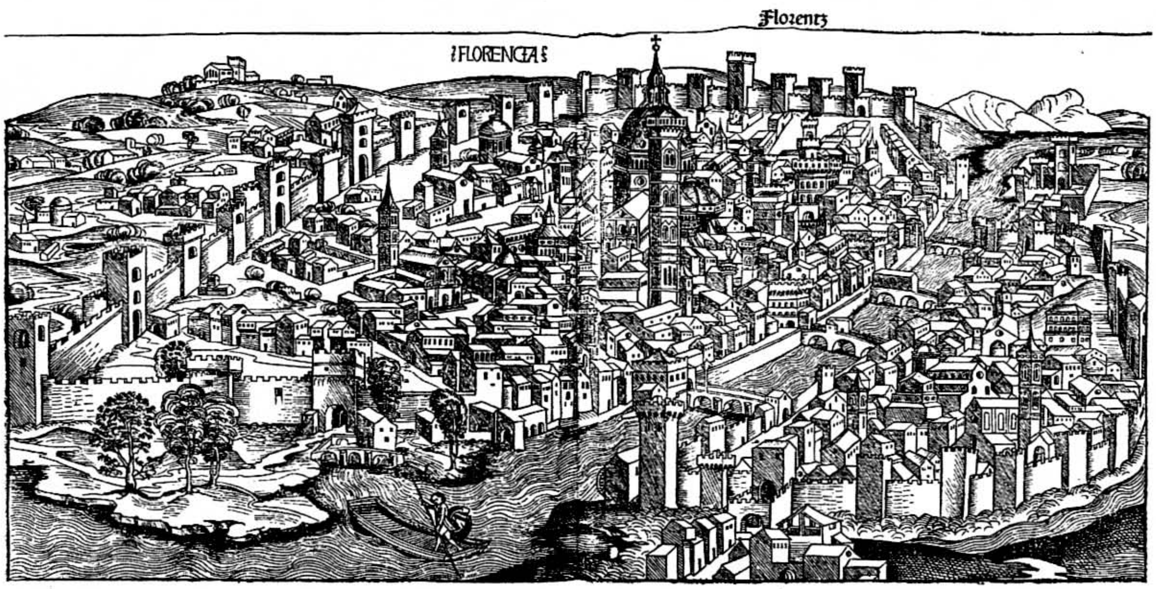
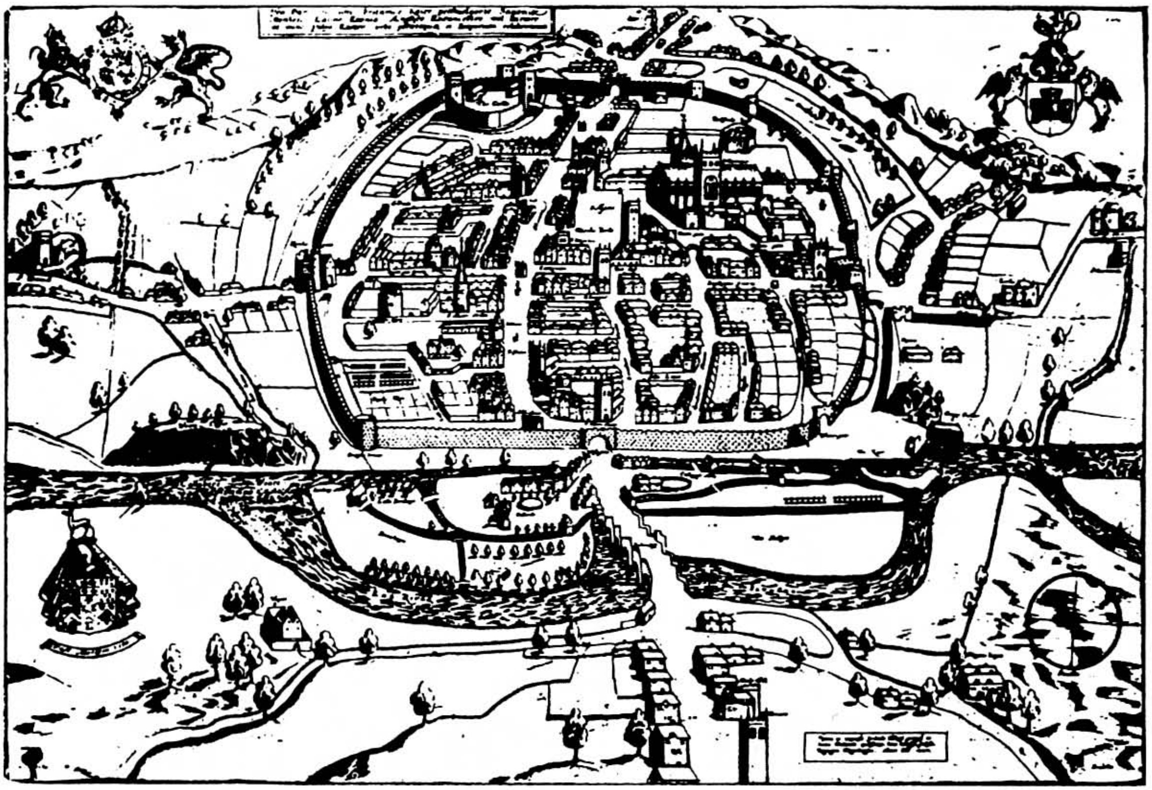


FIGURE 2. Exeter in 1587. Dense street edges surround open space. As Morris describes, there is no evidence of overcrowding.



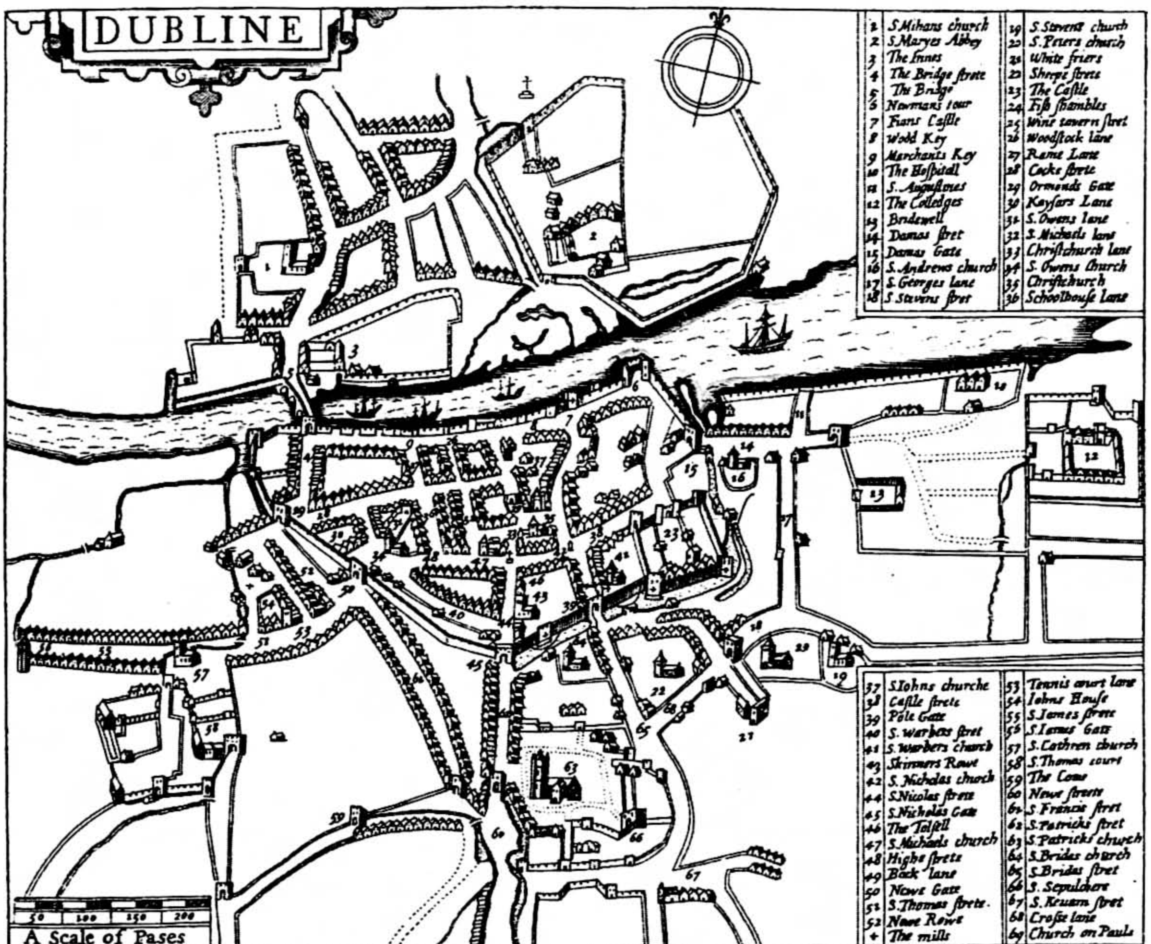
roamed the city (Mumford 1938, 46; Singman 1999, 188). A good deal of it was simply absorbed into the earth, creating a rich and fragrant mud. The excess waste from cesspits, as well as some of the rich mud, was collected and used as fertilizer, both within and outside the city. Human waste provided a valuable fertilizer, with an abundance of potassium and phosphorus (Gibson and Farrar 1974, 248).

The use of waste as fertilizer was a vital component of medieval agriculture. As Mumford discusses, the medieval city was closely tied to agricultural production and was typically self-sufficient. Approximately four out of five inhabitants worked the land; even in larger cities only a small minority were true specialists (Mumford 1938, 19; Morris 1994, 109). It was not uncommon for gardens, orchards, fields and pastures to be located within city walls as well as in the immediate hinterlands (Mumford 1938, 43). According to Ivan Illich (1985), as late as 1850 Paris generated enough produce on one-sixth of its land to supply the entire city (67; see also Katz 1986, 153-4). Medieval residences typically had a vegetable garden or larger green space behind the house, a fact belied by the often dense street edge (Singman 1999, 179; Morris 1994, 100). Indeed, Medieval towns and villages boasted an abundance of open space. It was only after 1300 as cities began to increase in population and size that a dense urban environment began to emerge (see figs 1–3).

Sanitation in this scheme was closely related to density. While densities remained relatively low sanitation was not a problem. As population and density increased, however, the old strategies of waste management became unworkable. E. J. Morris (1994) contends that it was only in the late medieval period and early Renaissance that cities became overcrowded to the point that sanitation became a problem (100). The output of cities began to overwhelm the capacity of natural waste sinks, and the buildup of waste in cities created a sanitation crisis. As Rebecca Williamson (2006) describes, legislation aimed at improving conditions was largely ineffective (155). In 1292 King Phillip Augustus decreed that all roads in Paris be paved, in part due to the stench. The few streets that were actually paved made matters worse: waste could no longer subside into the earth and rainwater could no longer infiltrate to cleanse the soil or recharge groundwater (Corbin 1986, 91). Various pieces of legislation prohibiting dumping in streets or rivers were ignored (Williamson 2006, 155). The sanitary conditions in cities continued to deteriorate as urbanization progressed.

The issues of sanitation and disease came to the fore with the Black Plague, which struck Europe in 1348, killing a quarter to a third of the total population within three to four years, and continuing the flare up throughout Europe until the middle of the seventeenth century. While modern science has shown that the plague was caused by microbes that were harbored by rats and transferred to humans by

FIGURE 3. John Speed's 1610 map of Dublin. Even at this seventeenth-century date there is a good deal of open land within the city.



Map of the City of Dublin as published by John Speed. A.D. 1610.

fleas, the science of the time, handed down from Hippocrates and Galen, blamed foul or corrupt air. This theory, later termed *miasmic theory*, is described by Carlo Cipolla (1981):

> [T]he basic, predominant idea was that [the plague] originated from venomous atoms. Whether generated by rotting matter or emanating from infected persons, animals, or objects, the venomous atoms would infect salubrious air and make it 'miasmatic'—that is, poisonous. It was indeed the 'corruption' of the air that, according to doctors of the Renaissance, was the basic precondition for the outbreak of an epidemic of plague. (8)

These venomous atoms were considered exceptionally sticky: they would stick to porous objects like wool, cotton, carpet, and grain, permeating them in much the same way as perfume or a foul odor (8). The theory was validated by the fact that those who handled porous materials were more likely to contract plague, when in fact this correspondence was due to the fleas that inhabited such materials. The theory also gained legitimacy from the fact that the plague flared up in the summer when the city was permeated by offensive odors: venomous miasmas were clearly created by rotting material and raw sewage.

The prevalence of this theory is evidenced by at least 281 "plague tractates"—pamphlets dating from 1348 onward written to inform the general public about the causes of, remedies to, and prevention of the plague (Winslow and Duran-Reynals 1948, 747). The authors of these tractates attributed corrupt air to various sources. The most common culprits were decaying organic matter (including vegetable matter, animals, and human corpses); "exhalations" from swamps, marshes, and stagnant water; and winds that brought foul air from afar (Byrne 2004, 43; Sterner 2007, 4). The British Parliamentary statute of 1388 prohibited the dumping of "dung, offal, entrails and other ordure into ditches, rivers, waters, or other places" explicitly because it led to corrupt and infected air, which caused "many illnesses and other intolerable diseases" (Luders 1810; quoted in Horrox 1994, 205).

The erroneous correlation between waste, odor, and disease proved a formative influence on modern waste management strategies. According to Cipolla (1981), "a common-sense sequitur to this view was that to avoid an outbreak or the further spread of an epidemic, the first and most important thing to do was to clean up the environment" (15)—that is, remove waste from human proximity. Miasmic theory also created a fear of "bad air" that contributed to the transformation olfactory perception and ultimately led to what Ivan Illich (1985) calls "the utopia of the odorless city" (47-8).

While the modern system of waste management, consisting of diluting waste in water and evacuating it from the city via sewers, is typically traced to the mid-nineteenth century, often specifically to the redevelopment of Paris under Baron Georges Haussmann, the same strategy was the subject of the discussion as early as the Renaissance. In *The Breath of Cities*, Rebecca Williamson traces the intellectual lineage of modern "urban infrastructure" to Renaissance thinkers concerned with air quality and waste. Their ideas, informed by miasmic theory as well as by emerging concepts of circulation within the body, survived into the eighteenth and nineteenth centuries in the work of Pierre Patte and Francesco Milizia, among others (Williamson 2006). Thus it is appropriate to look at Renaissance proposals as the genesis of the modern strategy.

Among European cities, those in Northern Italy—namely Venice, Milan, Genoa, and Florence—quickly became the most advanced in regards to hygiene and sanitation, and continued to advance throughout the fifteenth and sixteenth centuries (Cipolla 1981, 5). This is partially attributable to Italy's legacy of Roman infrastructure, which provided invaluable inspiration to Renaissance thinkers like Da Vinci, who began looking to the architecture of the past—and in particular the Roman aqueducts and sewers—for solutions to their contemporary problems. Leonardo da Vinci exhibited special interest in the issues of hygiene and waste; his sketches for ideal cities circa 1480 are largely structured by waste management strategies (Nicholl 2004, 493; see also Da Vinci 1517 582r; 583r/217v-c, v-b; 209r/76v-b). Indeed, his design for an ideal city at Romorantin in France departs dramatically from the standard practices of the day—and these new strategies, precursors to the modern system, had important implications for the form of Leonardo's city.

THE MODERN STRATEGY: DILUTION & EVACUATION

Leonardo's unbuilt city of Romorantin was designed in 1517 for François I, then King of France. Laporte (1978/1993) details François I's interested in hygiene, as evidenced by his Hygiene Edict of 1539 mandating the removal of waste from the city (47). Leonardo's design for a new palace and grounds quickly evolved into the design of a small city whose form was largely a response to contemporary problems of sanitation and disease. This ideal city represented a distinctly modern approach to the problem of waste, employing an elaborate system of canals and sewers to flush waste out of the city. The plans for Romorantin and its palace complex were never implemented; an epidemic in the area caused François to build in Chambord instead (Pedretti 1972, 1). The design, however, remains an important indicator of a new way of thinking about waste and city form.

Leonardo's design is structured by his waste management strategy: a vast network of canals that covered the region between the Loire and Saone rivers. Leonardo was unequivocal about the function of the canals: he was using water a medium for flushing waste out of the city: "The numerous canals keep numerous toilets clean. The numerous canals clean numerous streets [. . .]" (Da Vinci 1517; quoted in Pedretti 1972, 99).

The use of water to flush waste was not a new idea. Water flowed through the Roman sewers and the Cloaca Maxima, which washed Roman waste into the Mediterranean via the Tiber River (Robinson 1992, 117). Medieval monasteries and palaces often contained latrines that emptied into rivers (Hoffman 1996, 643-4). The novelty of Leonardo's design was, first, the extensive provision of man-made canals to perform this function, and second, the application of this concept to a city as a whole, rather than simply to the individual residences of elite patrons.

Leonardo's proposal was also consistent with burgeoning Renaissance thought. Leon Battista Alberti, a contemporary of Leonardo, wrote his influential *Ten Books on Architecture* in 1450, in which he makes a distinction between two types of drains, or sewers. One kind, the *subsidence pit,* collects waste and allows it to be "absorbed by the bowels of the earth" (Alberti 1450/1988, 113-4)—a description of the then-predominant form of *containment and reuse.* The second kind, the *diffuser,* discharged waste into a body of water. While Alberti does not explicitly indicate which method he prefers, he stresses the importance of drains "in maintaining the sanitation of the city, the cleanliness of buildings [. . .] and toward preserving the wholesomeness and purity of the air" (ibid.). His emphasis on *air quality*—informed, to be sure, by miasmic theory—favors a method of waste management that eliminates the source of corrupt air from the city.

Eliminating putrid air, however, is incompatible with the reuse of waste. As Gibson and Farrar (1974) observe, "If sewage does not putrefy, it is not broken down into simpler compounds which plants can utilize, and is useless for agriculture" (249). A key element of the medieval strategy was *containment*—the storage and concomitant putrefaction of waste prior to use. Thus Alberti's emphasis on air quality clearly favors diffusion. The process of diffusion further undermines the use of waste as fertilizer by reducing the concentration of nutrients and decreasing the nitrogen content (Gandy 1999, 30). The stench of waste is therefore inseparable from its fertility. Laporte (1978/1993) notes the historic ambivalence toward waste: sometimes praised as the best fertilizer, at other times it is considered unsanitary and wholly unfit for use (31-7). Leonardo's strategy takes a clear position in this debate.

Although Alberti wrote that waste could be diffused into any body of water—river, lake, or sea—Leonardo's design for Romorantin emphasizes the *movement* of water, not merely diffusing waste but flushing it out of city. The natural movement of the river was not adequate for this task: his design calls for damming the river at the north of the city in order to create torrents of water that could rush through the city's canals and sewers:

> The course of the river shall not pass through the ditches that are within the city, so that when the river becomes turbid it shall not unload soil at the bottom of the said ditches. Water, then, shall be given to these ditches by means of floodgates, so that it shall be used for the mills, as well as to sweep away the mud of the city and any other filth. (Da Vinci 1517; quoted in Pedretti 1972, 98)

This emphasis on movement had practical motivation: slow water would allow silt from a "turbid" river to clog city sewers; and rushing water could serve the additional function of powering mills' water-wheels. But moving water itself was also an important element of sanitation. Standing water was seen as dangerous because of its relationship to miasmic air. This idea had a long history: Vitruvius, who was a source of inspiration for both Leonardo and Alberti, stressed the importance of moving water. Places like marshes in which water could not move were seen "merely [to] putrefy as they stand, emitting heavy, unhealthy vapors" (Vitruvius 1960, 21). Contemporary science supported this notion. Leonardo's design specifically avoids stagnant water that could corrupt the air, favoring sluices and an underground sewer system to move waste out of the city.

The priority given to unobstructed flow is writ large in the city plan: wide, straight streets and a gridded network of canals provide easy movement of water, waste, and people—a dramatic reversal from the haphazard fabric of the medieval city. It was over a century later than William Harvey formulated his theory of circulation of the blood, and over two centuries after Harvey that Sir Edwin Chadwick applied this theory to city planning; but the concept was already clearly expressed in Leonardo's design.

According to miasmic theory, health is explicitly linked to the elimination of foul air. Leonardo's remarkably modern design for the palatial privies goes to great lengths to prevent odors from seeping into the rest of the building:

> Let all privies have ventilation [by shafts] through the thickness of the walls, so as to exhale through the roof. [. . .] The rooms leading to the privies must be numerous and leading one into the other so that the stench may not penetrate into the dwellings, and all their doors must shut themselves by means of counterweights. (Da Vinci 1517; quoted in Pedretti 1972, 80)

This is a departure from typical royal residences, which were among the worst offenders in regards to sanitation, surrounded by cesspits and stagnant sewage (Laporte 1978/1993, 12; Corbin 1986, 22).

The strategy proposed by Leonardo—evacuation of waste via water flowing through underground sewers, rational gridded cities, and ventilated bathrooms—anticipated a system of waste management that was not fully realized until the end of the nineteenth century. The debate between containment and evacuation—between sewers drained with water and cesspools cleared by manual labor ("night-soil collectors")—raged throughout Europe during 1850s, with cholera taking the place of plague (Corbin 1986, 117-9). Miasmic theory maintained its currency during this time, even as evidence mounted for germ theory; and the conflation of odor and disease formed the foundation of the case for evacuation.[3] By the end of the nineteenth century, combined waste and storm water sewers were becoming the norm across Europe (Gandy 1999, 31). The advent of inorganic fertilizers dealt the final blow to the medieval strategy of containment and reuse.

Matthew Gandy (1999) argues that another impetus for the expansion of sewers and the evacuation of waste in the nineteenth century was a changing standard of personal hygiene—motivated in part by a new sensibility regarding smell—that dramatically increased the use of water in dwellings. Whereas in medieval cities little water was used for bathing—washing was predominantly a collective activity (Mumford 1938, 37)—the standards of cleanliness and privacy underwent a dramatic shift during the eighteenth and nineteenth centuries (Gandy 1999, 31). Alain Corbin (1986) argues that standards of smell and odor are largely a social creation of this area. These factors—supported, if not created, by miasmic theory—created a demand for private washrooms and individual toilets, and a parallel demand for private sewer connections to flush water away (Gandy 1999, 32). The aversion to odor made the alternative solution of containment unacceptable; and the demand for sewers figured heavily in their expansion and ultimate success.

Gandy observes that the loss of continuity between waste and agriculture—between city and country—paralleled a new view of nature. Waste was no longer productive, but rather annoying; its odor "began to lose the last semblance of its rural associations with fertility;" and nature became, for city dwellers, simply a site for recreation and leisure—a commodity to be consumed (Gandy 1999, 32-3). The organic economy—the cyclical exchange of nutrients between city and country—had been usurped.

The rationale for the modern strategy has been obscured by its ubiquity, and it remains interestingly inconsistent with modern rationality that its adoption is rooted in delegitimized miasmic theory. Some of these discontinuities are resurfacing—if not self-consciously—in the arguments being advanced by the sustainability movement.

RECONSIDERING THE MEDIEVAL MODEL

As the sustainability movement has demonstrated, the modern waste management strategy, now in use around the globe, is not without its costs. The use of water as a medium for waste disposal is seen as a misuse of an increasingly scarce and vital resource: already water scarcity is a major problem in many regions. Furthermore, the dilution of waste in water—the strategy advocated by Leonardo and Alberti—itself does little in the way of sanitation. It relies on low concentrations of waste, yet the output of cities has long surpassed what water bodies can assimilate naturally. In response, cities have deployed complex systems of sewage treatment, but the treatment is incomplete: toxins, heavy metals, PCBs, and other pollutants frequently make it through the treatment facilities and are released into the environment, with increasingly problematic results (Wynn 2007, xvii). The treatment process often utilizes hazardous compounds and creates toxic byproducts (Roseland 1998, 59). Moreover, the continued growth of cities has overwhelmed the capacity of many municipalities' treatment plants. Major North American cities including Chicago, Cincinnati, Montreal, and Vancouver routinely discharge untreated sewage into local bodies of water, primarily during rain events and as a result of the overflow of combined sewage and storm water systems (MacDonald 2006; Sierra Legal Defense Fund 2004).

At the same time, the sustainability movement is rediscovering the value of waste. In *Cradle to Cradle* architect William McDonough and chemist Michael Braungart (2002) make the fundamental realization that "waste equals food" (92). They propose a closed-loop or cyclical economic model in which "waste" is continually recycled into new products. This is the essence of the medieval strategy: waste becomes a valuable resource. But there are significant barriers to reinstating a cyclical economy: regulations prohibit the reuse of waste (particularly human waste), and modern waste is laden with heavy metals and toxic or non-biodegradable compounds. McDonough and Braungart attempt to address the complex anatomy of the modern waste stream by sorting waste into two categories: "biological nutrients" that can biodegrade, and "technical nutrients" that must be recycled or reused (McDonough and Braungart 2002, 104).

If there is a lesson to be learned from history, it is that changes in the strategy of waste management do not leave the overall form of the urbs unchanged. What are the ramifications of implementing the containment and reuse model in the context of the modern city? As Herbert Girardet (2004) demonstrates, the hyper-dense metropolis of today relies upon a complex infrastructure that allows it to draw resources from vast distances and export its wastes to other locales. Yet the problem of the medieval system was precisely this: containment and reuse was not feasible beyond a certain density and scale; it was workable only while communities remained small. While hygienic improvements undoubtedly increase this limit, it is unrealistic to suppose that they eliminate it altogether. There remains a limit to the amount of waste that can be locally used or absorbed without adverse effects. It is appropriate to ask whether the distributed and localized nature of sustainable systems—composting toilets, biodigesters, and bioremediation systems—is compatible with the centralized order of the modern city. What are the limits of these new systems in terms of local absorption capacity and settlement density, and what do these limits tell us about city form? Would their adoption precipitate a change in the overall order and scale of the city?

The reuse of waste features prominently in the proposed alternatives to the modern system, all of which create valuable end products from excrement. How will these end products, namely compost, be put to use? In the medieval system it was used as fertilizer; and indeed, various proponents of urban sustainability have suggested a closer connection between the city and agricultural production, often in the form of urban agriculture. Similarly, the focus on the "ecological footprint" of cities implicitly suggests that more of a city's needs be met internally (Girardet 2004). Proposals for urban agriculture have tended to suggest radically different settlement patterns than those of present-day cities (see, for example, Roseland 1998; Katz 1986; and Girardet 2004). Many "sustainable" models of city planning—transit-oriented development and core-satellite models—likewise suggest some degree of decentralization (Duany 2003; see also Register 1987). However, proponents of sustainable waste systems have not adequately addressed the fate of the waste; and sustainable city planning has not yet been connected to the tasks of waste management or food production. In order to answer larger questions about the form of the city, as well as questions regarding the feasibility and implications of containment and reuse at a large scale, future work in sustainable waste management must engage these issues: the reuse of waste, its relationship to agriculture, and limits of scale and density.

Leonardo's design for Romorantin addressed the challenges of his time—urbanization, sanitation, and hygiene—by combining the science of the day (miasmic theory) with inspiration from the past (Roman precedents). The result was a design that utilized moving water to eliminate waste from the city—a strategy that eventually changed the form of the city and ultimately made possible the hyper-dense metropolises of today. Now, sustainable design takes up the problems that the modern system has been unable to resolve. Using the science of ecology, it addresses those conditions that have changed markedly since the Renaissance: an exploding population, scarcity of fresh water, and new forms of industrial waste. The strategy of evacuation is necessarily being questioned, but the debate is as yet disconnected from the larger questions of the city, its supporting infrastructure, and its relationship to agriculture. It is important to note that Leonardo's design for his ideal city at Romorantin was inextricably linked to his notion of the ideal sewer.

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NOTES

1. This discussion borrows from Alain Corbin's *The Foul and the Fragrant* (1986). Corbin was exploring waste and odor in eighteenth- and nineteenth-century France, but this distinction is clearly applicable to the Renaissance-era discussions considered here.
2. Research is currently being conducted on using ecological machines to produce fish, marketable plants, and other valuable products. For example, see Wolovitz 2000.
3. It was not until the 1860s and 70s that the work of Louis Pasteur and Robert Koch finally validated germ theory (Sterner 2007, 4).

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