Waste and City Form: Reconsidering the Medieval Strategy

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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 *idea* 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 called into question—that made the 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 Romoratin 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.[2]

Sustainable waste management strategies share a proclivity for the reuse of human waste. Considered here are composting toilets, biodigesters, and bioremediation systems. Composting toilets contain waste and treat it locally, producing compost—a "rich mud" that can be used as fertilizer. Compost can be pasteurized with additional heat to eliminate pathogens.[3] Biodigestion systems function similarly, but 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. All treat wastewater biologically through a series of vegetative filters: plants to eat the waste and excrete clean water, and the plants themselves can be composted or used as food for livestock or aquaculture. These systems tend to be decentralized—at the scale of a building or neighborhood rather than an entire city—and are therefore located within human settlement, a location that allows easy use of the valuable end products of fertilizer, methane, clean water, and/or food. These systems therefore represent a return 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."[4] 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 may reveal important considerations regarding sustainable waste management systems and their implications for urban form.

THE MEDIEVAL STRATEGY: CONTAINMENT AND REUSE

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. Consequently, there was little distinction between types of waste: human excrement and garbage were treated similarly.[5] 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.[6] 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 roamed the city.[7] 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, containing an abundance of potassium and phosphorus.[8]

The use of waste as fertilizer was a vital component of medieval agriculture. 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.[9] It was not uncommon for gardens, orchards, fields and pastures to be located within city walls as well as in the immediate hinterlands.[10] As late as 1850 Paris generated enough produce on one-sixth of its land to supply the entire city.[11] Medieval residences typically had a vegetable garden or larger green space behind the house (Figure 1), a fact belied by the often dense street edge. [12]

Sanitation in this scheme is closely related to density.[13] While densities remained relatively low sanitation was not a problem. However, with the growth of European cities after 1300, the old strategies of waste management became unworkable. As Rebecca Williamson describes, "the byproducts of everyday life in an urban milieu could no longer be simply absorbed back into the land […]."[14] The buildup of waste created a sanitation crisis, but "sporadic attempts at legislating urban cleanliness in France and Italy during the twelfth and fourteenth centuries largely came to nothing."[15] 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.[16] Various pieces of legislation prohibiting dumping in streets or rivers were ignored.[17] The sanitary conditions in cities continued to deteriorate as urbanization progressed.

The issues of sanitation and waste management 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 fleas, the science of the time blamed foul or corrupt air. This theory, later termed *miasmic theory*, is described by Carlo Cipolla:

> *[…] the 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.*[18]

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.[19] 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 erroneous correlation between waste, odor, and disease proved a formative influence on modern waste management strategies. According to Cipolla, "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"[20]—that is, removing waste from human proximity by evacuating it from the city. Miasmic theory also created a fear of "bad air" that contributed to the transformation olfactory perception and ultimately led to what Ivan Illich calls "the utopia of the odorless city."[21]

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.[22] 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 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.[23] Indeed, his design for an ideal city at Romoratin 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 AND EVACUATION

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 discussion as early as the Renaissance. Leonardo's unbuilt city of Romoratin, designed in 1517 for François I, then King of France, provides an excellent case study. François I was particularly interested in hygiene, as evidenced by his later Hygiene Edict of 1539 mandating the removal of waste from the city.[24] Leonardo's design for a new palace quickly evolved into the design of an entire 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 Romoratin and its palace complex were never implemented; an epidemic in the area caused François to build in Chambord instead.[25] 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 (Figure 2). 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 […]."[26]

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. [27] Medieval monasteries and palaces often contained latrines that emptied into rivers.[28] 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.

Leonardo's proposal was also consistent with burgeoning Renaissance thought. Leon Battista Alberti, a contemporary of Leonardo, wrote his influential *Ten Books on Architecture* around 1450, in which he makes a distinction between two types of drains (sewers). One kind, the "subsidence pit," collects waste and allows it to be "absorbed by the bowels of the earth"[29]—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."[30] His emphasis on *air quality*—informed, to be sure, by miasmic theory—favors a method of waste management that eliminates the source of miasma from the city.

Eliminating putrid air, however, is incompatible with the reuse of waste. As Gibson and Farrar observe, "If sewage does not putrefy, it is not broken down into simpler compounds which plants can utilize, and its useless for agriculture."[31] 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.[32] The stench of waste is therefore inseparable from its fertility. Laporte notes the historic ambivalence toward waste: sometimes praised as the best fertilizer, at other times it is considered unsanitary and wholly unfit for use.[33] 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 Romoratin 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.*[34]

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. 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."[35] 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 tightly-knit 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.*[36]

This is a departure from typical royal residences, which were among the worst offenders in regards to sanitation, surrounded by cesspits and stagnant sewage.[37]

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.[38] 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. By the end of the nineteenth century, combined waste and storm water sewers were becoming the norm across Europe.[39] The advent of inorganic fertilizers dealt the final blow to the medieval strategy of containment and reuse.

Matthew Gandy 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 in the use of water in dwellings. Whereas in medieval cities little water was used for bathing—washing was predominantly a collective activity[40]—the standards of cleanliness and privacy underwent a dramatic shift during the eighteenth and nineteenth centuries.[41] Alain Corbin argues that standards of smell and odor are largely a social creation of this area.[42] 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.[43] 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.[44] The organic economy—the 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.

SUSTAINABILITY: 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. Supplies of fresh water are not replenished as fast as they are consumed, and water consumption is increasing. Already water scarcity is a major problem around the world. 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 rivers can assimilate naturally. In response, cities have deployed complex systems of sewage treatment, but the treatment is incomplete: toxins from cleaners, heavy metals, PCBs, and other pollutants frequently make it through the treatment facilities and are released into the environment, with increasingly problematic results.[45] The treatment process often utilizes hazardous compounds and creates toxic byproducts.[46] Moreover, the continued growth of cities has overwhelmed the capacity of many municipalities' treatment plants. Major North American cities such as 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.[47]

At the same time, the sustainability movement is rediscovering the value of waste. In *Cradle to Cradle* architect William McDonough and chemist Michael Braungart make the fundamental realization that "waste equals food."[48] Their proposal attempts 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 by humans.[49] This would mean a differentiated waste stream: the organic and the inorganic, would no longer share the same fate.

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 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.[50] Yet the problem of the medieval system was precisely this: containment and reuse was not feasible beyond a certain density. 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 therefore 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? Various proponents of urban sustainability have suggested a closer connection between the city and agricultural production, often in the form of urban agriculture.[51] Proposals for urban agriculture have tended to suggest radically different settlement patterns than those of present-day cities.[52] 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 Romoratin addressed the challenges of his time—urbanization, sanitation, and hygiene—by combining the science of the day (miasmic theory) with inspiration from to 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 fatally 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 Romoratin was inextricably linked to his notion of the ideal sewer.

ENDNOTES

1. The distinction between the strategies of containment and evacuation is borrowed from Alain Corbin's The Foul and the Fragrant (Cambridge, Mass.: Harvard University Press, 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. This paper is based on research conducted for a graduate seminar under Rebecca Williamson in spring of 2007 at the University of Cincinnati.

3. Advanced Composting Systems, LLC, "Phoenix Composting Toilet Public Facilities Application Guide," Advanced Composting Systems, LLC, http://www.compostingtoilet.com/Public/Ap_Guide/Ap_Guide.htm, 12.

4. Dominique Laporte, History of Shit, trans. Nadia Benabib and Rodolphe el-Khoury (1978; reprint, Cambridge, Mass.; London: MIT Press, 1993), 31.

5. Lewis Mumford, The Culture of Cities (New York: Harcourt, Brace and Co., 1938), 46.

6. Jeffrey L. Singman, Daily Life in Medieval Europe (Westport, Conn.; London: Greenwood Press, 1999), 188.

7. Mumford, 46; Singman, 188.

8. A. Gibson and W. V. Farrar, "Robert Angus Smith, F.R.S., and the 'Sanitary Science,'" Notes and Records of the Royal Society of London 28, (2) (1974), 248.

9. Mumford, 19; A. E. J. Morris, History of Urban Form: Before the Industrial Revolutions, 3rd ed. (New York: Wiley, 1994), 109.

10. Mumford, 43.

11. Ivan Illich, H20 and the Waters of Forgetfulness (Dallas, Texas: The Dallas Institute of Humanities and Culture, 1985), 67. Also see David Katz, "Metropolitan Food Systems and the Sustainable City," in Sustainable Communities: A New Design Synthesis for Cities, Suburbs, and Towns, ed. Sim Van der Ryn and Peter Calthorpe (San Francisco: Sierra Club Books, 1986), 153-4.

12. Singman, 179; Morris, 100.

13. Morris, 100. Morris contends that it was only in the late medieval period and early Renaissance that the cities became overcrowded to the point that sanitation became a problem.

14. Rebecca Williamson, "The Breath of Cities," in Aeolian Winds and the Spirit in Renaissance Architecture: Academia Eolia Revisited, ed. Barbara Kenda (London; New York: Routledge, 2006), 155.

15. Ibid.

16. Corbin, 91.

17. Williamson, 155.

18. Carlo M. Cipolla, Fighting the Plague in Seventeenth-Century Italy (Madison, Wis.: University of Wisconsin Press, 1981), 8.

19. Ibid.

20. Cipolla, 15.

21. Illich, 47-48.

22. Cipolla, 5.

23. Charles Nicholl, Leonardo da Vinci: Flights of the Mind (New York: Viking, 2004), 493. See also Leonardo da Vinci, Codex Atlanticus (Biblioteca Ambrosiana: Milan, 1517), 582r; 583r/217v-c, v-b; 209r/76v-b.

24. Laporte, 47.

25. Carlo Pedretti, Leonardo da Vinci: The Royal Palace at Romorantin (Cambridge, Mass.: Harvard University Press, 1972), 1.

26. Da Vinci, quoted in Pedretti, 99.

27. O. F. Robinson, Ancient Rome: City Planning and Administration (London; New York: Routledge, 1992), 117.

28. Richard C. Hoffmann, “Economic Development and Aquatic Ecosystems in Medieval Europe,” The American Historical Review 101 (3) (1996), 643-4.

29. Leon Battista Alberti, On the Art of Building in Ten Books, trans. Joseph Rykwert, Neil Leach, and Robert Tavernor (1450; reprint, Cambridge, Mass.: MIT Press, 1988), 113-114.

30. Ibid.

31. Gibson and Farrar, 249.

32. Matthew Gandy, “The Paris Sewers and the Rationalization of Urban Space,” Transactions of the Institute of British Geographers, New Series 24 (1) (1999), 30.

33. Laporte, 31-7.

34. Da Vinci, quoted in Pedretti, 98. See also Da Vinci, Codex Atlanticus, 217 verso-b and c.

35. Vitruvius, The Ten Books on Architecture, trans. Morris Hickey Morgan (reprint, New York: Dover Publications, Inc., 1960), 21.

36. Da Vinci, quoted in Pedretti, 80. See also Da Vinci, Codex Atlanticus, 76 v-b.

37. Laporte, 12; Corbin, 22.

38. Corbin, 117-19.

39. Gandy, 31.

40. Mumford, 37.

41. Gandy, 31.

42. Corbin.

43. Gandy, 32.

44. Gandy, 32-3.

45. Graeme Wynn, “Risk and Responsibility in a Waste-Full World,” forward to The Culture of Flushing: A Social and Legal History of Sewage, by Jamie Benidickson (Vancouver: UBC Press, 2007), xvii.

46. Mark Roseland, Toward Sustainable Communities: Resources for Citizens and Their Governments, rev. and updated ed. (Gabriola Island, BC; New Haven, Conn.: New Society Publishers, 1998), 59.

47. Elaine MacDonald, The Great Lakes Sewage Report Card. (Canada: Sierra Legal, 2006 http://www.sierralegal.org/reports/great.lakes.sewage.report.nov.2006b.pdf); Sierra Legal Defense Fund, The National Sewage Report Card (Number Three): Grading The Sewage Treatment of 22 Canadian Cities (Canada: Sierra Legal Defense Fund, 2004, http://www.sierralegal.org/reports/sewage_report_card_III.pdf).

48. William McDonough and Michael Braungart, Cradle to Cradle: Remaking the Way we Make Things (New York: North Point Press, 2002), 92.

49. McDonough and Braungart, 104.

50. Herbert Girardet, Cities People Planet: Liveable Cities for a Sustainable World (Chichester; Hoboken, NJ: Wiley-Academy, 2004).

51. Urban agriculture is defined in numerous ways, and can include everything from urban gardens to small farms on the periphery of cities.

52. For example, see Roseland (1998), Katz (1986), or Girardet (2004).