

## **Recycling in the Roman world — concepts, questions, materials, and organization**

J. Theodore Peña

Department of Classics/Graduate Group in Ancient History and Mediterranean Archaeology

University of California, Berkeley

### **Introduction**

Our planet is choking on refuse.<sup>1</sup> As I write this essay the news on the internet drives this point home with considerable force. Environmental scientists learn that the gyres – vast fields of floating plastic debris in the Atlantic, Pacific, and Indian Oceans that makes its way into the digestive tracts of many sea creatures – are far more extensive than previously has been appreciated.<sup>2</sup> China, overburdened with massive amounts of recycled materials that its industry cannot make use of, announces its intention to ban their import from abroad, touching off a crisis in the recycling industry on the west coast of the USA.<sup>3</sup> A ‘fatberg’ composed largely of congealed fat, discarded wet wipes, and disposable diapers that is 250 meters long and weighs the equivalent of eleven double-decker buses is discovered blocking one of London’s sewers.<sup>4</sup> To disaggregate and remove this thing will require sanitation workers an estimated three weeks. Choking — both literally and figuratively — at every imaginable scale.

---

<sup>1</sup> For the manifold facets of refuse in the contemporary world and an exhaustive compilation of references to research bearing on this see Liboiron (2010).

<sup>2</sup> Loomis (2017).

<sup>3</sup> Profita (2017).

<sup>4</sup> Taylor (2017).

The Mediterranean Sea and the lands that border on it currently face a particularly acute set of challenges in this regard.<sup>5</sup> For a variety of reasons — high population density and high levels of industrialization and urbanism, the enclosed nature of the Mediterranean basin, the regional climate and weather patterns, the large number of nations involved, the pronounced differentials in the level of economic development between nations — these countries, their inhabitants, and the natural environment all find themselves under siege from refuse. As Romanists, we are in a position to provide a certain amount of historical perspective on this problem. The Roman Empire represents the only time in history in which the Mediterranean has been politically unified, and the first and only time prior to the modern period in which it has had an integrated economic system.<sup>6</sup> The Roman world — with its vast population and comparatively high level of urbanism, its mass distribution of packaged foodstuffs, and its harnessing of sophisticated and novel technologies for the extraction of raw materials, the production of consumer goods, and the shaping of the built environment — surely generated what were unprecedented volumes and concentrations of refuse not matched in this part of the world until the later eighteenth or nineteenth century. Roman refuse and the ways in which the Romans generated and managed it are thus topics worthy of the attention of both scholars and the general public.

---

<sup>5</sup> These were illustrated in compelling fashion by an exhibit titled *Vies d'ordures: de l'économie des déchets* held at the Musée des Civilisations de l'Europe et de la Méditerranée (MUCEM) in Marseille 31 March–14 August 2017. For the catalog of this exhibit see Chevallier and Tastevin (2017).

<sup>6</sup> The nature and degree of this integration are points vigorously debated by students of the Roman economy.

Recycling, although no panacea, is a fundamental element of the equation in how society is today seeking to confront the challenges raised by the refuse problem.<sup>7</sup> The contributions to this volume and the conference in which they originated represent the first effort to take a comprehensive look at approaches to recycling in the Roman world, an undertaking that many will agree is long overdue. In this essay my aim is to furnish some general context for the several narrowly targeted contributions that follow by defining certain basic concepts and terms linked to recycling, articulating a set of general questions that we may pose regarding recycling in the Roman world, and then offering what must be regarded as preliminary efforts both to identify the range of materials that the Romans recycled and to characterize the various ways in which Roman recycling activities were organized and carried out. This program is rather expansive and the evidence on which it draws is both varied and complex, implicating a wide range of specializations. In this contribution I can thus do no more than offer a broad overview of these topics.

### **Basic concepts and terms<sup>8</sup>**

**Waste** can be defined as any substance that is a by-product of some human activity that is unwanted by those who wind up in contact with or in possession of it at the time that it is generated. In some cases waste is simply allowed to remain in the location in which it was generated. Often, however, the persons in contact with it transfer it to some other location so as

---

<sup>7</sup> For short histories of recycling see Downs and Medina (2000); Rathje and Murphy (2001: 188–213).

<sup>8</sup> For basic terms and concepts regarding waste see Zimring and Rathje (2012).

to be free of it. As a result of this action, which we can term **discard**, the substance in question becomes what we can term **refuse**.<sup>9</sup>

It generally transpires that objects or substances that are the desired product of some human activity - thus not waste - eventually come to be no longer wanted by the persons who possess them for a number of different reasons (wear, breakage, technological, functional, or stylistic obsolescence, functional substitution by some new or different item, negative associations) and these too are subjected to discard, also thereby becoming refuse. Not infrequently waste and/or items that are no longer wanted that are intended for discard are accumulated on a temporary basis and set aside somewhere in the vicinity where they are to be found pending this action in what is termed **provisional discard**. In some cases objects that are no longer wanted are simply abandoned, either because they are fixed (the case with buildings and other earth-fast structures), they are too large or too complicated to disassemble or move without excessive inconvenience, or the person or persons who possess them or use them shift their residence, place of work, locus or worship, or similar. Items that have been abandoned in this way can be termed **de facto refuse**.

Societies generally maintain some sort of more or less regularly structured pathway that serves for the transfer of refuse from the place where it was generated to the place where it is ultimately deposited. Both this pathway — which may be more or less complex in terms of the discrete steps and locations that it involves and more or less lengthy — and the materials that move along

---

<sup>9</sup> The representation of discard and related practices presented in this section and as used throughout this essay is essentially that articulated by the archaeologist Michael Schiffer. For the classic exposition of this see Schiffer (1987), and in particular pages 25–46.

it can be termed a **refuse stream** (or **waste stream**). The deposition of refuse in the locus that represents the end of the refuse stream can be termed **definitive discard**.

Undiscarded wastes (that is, waste material allowed to remain in the place where it was generated), objects, parts of objects, or substances marked for discard but that have yet to be discarded (often in provisional discard), items in de facto discard, or refuse at some point or other along the refuse stream are/is sometimes taken up and utilized as a raw material in a productive process of some kind. It is to this practice that the term **recycling** is properly applied.<sup>10</sup>

Materials that are susceptible to recycling can be referred to as **recyclables**, and those in the process of being recycled as **recyclate**. It is often necessary to convert recyclate to some form different from that in which it was obtained before it can be employed in a productive process. This operation, referred to as **reprocessing**, may involve heating the material with a view either to converting it from a solid to a liquid state (as is commonly done with plastic, glass, and most metals) or inducing a chemical reaction that promotes its disaggregation (as is done with limestone and marble destined for conversion to quick lime), its crushing or grinding (as is commonly done with ceramics), or its chopping, shredding or pulping (as is often done with rubber, textiles, and paper products).

Specific recycling applications can be characterized as involving **upcycling** — the transformation of the recyclate into a material or product regarded as being in some way of

---

<sup>10</sup> Liboiron (2012). Materials can also be obtained for recycling from buildings and other structures that are in still in use, and the theft of recyclables today represents a considerable problem in some parts of the world.

higher quality, as when plastic shopping bags are woven together to make a purse, or **downcycling** — the transformation of recyclate into a material or product regarded as being in some way of lower quality, as when rubber tires are shredded for use as insulation.

Some activities that involve the utilization of organic waste that are not technically speaking recycling, in that they do not entail its use as a raw material, may usefully be considered alongside recycling, as these, too represent elements of what is today broadly understood as a circular economy. These include the use of certain kinds of organic waste for the nutrients that they contain, as when food wastes are employed as food for domestic animals or when food wastes and human and/or animal excrement are utilized as fertilizer, and the use of some kinds of organic waste for the energy that they contain, as when manure, prunings from trees, pomace (olive pressings), and chaff are utilized as fuel.

Finally, it should be noted that it is sometimes difficult to distinguish between recycling and a suite of practices that can be subsumed under the term **reuse**. The concept of reuse is difficult to define in a way that is both comprehensive and uniformly applicable, although it is generally seen as including (though by no means limited to) the practice of employing objects recovered from provisional discard, de facto discard, and/or the refuse stream either for their original purpose or for some other application. The difficulty in distinguishing this practice from recycling arises in determining when a particular instance should or should not be regarded as constituting the use of an object as a raw material. This problem is for the most part limited to the realm of construction materials, with some researchers regarding the use of a previously used item such as a column, a beam, or a brick as constituting reuse, Although others would consider

this to be recycling.<sup>11</sup> Instances of this kind can be distinguished by being termed **reuse-recycling**.

This essay adopts an inclusive approach in the range of practices that it considers in the interest of providing a more rather than less comprehensive picture of recycling and related activities in the Roman world, treating not only activities that can be narrowly defined as recycling, but also those involving reuse-recycling and the use of materials recovered for either their nutrient or their energy value. For ease of discussion these practices will all be referred to simply as recycling unless the specific context requires otherwise.

### **Questions regarding recycling**

The following are some general questions that we may ask about recycling in the Roman world:

1. Which recyclables were and were not recycled? In what quantities? In what times and places?
2. Who participated in recycling operations and how was the work organized?
3. What were the motivations for recycling generally and in specific cases?

---

<sup>11</sup> Munro (2011: 76) solves this problem by limiting recycling to practices that involve the fundamental transformation of the nature of the material through reprocessing, including the melting of glass and metal and the calcination of marble and limestone.

4. What were the specific practices involved in recycling in particular times and places and with particular kinds of recyclables?
5. To what extent did recycling have an impact on the extraction and distribution of virgin raw materials?
6. To what extent did recycling affect the locus, organization, costs, and/or practices and techniques of production?
7. What effects, if any, did recycling have on the health, well-being, and quality of life of specific groups (including those responsible for recycling operations) and of the general population?
8. What role did municipal administration and the state more generally play in recycling?
9. To what extent were the ways in which construction, household activities, and manufacturing and distribution undertaken shaped by recycling?
10. How intensive, extensive, and thus thorough were recycling practices, and what impacts did these have on the volume and composition of refuse streams and the representation of different kinds of recyclables in refuse deposits?

11. How did recycling practices differ between the period prior to the late empire (before c. AD 250/275) and the period of the late empire, when demographic and economic contraction led to a decrease in the extraction of virgin raw materials and to an expansion of opportunities for the recovery of recyclables?
  
12. To what extent and in what ways did Roman concepts of and attitudes towards cleanliness, pollution, health, old and new, thrift, wealth, and consumption determine or condition recycling practices?

Although many of these questions probably lie to a significant degree beyond our purview, researchers would be advised to keep them in mind when conducting investigations into aspects of Roman recycling.

Before addressing the questions of which materials the Romans recycled and how they recycled these it will prove useful to review two topics: the nature of the evidence at our disposal for the study of Roman recycling, and Roman practices of refuse discard.

### **The evidence for recycling in the Roman world**

Any effort to investigate recycling in a past society is made problematic by the fact that, as already noted, many recycling applications involve reprocessing of the recyclate, and that this operation often results in its transformation into some new and different form that either renders it either impossible to recognize or recognizable only by means of expensive, time-consuming, narrowly available, and/or destructive forms of physico-chemical analysis. Further, many of the materials regularly subject to recycling are perishable organics, meaning that they are apt to be preserved in the archaeological record only in a limited number of exceptional cases, chiefly

desiccated and waterlogged environments. Compounding the problem is the fact that, cross-culturally, occupations concerned with the collection and management of refuse tend to be of low status, with their practitioners generally both poor and non-literate, and thus unlikely to produce texts that might furnish insights into their identities and/or occupational practices. At the same time, the low status individuals and groups generally renders them of little or no interest to the high status persons, who are in most cases far more apt to produce texts of some kind.

In the area of material/archaeological evidence we can recognize six more or less distinct categories:

1. Buildings and other structures that either have been stripped of one or more of their elements or more substantially disassembled certainly or possibly for the purpose of obtaining materials for recycling. In theory, we might also recover the remains of compound portable/moveable artifacts, such as furniture, wheeled vehicles, or water craft that have been stripped of one or more of their elements, although the likelihood of this is low, given the fact that the elements left behind would have consisted in the main of perishable organic materials unlikely to be preserved.

2. Facilities for the reprocessing of recyclate. These consist for the most part of activity areas equipped with fixtures such as furnaces or kilns that on the basis of their location and/or associated recyclate and/or reprocessing waste can be identified as installations that served for the melting of glass or metal or for the calcination of limestone and/or marble.<sup>12</sup> These can be situated at the point at which the recyclate was recovered, the locus at which it was utilized, or some other location.

---

<sup>12</sup> Munro (2011: 83–4).

3. Loci at which recyclate was utilized. These consist for the most part of craft production facilities at which the recovery of unused recyclate and/or waste from the use of recyclate indicates its employment there in some productive process. Also falling under this category are construction sites at which the recovery of unused recyclate and/or waste from the use of recyclate indicate the intended use or use of this material at that location, and sites of various kinds at which the recovery of the remains of expended fuel that can be identified as recyclate found in association with a hearth, oven, kiln, or similar installation points to the use of this material at that location.

4. Caches (or hoards) of recyclate. Deposits consisting of used (often conspicuously worn and/or broken) items apparently assembled as recyclate have been recovered at different kinds of sites, including not just craft production workshops and reprocessing facilities, but also sites not otherwise associated with recycling operations. These deposits, which can be classified as de facto refuse, presumably consist of material collected in anticipation of being recycled that were for some reason never employed for this purpose. Examples include deposits of construction materials of various kinds, statuary, items in one or more metals and/or metal alloys, items in glass, pots or, more often, sherds, and animal bone. The materials may simply be piled on the ground or they may be placed in a pit, basin, or vessel of some kind, and may display no particular arrangement or be arranged in some more or less structured way (for example pieces of glass sorted by colour). In a small number of cases a deposit of this kind consisting of architectural elements, glass, or metal items has been recovered at a shipwreck site in a context and/or in an abundance that indicates that the material was part of the ship's cargo.

---

5. Portable artifacts and structures/features manufactured all or in part from recyclate.

These include items composed in some part of elements that can be identified as certain or possible recyclate either with the naked eye or under magnification and items whose chemical composition indicates that their manufacture involved the use of recyclate. The former group includes items such as pottery containing ceramic temper, cartonnage mummy masks fabricated with sheets of used papyrus, patched items in textile or leather, concrete wall construction or paving containing ceramic, organic ash, pomace, or shell fill, pavings and similar features composed of potsherds, slag or organic ash, and buildings and other structures with used architectural elements embedded or otherwise included in their construction. The latter group consists of artifacts manufactured in various metals, metal alloys, and glass.

6. Refuse deposits. Refuse deposits of various kinds may contain waste products from the reprocessing and/or use of recyclates. They also typically contain recyclables of various kinds, and the quantitative or qualitative characterization of this material can shed light on practices of the recovery of these recyclables at various points in the refuse stream. Although coin hoards are not refuse deposits, we can for the sake of convenience recognize these as a distinct subcategory of this type of evidence, as their analysis can provide information regarding the recycling of coinage.

There is only a limited amount of textual evidence regarding recycling in the Roman world, and much of what we do possess is not particularly informative. The small number of passages in Latin and Greek literary texts that bear on recycling mostly do little more than allude in a general way to the use of specific types of recyclate (metals, ceramics, glass, excrement, urine) for some application that often either is known to us through the material evidence or could be inferred on

the basis of logical considerations, and provide little or no information regarding the organization of recycling practices. An exception is represented by a set of four passages from three different Latin authors that shed interesting light on the recycling of glass at Rome during the later first century AD, as will be discussed below.

Considerably more informative are several passages in Hebrew/Aramaic from the rabbinic literature. Most of these occur in the *Mishnah* in the tractate *Kelim* and in *Tosephta* in the tractate of the same name.<sup>13</sup> In both works this section is concerned with the issues of purity and impurity in Jewish law as these relate to utensils, with a considerable attention paid to the question of when items susceptible to uncleanness cease to be so on account of having been broken or otherwise transformed, as might occur in connection with their recycling. Although the preoccupation that lies behind these texts is a specifically Jewish one, the circumstances and practices that they consider are often of a broader nature and can thus shed light on recycling practices more generally. Dating passages in the *Mishnah* and *Tospehta* is to some extent problematic, as both works, though redacted in the early third century AD and probably reflecting for the most part practices during the second and earlier third centuries AD, also contain material that goes back to the period prior to the destruction of the Second Temple in AD 70.<sup>14</sup>

An additional category of textual evidence that should not be overlooked is the corpus of epigraphical texts that relate to occupations and occupational organizations. These report

---

<sup>13</sup> For these texts and their implications for our understanding of the reuse and recycling of various kinds of material culture see Schwartz (2005: 148–51).

<sup>14</sup> For issues of dating see Schwartz (2005: 149 n. 7); Ponting and Levene (2015: 7).

occupational titles and/or occupational organizations consisting of persons who held these titles that certainly were or might have been involved in recycling operations. Although helpful, this information is generally of uncertain significance due to the difficulty often encountered in determining the specific activities associated with a particular occupational title in the Roman world.

We can also draw on comparative evidence relating to recycling practices in other cultures in order to gain insights into various aspects of recycling in the Roman case that are not documented by either material or textual evidence. The applicability of information of this kind must be weighed carefully on a case-by-case basis.

### **Roman practices of refuse discard**

Although the specific methods employed for the discard of refuse across the Roman world were doubtless varied and complex, it is nonetheless possible to venture some general statements regarding what were probably common practices.<sup>15</sup> For our purposes it will be helpful to distinguish between discard practices in cities and towns (henceforth referred to as towns unless the specific context requires otherwise) and discard practices in rural areas.

In towns, a substantial amount of the refuse generated by residential groups and commercial/manufacturing establishments was discarded somewhere on the grounds of the

---

<sup>15</sup> For general considerations of Roman refuse discard practices see Remolá (2000); Peña (2007: 277–91); Carreras Monfort (2011). For the terminology employed in Latin and ancient Greek to refer to refuse see Cordier (2003).

residence or establishment.<sup>16</sup> This often involved discard in disused rooms and/or in unroofed spaces, such as courtyards and gardens, particularly in pits or other subterranean features. A substantial amount of household refuse was also discarded by being thrown into cesspits. These deposits may well have been intended as provisional discard, undertaken with the idea that the refuse that they contain eventually would be gathered up and discarded in a definitive manner somewhere off the premises. This was probably particularly true with refuse discarded in cesspits, as these were presumably emptied of their content from time to time and the material either taken to some location off the premises for definitive discard or recycled as fertilizer (see below). So far as discard off the premises is concerned, it is clear that some portion of the refuse generated by residential groups and commercial/manufacturing establishments was simply thrown or dumped into the spaces that bordered the premises — public thoroughfares, in particular. Some of this refuse, as well as much construction refuse, was also presumably carried off the premises and discarded in convenient places located elsewhere within the settlement, such as vacant lots, abandoned buildings, and unsupervised public spaces.

In many instances towns were flanked or even ringed by large refuse middens lying immediately beyond their fortifications walls or their contiguous built-up area, and it is evident that a very substantial portion of the refuse of many different kinds generated by the community wound up being discarded in a definitive fashion in these areas/onto these features. In settlements flanked by a water course we can posit that a substantial portion of the refuse generated by its inhabitants

---

<sup>16</sup> For refuse discard practices in Roman cities and towns see the various case studies regarding Gaul in Ballet, P, Cordier, P, and Dieudonné-Glad (2003) and regarding Hispania in Remolà and Pérez (2011).

was discarded into or along its banks.<sup>17</sup> Harbors would have represented another locale in which there would have tended to be appreciable accumulations of refuse, as cargo was inadvertently lost overboard during loading and unloading operations, damaged cargo was deliberately jettisoned into the water or abandoned at quayside, and storage facilities disposed of spoiled and damaged goods or otherwise unwanted materials.<sup>18</sup>

In rural areas the lower density of development would have meant that most refuse generated by residences, agricultural, and manufacturing establishments could have been discarded in a casual fashion in any conveniently located open space. Much household and agricultural refuse, which would have had a high organic component, was probably dumped onto the surface of and then spread over agricultural fields as fertilizer.

Any effort to envisage how recycling operations might have been organized and conducted in Roman towns is very substantially hampered by the almost complete absence of any information regarding regular arrangements that might have been in place for the collection and removal of refuse from the settlement. Panciera, Manacorda, and Robinson, all of whom considered the case of the city of Rome, concluded, in effect, that a settlement of Rome's immense size served as it was by a large and complex municipal administration must have been provided with an organized refuse collection service of some kind.<sup>19</sup> Carreras Monfort, who examined the

---

<sup>17</sup> For discard of refuse into or along the banks of watercourses that bounded Roman cities and towns see Gelichi (2000: 17–18); Manacorda (2000: 70); Remolà (2000: 111–12).

<sup>18</sup> For refuse disposal at harbors in the Roman world see Gianfrotta (2000).

<sup>19</sup> Panciera (2000); Manacorda (2000: 69–70); Robinson (1992: 123–4).

evidence for the Roman world, more generally, similarly concluded that municipalities must have offered some kind of refuse collection service.<sup>20</sup> Liebeschuetz, in contrast, who considered the question for both Greek and Roman towns, concluded that organized refuse collection was not a service normally offered by municipalities, and that residents were responsible for disposing of their refuse by themselves.<sup>21</sup>

The question of whether or not there were services for the regular collection and removal of waste in Roman towns is important with regard to our consideration of the organization of recycling operations. If there was not a service of this kind, various manufacturing/commercial establishments (such as pottery and metallurgical workshops, tanneries, butchers, and warehouses), builders, and other establishments (such as public baths) that tended to generate large amounts of waste would have needed to devote considerable effort to the disposal of this material. In cases in which the material in question constituted a recyclable, there would have been a strong impetus for these establishments to institute some sort of regular arrangement for the transfer of waste to some person or establishment who/that could make use of it. On the other hand, if there was a refuse collection service of some kind, this presumably would have entailed the temporary discard of large amounts of refuse at designated locations within the settlement that were accessible to the public (street fronts, intersections, plazas or other open spaces) for some shorter or longer period of time, exposing it to the scavenging of recyclables.

---

<sup>20</sup> Carreras Monfort (2011: 22).

<sup>21</sup> Liebeschuetz (2000: 54).

It will prove useful at this juncture to say something regarding the quantities of refuse that the Romans generated. We have no data regarding this question nor any way of effectively determining by direct measurement the amounts of refuse that were produced by individuals, households, communities, manufacturing/commercial establishments, or settlements in the Roman world, either in any specific instance or more generally. In the absence of information relevant to this question we can turn to comparative data, with the understanding that these can do no more than offer a very approximate idea of the scale of the phenomenon. Most useful for our purposes are the data regarding the amount of municipal solid waste (MSW) collected per person per year by country published on the *Waste Atlas* website.<sup>22</sup> MSW (termed ‘mixed municipal waste’ by the European Union) consists of general waste produced by residences and commercial establishments and does not include sewage or construction, industrial, or agricultural waste.<sup>23</sup> The figures reported range from a low of 109.8 kg per person per year for Ethiopia to a high of 777.0 kg per person per year for Canada. The data near the low end of the range probably constitute the most appropriate analogs for the Roman world. Taking the set of countries that fell wholly or partially within the Roman Empire as constituting perhaps the most

---

<sup>22</sup> D-Waste (n.d.). The *Waste atlas* website obtains data from environmental specialists through crowd-sourcing on a continuous basis and the specific year in which the data reported on the site were collected is not indicated.

<sup>23</sup> United States Environmental Protection Agency (n.d.). Waste from equivalent sources in the Roman world would have differed from modern MSW in that it probably would have contained a substantial component of organic ash from burned cooking and heating fuel and perhaps also human feces.

appropriate points of comparison, the four lowest values registered are those for Kosovo, Morocco, Tunisia, and Syria, at 192, 208.0, 210.8, and 216.1 kg per person per year, respectively. On this basis we can posit a range of *c.* 200–210 kg of MSW refuse per person per year as a plausible value for the Roman world, or the equivalent of *c.* 550–575 g per person per day.<sup>24</sup> This same website also presents data for the percentage of MSW that consists of organic material (for the most part food wastes) by country. This is negatively correlated with level of economic development, with countries with relatively undeveloped economies displaying substantially higher values than those with a developed economy. Although no data are provided for either Kosovo or Syria, Tunisia has a value of 68 percent and Morocco one of 65 percent. This suggest that for the Roman world the equivalent of MSW might have consisted of *c.* two-thirds organic material and one-third non-organic material, or roughly 370–385 g per person per day and 180–190 g per person per day, respectively. Chevallier and Tastevin compile data drawn from the *Waste atlas* website and from other sources to derive estimates for the constituents of the non-organic constituents of the MSW for Tunisia and Morocco, arriving at values of roughly one-third paper and cardboard, one-third plastic, and one-third glass, metal and other materials.<sup>25</sup> The main functional analogs for these in the Roman world probably would have been pottery,

---

<sup>24</sup> The figures for individuals and groups in the Roman world would have varied very considerably, of course, as a function of several factors, including socioeconomic status, region, urban/rural location, and time period.

<sup>25</sup> Chevallier and Tastevin (2017: unnumbered page in front work; unnumbered table labelled COMPOSITION DE 11 POUBELLES).

vessel glass, basketry, wooden containers and implements, metal containers and implements, and textiles.

Although these values may seem small, cumulatively they would have represented a significant amount of material. For example, for a medium-sized town with *c.* 10,000 inhabitants, such as Pompeii, this would come to *c.* 5,500–5,750 kg of MSW refuse per day, including *c.* 1,800–1,900 kg of non-organic material. Over the course of a year this would add up to *c.* 650,000–700,000 kg of non-organic MSW refuse.<sup>26</sup> A significant portion of this material would have consisted of recyclables of various kinds that were susceptible to recovery by those willing to make the necessary investments of time and effort.

### **What did the Romans recycle?**

The set of materials that any community chooses to recycle is determined by a complex, community-specific, and often shifting array of circumstances, including the size of the community, the general nature and specific configuration of the refuse stream, and the stock of abandoned buildings; the demand for various kinds of recyclate; the availability of persons willing to undertake work of this kind; the cost and availability of virgin raw materials and recyclate of non-local origin; the disposition of local authorities to allow, regulate, and/or

---

<sup>26</sup> A minimal estimate determined by taking the lowest per capita figure published on the *Waste atlas* website (109.8 kg) and multiplying this by one-ninth to reflect the portion of MSW represented by materials available in the Roman world comes to a still quite substantial *c.* 120,000 kg of non-organic MSW refuse per year.

facilitate recycling activities; and the cluster of cultural attitudes indicated in the last of the questions included in our list.<sup>27</sup>

The materials that the Romans recycled must by definition have been a subset of the various kinds of refuse that they generated, and it will prove useful to formulate a list of these so that we can gain a clear idea of the range of materials available to the Romans for recycling. In the contemporary field of waste management, waste (and, following from this, refuse) is often divided into three general categories: construction waste, household waste, and industrial/commercial waste.<sup>28</sup> This scheme can be applied to the Roman case,<sup>29</sup> and it is here employed as the basis for structuring our list, with two modifications, namely the rechristening of the industrial/commercial refuse category as manufacturing/commercial refuse, and separating out from this as a distinct category the refuse generated by agricultural activities.<sup>30</sup>

---

<sup>27</sup> For the last of these factors see Lukas (2012). For a set of recently published essays regarding attitudes towards refuse see Spelman (2016).

<sup>28</sup> In both the contemporary developed and developing worlds construction refuse is generally the quantitatively dominant category.

<sup>29</sup> For the application of an essentially identical tripartite scheme to the analysis of Roman refuse see Remolá (2000: 109).

<sup>30</sup> This scheme might be elaborated in various ways, by, for example, adding categories such as military refuse, the refuse generated by municipal government and public services, and the refuse generated by religious activities.

In the category of construction refuse, the refuse materials that the Romans generated (to some appreciable extent de facto refuse in the form of materials incorporated in abandoned buildings) would have consisted of the following:

masonry blocks or fragments thereof;

concrete facing elements such as bricks and *cubilia*;

concrete and other kinds of rubble;

marble revetment plaques and similar;

sculpted stone architectural and decorative elements and fixtures, such as columns, architraves, basins, and statuary;

paving stones in basalt and other kinds of stone;

mosaic tesserae in stone, glass, and ceramic;

roof tiles, paving tiles, and other ceramic architectural elements, such as decorative plaques, downpipes, and box flue tiles;

iron or copper alloy clamps, pins, nails and fittings, such as window grates, spigots, and lock plates;

lead pipes and other plumbing elements and lead sealant;

fragments of plaster, mortar, *cocciopesto* and similar;

wooden beams, planks, and fixtures, such as doors and shutters;

bone door pivots;

textile fittings, such as awnings and curtains;

glass window panes.

For the category of household refuse we can list the following:

used craft goods manufactured in a wide variety of materials, including various kinds of stone, glass, ceramic, and faience; various metals, including lead, tin, iron, silver, and gold, and metal alloys, including bronze, brass, gunmetal, and pewter; hard animal parts, including bone, tooth, horn, antler, ivory, carapace, and shell; soft animal parts, including leather, parchment, and sinew; sponge; wood; textile — chiefly wool and linen, though also limited amounts of silk; felt; and various kinds of plant fiber, including papyrus.

used craft goods manufactured in combinations of two or more of these materials, such as cutlery, weapons, furniture, musical instruments, vehicles, and some clothing and items of personal adornment;

food wastes, including biodegradable animal and plant remains, along with more durable (also termed inert) materials, including bone, tooth/tusk, horn, antler, and shell;

the carcasses of animals probably present in and around residences, such as dogs, cats, donkeys, mules, and horses;

organic ash generated by cooking and heating;

straw from the stabling of animals;

human excrement and urine;

animal excrement (manure).

For the category of manufacturing/commercial refuse we can list the following:

unused raw materials (including animal bone and soft animal parts from butchers shops and similar establishments);

tools for manufacturing and exchange operations in various materials;

waste products left over from the processing of raw materials, such as slag;

waste products generated by various reductive manufacturing processes, such as bone and leather offcuts, stone chips, and metal and wood offcuts and shavings;

finished and uncompleted craft goods marred by manufacturing defects that rendered them unusable, such as waster pottery;

finished craft goods that were damaged during distribution or never transferred to an end consumer;

the remains of manufacturing tools, facilities and fixtures, such as pottery kilns and glass and metallurgical furnaces;

organic ash produced by the combustion of fuel as required by several manufacturing processes;

the remains of vehicles and other equipment associated with distribution.

Finally, for the category of agricultural refuse we can list the following:

tools, facilities, and fixtures in various materials;

organic by-products, such as the prunings of fruit trees and vines, pomace, grape pressings, the straw and chaff left behind after the processing of grain;

straw from the stabling of farm animals.

manure produced by farm animals;

For which of these refuse materials do we possess evidence that they were recycled? The subsections that follow consider each of these in turn.

### *Construction materials*

There is a substantial amount of archaeological evidence and a modest amount of textual evidence indicating that several different kinds of construction materials were regularly recycled.<sup>31</sup> These included wall facing and paving elements of different kinds, sculpted stone architectural elements, various kinds of metal clamps, fittings, and sealing elements, window glass, and roof tiles.<sup>32</sup> Wooden elements such as doors and beams were also presumably salvaged and recycled, although the evidence for this is lacking due to the rarity with which wooden architectural elements are preserved.

These materials would have been employed for the most part for the repair/remodeling of existing buildings or for the construction of new ones. Window glass and metal elements would have been reprocessed by being melted down in a furnace, and some limestone/marble elements

---

<sup>31</sup> For general overviews see Munro (2011); Barker (2012). See also B. Munro's, S. Barker's, and R. Fleming's contributions to this volume.

<sup>32</sup> For the recovery and recycling of metal elements see in particular Bernard (2008).

by being calcined in a lime kiln. Some stone, ceramic, and presumably also wooden elements would have been reworked by being recut or otherwise modified. These reprocessing operations may have been carried out at the structure from which the materials were recovered, at a structure or construction site at which they were to be utilized, or at some other location.

The archaeological evidence for this practice consists of structures that have been stripped of one or more of their elements apparently for recycling or structures that have been partially dismantled apparently for this purpose, the remains of reprocessing facilities, caches of used construction materials apparently assembled for reuse, and structures that incorporate what appear to be previously used construction materials. A small number of legal texts consider demolition and the recycling of materials recovered in the course of this work.<sup>33</sup>

One important issue regarding the recycling of construction materials is the extent to which activities of this kind were limited to/characteristic of the Late Empire, when the stock of abandoned buildings susceptible to stripping or dismantling in both towns and rural areas would have been appreciably greater than previously would have been the case. Although some expressions of this activity, such as the calcination of marble and limestone construction elements for the production of quick lime for use in mortar appear to have been largely limited to the late imperial period,<sup>34</sup> the demolition of buildings was a regular practice in Roman towns during earlier times, along with the recycling of a wide range of construction materials.<sup>35</sup>

---

<sup>33</sup> Marano (2016); Barker and Marano (2017).

<sup>34</sup> Munro (2016: 48–57).

<sup>35</sup> Barker (2012); Marano (2015); Barker and Marano (2016).

### *Glass craft goods*

There is a substantial amount of archaeological evidence and limited amount of textual evidence that indicate that glass vessels and other glass items were regularly recycled. This involved the collection of old or broken items and then reprocessing this material by first sorting by color and then melting in a furnace. The resulting molten glass was then employed for the manufacture of new items.

Recycling was of particular importance in the glass industry, as raw glass was produced at a restricted number of primary production facilities located almost exclusively in Syro-Palestine and, to a lesser extent, Egypt.<sup>36</sup> The raw glass manufactured at these facilities was exported to other parts of the Roman world, where secondary production facilities re-melted it and fashioned it into vessels and other items.<sup>37</sup> The availability of raw glass was thus to some extent limited and its cost presumably high. In contrast, glass vessels and other glass items were distributed across the Roman world, meaning that used glass could be collected for recycling in virtually any location. Recycled glass was thus probably an important raw material for many secondary workshops, and in some cases may have represented the principal or even sole raw material available to a workshop.

Caches of broken glass apparently assembled for recycling (termed cullet) have been recovered at several sites in different parts of the Roman world, including both secondary workshop sites

---

<sup>36</sup> Degryse *et al.* (2014).

<sup>37</sup> Nenna (2007: 130–136).

and non-workshop sites located in towns, rural areas, and military bases.<sup>38</sup> The Grado shipwreck, at the head of the Adriatic and dating to the middle of the second century AD, was carrying among its cargo a cask of cullet.<sup>39</sup> Various programs of research involving stable isotope analysis and, to a lesser extent, trace element analysis of items manufactured in glass have demonstrated that these were produced from glass originating at multiple sources, apparently due to the fact that the raw material employed included recycled glass.<sup>40</sup> Finally, as discussed below, four passages from three different Latin authors of the late first century AD furnish interesting information regarding the arrangements then in place for the collection of glass for recycling at Rome.

#### *Pottery and other ceramic craft goods*

A substantial amount of archaeological evidence and a limited amount of textual evidence indicate that pottery and other ceramic items (including architectural ceramics) were regularly recycled for a variety of applications, for the most part architectural.<sup>41</sup> For many of these applications the material was reprocessed by either being crushed or ground. In many cases crushing probably involved simply placing the material on a hard surface and then pounding it

---

<sup>38</sup> Keller (2005: 65–7); Nenna (2007: 131).

<sup>39</sup> Toniolo (2008).

<sup>40</sup> See P. Degryse's contribution to this volume. For overviews of these methods see Degryse (2012: 377–8); Brems, Ganio, and Degryse (2014); Brems and Degryse (2014).

<sup>41</sup> For a general overview of the recycling of pottery in the Roman world see Peña (2006: 250–71).

with a hard, heavy object, such as a log or a stone. Grinding, on the other hand, probably entailed first crushing the material and then reducing it further in a stone mortar or quern, perhaps in some cases followed by sieving.<sup>42</sup>

Archaeological evidence indicates that sherds were sometimes employed as facing, fill, or bedding elements in various kinds of construction. Crushed or ground ceramic was regularly utilized in large amounts as a fill/pozzolana in structural mortar, in mortar employed for waterproof linings, and in wall plaster.<sup>43</sup> Ground ceramic was also sometimes employed as temper in pottery. These applications all represent instances of downcycling.

Various texts — for the most part technical treatises, such as Vitruvius' *De architectura* and Faventinus' *De diversis fabricis architectonicae* — refer to the use of sherds, crushed, or ground pottery for some of these architectural applications without shedding much light on these practices.

---

<sup>42</sup> A quern containing crushed ceramic material was found at the villa at Terzigno – Boccia al Mauro, near Pompeii. See Cicirelli (1996: 168).

<sup>43</sup> For these applications see Siddall (2011); Lancaster (2015: 23 fig. 9, 25, 27). For the chemistry of ceramic material as a pozzolana see Hobbs and Siddall (2011: 52–4).

Siddall, who carried out analyses of the use of ceramic recyclate as an additive in Roman-period mortars at Corinth, calculated that the production of one cubic meter of *opus signinum* would have required between *c.* 750 and 1,125 kg of crushed ceramic material.<sup>44</sup>

### *Metal craft goods*

There is a substantial amount of both archaeological and textual evidence indicating that items manufactured in several different metals and metal alloys, including silver, copper alloy, pewter, iron, and lead were regularly recycled. This is hardly surprising, given the demand for metal objects, the limited number and often the remote location of the sources of most metals, and the high prices they commanded on the market.

The archaeological evidence for the recycling of metals consists of caches of worn and broken metal items apparently assembled for the purpose of recycling that have been recovered at a wide variety of sites, including reprocessing facilities and metallurgical workshops. The Caesarea shipwreck, dating to *c.* AD 310, was carrying a cargo consisting of a wide array of copper alloy and lead recyclate.<sup>45</sup> Elsewhere, a group of *c.* 400 fragments of copper alloy sculpture recovered on the sea floor off Brindisi is believed to represent a cargo of scrap destined for recycling that was either lost at sea or deliberately jettisoned, perhaps as early as the third century AD, although

---

<sup>44</sup> Siddall (2011: 166). See also Peña (2007: 266–7) for a similar calculation regarding the amount of crushed ceramic that would have been required to produce cement pavements at Pompeii.

<sup>45</sup> See J. Sharvit's contribution to this volume.

possibly during post-Roman times.<sup>46</sup> Chemical analysis of artifacts in various metals and metal alloys has also demonstrated that the practice of recycling metal objects was widespread.<sup>47</sup>

In the area of literary evidence, a passage in Martial's *Epigrammata* (10.61-64) (written AD 95–98) describes the melting down of a gigantic statue (presumably in copper alloy) for the manufacture of a variety of different kinds of vessels. Elsewhere, a passage in the *Mishnah* (Kelim 11.4) considers the melting down of iron objects and mixing the resulting material with molten iron derived from one or more other sources, presumably for the purpose of fashioning objects of some kind. Another passage from this same tractate (Kelim 11.3) considers the manufacture of unspecified metal objects from various kinds of scrap and manufacturing waste.<sup>48</sup> The different kinds of scrap mentioned in this passage include the rims, bases, and handles of vessels (all presumably in copper alloy), the tire from a wheel (presumably in iron), nails (presumably in iron and/or copper alloy), and metal plate and metal sheeting (perhaps in copper alloy and/or lead). A passage in the *Talmud Bavli* (Avoda Zara 53a) refers to the purchase of scrap metal,<sup>49</sup> while a passage in *Tosefta* (Kelim Bava Metsia 1.3) refers to the manufacture of items from scrap metal of both local and imported origin.<sup>50</sup>

---

<sup>46</sup> Marinazzo (2010). For copper alloy sculpture as scrap see Croxford (2016).

<sup>47</sup> See P. Bray and M. Pollard's contribution to this volume. For an overview of these techniques see Pollard and Bray (2014).

<sup>48</sup> For this passage see Ponting and Levene (2015: 8–9).

<sup>49</sup> For this passage see Ponting and Levene (2015: 10–11).

<sup>50</sup> For this passage see Ponting and Levene (2015: 11, 15).

Coins represent a special class of metal object. Here, compositional research and the analysis of hoards have demonstrated that the state regularly withdrew from circulation larger or smaller segments of the coinage supply so that this could be melted down, with the purity of the metal often modified, and this then employed for the minting of new coin.<sup>51</sup> This was to some extent done gradually and on an ongoing basis, although the evidence makes clear that there were also numerous episodes in which a more proactive effort was made to withdraw specific issues or types of coins for recycling over the short term, either for political purposes or as part of an effort to effect monetary reform.<sup>52</sup> Evidence shows that heavily worn and/or demonetized coins were sometimes treated as scrap or discarded.

#### *Leather craft goods*

Finished leather items of various kinds recovered from Roman sites sometimes show patches that presumably were made either with material obtained from used leather items and/or offcuts from the workshops of leatherworkers.

#### *Textile craft goods*

Clothing and other textile items of various kinds recovered from Roman sites often exhibit patches, additions, and other kinds of repairs that involved the use of material apparently

---

<sup>51</sup> See M. Ponting's contribution to this volume.

<sup>52</sup> Harl (1996: 7–8); Butcher and Ponting (2014: 35–38). For the numerous specific instances of this practice see Harl (1996: 8, 14, 76, 84, 91, 92–34, 95, 99, 103, 104, 105, 114, 116, 119, 120, 123, 129–33, 139, 140, 44, 146, 149–50, 159–60, 162–5, 169, 172, 192, 209, 228–9, 295, 313).

obtained from used cloth/garments.<sup>53</sup> Bits of used textile were also regularly utilized as padding or stuffing, and for myriad other purposes, such as the stoppering of amphoras.<sup>54</sup> There is no evidence that the Romans adopted the practice of pulling apart woolen textiles and employing the resulting fibers to manufacture low quality cloth akin to the mungo or shoddy of the nineteenth and early twentieth centuries.<sup>55</sup> A passage in the *Mishnah* (Kelim 27.11) envisions the recovery of pieces of used textile of varying sizes from both dung heaps and refuse deposits located inside residences.

### *Papyrus*

Papyrus sheets bearing texts were commonly recycled for a variety purposes, including the fabrication of cartonnage mummy masks.<sup>56</sup>

### *Furniture*

A small number of passages in the rabbinic literature envision the recycling of elements of beds for a variety of purposes.<sup>57</sup>

### *Water craft*

---

<sup>53</sup> See J. Wild's contribution to this volume.

<sup>54</sup> Thomas (2011: 19, 20).

<sup>55</sup> J. Wild personal communication.

<sup>56</sup> See E. Salmenkivi's contribution to this volume.

<sup>57</sup> Schwartz (2005: 173–6).

It seems probable that watercraft of different kinds that were no longer serviceable were stripped of various elements or were entirely dismantled to recover materials for recycling.<sup>58</sup> Excavations at the Egyptian Red Sea ports of Quseir al-Qaddim (Myos Hormos) and Berenike have recovered a few instances of planks apparently removed from ships that were recycled in the construction of buildings and tombs, and used lead sheathing (for covering the exterior of a ship's hull below the water line) and the copper alloy tacks for attaching this that were apparently destined for recycling.<sup>59</sup>

#### *Wheeled vehicles*

It seems probable that wheeled vehicles that had reached the end of their useful life were stripped of components or dismantled entirely to recover materials for recycling. As noted above, a passage in the *Mishnah* (Kelim 11.4) include a metal tire (presumably in iron) among a list of items that it envisions being melted down for recycling.<sup>60</sup>

---

<sup>58</sup> Two of the ships recovered from the floor of the harbor at the Naples – Piazza Municipio site (Napoli A and Napoli C) have been interpreted by the excavators as hulks that were probably deliberately sunk. Although the preserved portions of these vessels appear to be missing some of their elements, it is by no means clear that they were stripped of recyclables before they sank. For these two ships see Boetto, Carsana, and Giampaolo (2009: 464–8); Boetto, Carsana, and Giampaolo (2010: 118).

<sup>59</sup> For Quseir al-Qaddim see Whitewright (2011: 177); Blue, Whitewright, and Thomas (2011: 179–84, 186–8). For Berenike see Sidebotham (2011: 213).

<sup>60</sup> For this passage see Ponting and Levene (2015: 8–9).

*Animal bone*

The various items that the Romans regularly manufactured from bone (hair/dress pins, bracelets, amulets, combs, needles, spatulas, spoons, tokens/gaming pieces, dice, dolls, knife handles, pyxides and their lids, furniture appliques and inlays, box hinges, door pivots) were presumably produced from recycled animal bone.<sup>61</sup> As discussed below, much of this material was likely fresh bone obtained from butchers, and may have required degreasing before it could be utilized. This application represents an instance of upcycling.

In some cases deposits of discarded animal bone consist of bones that appear to have been subjected to a rendering process that involved boiling the bone in water.<sup>62</sup> This was presumably undertaken to extract collagen, which would have been utilized for the manufacture of glue, and fat, which might have been employed for a wide variety of purposes. In some cases it appears that following the completion of the process the boiled bone waste was then used as fill for roadbeds and similar applications.<sup>63</sup>

---

<sup>61</sup> For general discussions of the use of bone as a raw material in the manufacture of these items see Choyke (2012a); (2012b); Vecsey (2012). For the analysis of several discard deposits of bone from Aquae Sextae (Aix-en-Provence) that elucidate the supply and use of bone for this industry see Nin and Leguilloux (2003: 152–60).

<sup>62</sup> Rodet-Belarbi (2003: 203–5).

<sup>63</sup> Rodet-Belarbi (2003: 205).

### *Murex shell*

Structures at three coastal sites in North Africa – Sabratha and Lepcis Magna in Tripolitania and Meninx, on the island of Gjerba, in Tunisia — demonstrate that crushed murex shell was sometimes employed as fill in mortar.<sup>64</sup> This material probably originated as waste at facilities for the manufacture of purple dye, for which murex shell was the principal raw material. This practice was probably limited to the environs of facilities of this kind.<sup>65</sup>

### *Organic ash*

Structures at numerous sites demonstrate that organic ash was regularly employed as a fill/pozzolana in mortar.<sup>66</sup> These sites are concentrated in the Levant, North Africa, Sardinia, and southern Spain. Lancaster has observed that these are areas of Punic influence, and suggests that this practice may have derived from Punic architectural tradition.<sup>67</sup> It seems probable that organic ash was also recycled as paving for courtyards, paths and streets, and perhaps also as fill for brick and mud brick.<sup>68</sup>

---

<sup>64</sup> Marzano (2013: 99, 152).

<sup>65</sup> For the distribution of known facilities for the production of purple dye in the Roman world see Pérez-González (2017: 160 fig. 2).

<sup>66</sup> Lancaster (2015: 23 fig. 9, 25–7).

<sup>67</sup> Lancaster (2015: 29).

<sup>68</sup> I know of no evidence for the use of organic ash for the manufacture of architectural ceramics or as a paving material. For the construction of houses at Rome during tenth and the early eleventh century AD in a mixture of clay and ash see the Ceci (2013: 129).

### *Slag*

Iron slag was probably recycled on a regular basis for a variety of construction applications. For example, iron slag was widely utilized as road metaling in the Weald iron-production district in the south-east of England. One section of road excavated at Holtye has slag paving for a length of *c.* 250 meters that reaches a thickness of *c.* 30 at the center of the roadway and thins to *c.* 7.5 cm at its edges.<sup>69</sup>

### *Excrement*

Textual evidence indicates that both human excrement and manure were employed as fertilizer, and that manure was also utilized as fuel.<sup>70</sup>

### *Urine*

Textual evidence indicates that both human and animal urine were employed as fertilizer for fruit trees and vines, for various veterinary purposes, and as an industrial reagent for the tanning of hides and the fulling and dyeing of textiles.<sup>71</sup>

### *Pomace*

The recovery of carbonized olive stones at several sites indicates that pomace was widely utilized as both a domestic and an industrial fuel beginning in the first century AD.<sup>72</sup> This

---

<sup>69</sup> Margary (1965: 153).

<sup>70</sup> Flohr and Wilson (2011: 147).

<sup>71</sup> Flohr and Wilson (2011: 149–51).

evidence indicates that it was employed both at rural sites and in towns, and was utilized for cooking, for the firing of pottery, and for the calcination of limestone.

### *General refuse*

General refuse was widely used in the Roman world as landfill in connection with a variety of operations - the infilling of excavations and abandoned structures, the raising of ground level for new construction, the creation of terraces, and so forth.<sup>73</sup> Whether we should regard this practice as constituting recycling is open to question, given the fact that the specific nature of the materials in question was of little or no consequence to their suitability for this application.<sup>74</sup>

### **How did the Romans recycle?**

We may now turn to the question of how recycling operations in the Roman world were organized and who participated in them.<sup>75</sup> This section employs an organization similar to that used in the preceding section — with a subsection devoted to each category of recyclate considered — and, to the extent possible, follows the same order as that employed in the

---

<sup>72</sup> Rowan (2015).

<sup>73</sup> For the analysis of deposits of mixed refuse at Pompeii with a view to elucidating the management of urban refuse see Dicus (2014).

<sup>74</sup> For the use of mixed refuse as fill in concrete in the construction of an apartment building on the Caelian in Rome during the second or early third century AD see Pavolini (1993: 332).

<sup>75</sup> This section does not consider activities that involved the salvage of materials in the aftermath of catastrophic events, such as fires, earthquakes, volcanic eruptions, and shipwreck.

preceding section. It departs from this, however, in that there is no information regarding three of the categories of recyclate recognized in the preceding section (papyrus, furniture, wheeled vehicles), and it is convenient to subsume another four of these (pottery and ceramic craft goods, murex shell, organic ash, and slag) under the category of construction materials. Further, this section concludes with two subsections dedicated to each of two generalized categories of recycling workers that we can conjecture might have been responsible for a substantial amount of recycling activity, namely town-based waste pickers and rural peddlers/recyclate collectors.

### *Construction materials*

The recovery of construction materials for recycling would have involved operations ranging from the more or less casual stripping of one or more of the relatively exposed elements of a structure, such as wooden fittings or roof tiles, to the extensive dismantling or complete demolition of a structure and the recovery of a wider range of materials. These operations would have had requirements unlike and far more demanding than those for any other kind of recycling practice. Although this work might have been accomplished to some extent by individuals or small teams of people operating on a casual basis, the scale and complexity of the task, the experience, knowledge, and specialized equipment required, and the physical risk involved, not to mention the challenge posed by the need to dispose of the substantial amounts of recyclate of many different kinds, would have greatly advantaged the work of professional teams of specialists.<sup>76</sup>

---

<sup>76</sup> Munro (2011); Barker (2012). See also B. Munro's and S. Barker's contributions to this volume.

There is textual evidence that professional demolition workers operated at Rome during the later first century AD in the form of an inscribed dedication found there (*CIL* 6.940) dating to the period AD 79–81 that was set up by the *curator* of a *collegium subrutorum*.<sup>77</sup> The root of this occupational title is the verb *subruere* (to dig out, break down, demolish),<sup>78</sup> which suggests that this occupational organization consisted of workers who were involved in the demolition of buildings, presumably including the recovery of recyclables. No such *collegium* is attested anywhere else in the Roman world, and the existence of an organization of this kind may have been unique to Rome of this period, a consequence of the immense amount of demolition work that must have been undertaken there in the years following the Fire of AD 64.

We can posit that much of the recyclate recovered was acquired by suppliers of construction material, some perhaps specialized in second-hand materials. We have evidence for the sale of second-hand construction materials in the form of a painted sign on an exterior wall in *Insula* 3.7 at Pompeii (*CIL* 4.7124) of probable late Republican date that advertises the sale of used roof tiles.<sup>79</sup>

Construction firms that wished to employ used architectural elements such as roof tiles and columns could have acquired these from such an establishment. For other forms of recyclate they probably would have been required to turn elsewhere. Specifically, in many cases builders would have had need of large amounts of material to use as fill in concrete and for similar applications,

---

<sup>77</sup> For this text see Barker (2011: XXX).

<sup>78</sup> Lewis and Short (1956: s.v. subruo).

<sup>79</sup> For this text see Fant, Russel, and Barker (2014: 202).

such as pottery and other ceramic, murex shell, organic ash, and slag. The fact that some of these materials would have been generated in substantial quantities and on a regular basis as waste at various kinds of establishments (organic ash at bath complexes and bakeries; murex shell and organic ash at dye production facilities; slag and organic ash at metallurgical workshops; pottery and organic ash at pottery workshops; pottery at warehouses), and given the likelihood that many of these establishments would have been eager to dispose of this material, it seems probable that construction firms would have made arrangements directly with one or more such establishments for the transfer of this in a direct supply arrangement, and conversely, that such establishments would have sought to establish arrangements of this kind with as many construction firms as required to effect the disposal of this material. This would have been particularly the case for establishments located in towns, where the space available for the retention of waste and for its discard would have been relatively restricted.

An arrangement of this kind might not have proven adequate for the supply of ceramic material, which often would have been required in very large quantities. Given that much of the waste pottery generated by pottery workshops would have been overfired and thus both difficult to crush and less effective as a pozzolana, and that the intact or largely intact amphorae that would have been the main kind of ceramic recyclable generated by warehouses also would have been to some extent onerous to crush, it may be that much of the ceramic employed in connection with construction was scavenged from refuse deposits. Professional waste pickers — to the extent that they existed (see below) — probably would have found the scavenging of sherds to be an unrewarding undertaking, given their great weight and presumably low value relative to many other kinds of recycle. We may thus speculate that for the supply of ceramic material construction firms struck up an ad hoc arrangement with individuals (conceivably un- and/or

under-employed adults and children of both sexes from the neighborhood) who collected sherds from nearby refuse deposits, a simple task requiring little in the way of knowledge, skill, or discernment.<sup>80</sup> These same individuals also might have assisted with the tedious, low-skill jobs of crushing and grinding these. Alternatively, construction firms might have assigned the task of collecting and crushing/grinding pottery to the more unskilled members of the crew or to neophytes.

### *Glass craft goods*

Glass represents the category of recycle for which we possess the greatest amount of information regarding the arrangements employed for its recycling.

As already noted, a unique constellation of four passages by three different Latin authors from the late first century AD refer to the recycling of glass. These include two passages in Martial's *Epigrammata* (1.4.3-5; 10.3.3-4), and one each in Juvenal's *Saturae* (5.46-48) and Statius' *Silvae* (1.6.73-74). All four passages make brief allusion to the fact that at Rome at that time fragments of broken glass vessels were collected from individuals — presumably for recycling — who were compensated by being given pieces of sulfur and/or sulfur coated splinters of wood that

---

<sup>80</sup> Some refuse deposits were probably known to be particularly rich in potsherds. For a sixth-century AD letter from Oxyrhynchus in which a lot (presumably somewhere in the town of Oxyrhynchus) is characterized as undesirable due to the fact that it is ὀστρακώδης ('sherdy') see *P.Oxy.* 941.

served as fire-starters.<sup>81</sup> One of the two passages by Martial (1.4.3-5) refers to this activity as being carried out by a *Transtiberinus ambulator* (transtiberine peddler/itinerant) (that is, one who worked on the Trastevere or right bank of the Tiber, across the river from the main part of the city). The other (10.3.3-4) indicates that the transaction was undertaken by a *proxeneta* (broker/middleman). In the first case it would appear that the individual was envisaged by the Martial as an itinerant whose activity covered some portion of the city that lay on the right bank of the Tiber. Unclear, however, is whether he saw this individual as a specialized collector of glass recycle or of recycle more generally, or rather as an urban peddler who also collected glass recycle. Similarly ambiguous is Martial's use of the term *proxeneta* in the other passage. Although it might simply refer to the same occupation as that indicated for the man in the first passage, it probably indicates an occupation that was in some way different. If so, this difference may have lain in the fact that this other man was a fixed rather than a mobile collector of glass recycle. We may speculate that he served as a middleman for the *Transtiberinus ambulator* of the first passage, who consigned to him the glass that he collected. He might have specialized in the bulking of cullet and its supply to secondary glass workshops or dealt in some wider range of materials, including other kinds of recycle.

The fact that all three of these late-first century AD authors make reference to the practice of exchanging sulfur/sulfur-coated fire-starters for broken glass vessels and that no other mention of this or a similar practice occurs anywhere else in the ancient sources is a point of interest. It suggests, on the one hand, that this was a well-known practice at that time in Rome, and, on the

---

<sup>81</sup> That the latter would have functioned like modern friction matches is doubtful. For the nature of the items involved in these transactions see Harrison (1987).

other, that there was something remarkable about it. Perhaps the best explanation is that this was a peculiarly Roman custom.

Also interesting is the practice of exchanging recyclate for a low-value item likely to be of utility around the house, in that similar practices are attested for peddlers and recyclate collectors in other times and places. In some parts of the USA during the nineteenth century, rural peddlers collected recyclate (mainly rags), offering in exchange low-cost tin-ware.<sup>82</sup> Again, the rag and bone men who operated in northern England during the first part of the twentieth century gave out bars of Donkey-stone (a specially-formulated composite material) that homeowners employed to polish the front steps of their house in return for the materials that they collected.<sup>83</sup> This practice presumably reflects the fact that the value of the recyclate involved in exchanges of this kind is often quite low, and perhaps also the desire on the part of one or both parties to avoid engaging in a monetary transaction.

Whether or not arrangements for the collection of glass recyclate were identical or similar to those referred to by these three authors existed at other places in the Roman world and at other times is not known, although a set of arrangements that included a combination of collectors/middlemen at fixed locations in towns and itinerant collectors in rural areas and perhaps also in towns (particularly smaller towns that produced relatively little broken glass and

---

<sup>82</sup> Medina (2007: 36).

<sup>83</sup> I would like to thank J. Wild for bringing this practice to my attention. For Donkey stone and the role that they played in the activities of the rag and bone men see Whitehead (2017).

also lacked a secondary glass workshop) seems entirely possible.<sup>84</sup> Persons working in either capacity could have furnished the glass that was collected to secondary workshops so that they could melt this down and employ it to fashion new items.

The presence of a cask of cullet aboard the Grado shipwreck is a point of considerable interest, as it points to the transfer of glass recyclate in at least modest amounts from one port town to another, and perhaps the collection of cullet at multiple port towns for transfer to some other location or locations for recycling. In all likelihood, the merchant or one of the merchants who owned the cargo aboard the ship acquired this material for sale to a secondary glass workshop or a middleman at the vessel's destination. This is by no means surprising, as, although glass vessels were probably consumed across the Roman world, and thus there would have been potentially recyclable glass fragments available for collection in nearly every location, there would not have been a secondary glass workshop that could make use of this material in every town.<sup>85</sup>

#### *Metal craft goods and other metal*

The structures in place for the recycling of metal must have been complex and varied, given the several different metals and metal alloys involved and their widely varying values, the fact that very large amounts of material must sometimes have become available at particular times

---

<sup>84</sup> Interesting in this regard is the presence of a basket of glass cullet at the Villa Pisanella, c. 1.5 km north of Pompeii. For this see Pasqui (1897: 518).

<sup>85</sup> See Nenna (2007: 130 fig. 3), for example, which shows the distribution of known secondary glass workshops in France.

(sometimes suddenly and unexpectedly), the large amounts of material involved overall, the several different sources of this (the stripping and/or demolition of buildings, the stripping and/or breaking up of ships, the removal or replacement of sculpture, household refuse, military activities), and the different potential end users of this material (metallurgical workshops, construction firms).

Our most informative textual evidence regarding the methods employed for the recycling of metals comes from the rabbinic literature. Ponting and Levene have interpreted two passages in the *Talmud Bavli* (Shabbat 123a; Bava Metsia 52b) to indicate that it would have been a normal practice for a household or commercial establishment to maintain a scrap collection to which they consigned old or broken items (in the passages in question, a needle with its tip or eye broken off and a worn silver coin) on an ongoing basis, presumably with the intention of selling this either to a metallurgical workshop or to a middleman.<sup>86</sup> They further note that a third passage in the *Talmud Bavli* (Avoda Zara 53a) refers to the purchase from non-Jews of a collection of scrap metal containing an idol, while a passage in *Tosefta* (Kelim Bava Metsia 1.3) refers to the manufacture of unspecified items from scrap metal of both local and imported origin. This last passage implies the involvement of a middleman, who would have been responsible for the transfer of the scrap from one region to another.

The involvement of middlemen in the recycling of iron is also indicated by an inscribed religious dedication from Palestrina (*CIL* 1.3068). This dedication, which can be dated to the period c. 120–70 BC, was set up by the *magistres* (sic) (officers) of the *conlegium scru(tarium) et fabrum ferrarium* (guild of the *scrutarii* and of the iron workers). The precise meaning of the

---

<sup>86</sup> Ponting and Levene (2015: 9–11).

occupational title *scrutarius* remains somewhat obscure.<sup>87</sup> It is formed on *scruta* (a neuter plural), borrowed into Latin from the Greek γρύτη, both words that indicate old or broken things, trash, or frippery.<sup>88</sup> As a Latin occupational title *scrutarius* is attested but once in the literature, in a passage in Aulus Gellius' *Noctes Atticae* (3.14.10) (written c. AD 150–170), reprising Lucilius (writing c. 140–105 BC), which refers to a *scrutarius* who lauds the *scruta* that he is selling, among which are a split strigil and half of a shoe. On the basis of this evidence this occupation and its Greek equivalent, γρυτοπώλης, have been thought to indicate dealers in second-hand items or similar. Interestingly, γρύτη was also borrowed into Hebrew as גרוטים, a term which Ponting and Levene have argued was employed in the rabbinic literature to indicate scrap metal.<sup>89</sup> In light of this observation, we can surmise that the *scrutarii* in the Praeneste dedication were dealers in recycled metal, perhaps specifically iron scrap.

The large amount of both lead and copper alloy scrap being carried aboard the Caesarea wreck and the Brindisi bronzes — if this group of material was assembled and lost during the Roman period — can only be accounted for if we assume the presence of middlemen who dealt in large volumes of recycled metal and undertook the occasional or even regular transfer of this material by ship to locations other than where it was collected, perhaps in some cases over quite long

---

<sup>87</sup> For *scrutarii* see Liu (2009: 72–3).

<sup>88</sup> For *scruta* see Lewis and Short (1956: s.v. *scruta*). For γρύτη see Liddel and Scott (1940; s.v. γρύτη).

<sup>89</sup> Ponting and Levene (2015: 10).

distances. The date of these two instances raises the possibility that this practice might have appeared only during the Late Empire.

Turning to the recycling of coins by the state, hoard evidence suggests that the gradual removal of coinage from circulation often took place over a period of several years or, in some cases, as long as a few decades.<sup>90</sup> An operation of this kind might well have been accomplished by the state by means of regular mechanisms such as taxation and confiscation. How initiatives to effect the more rapid removal of coinage from circulation for this purpose were achieved remains unclear. The state might have sought to purchase coin from persons who handled large amounts of it, such as *argentarii* (bankers/money lenders), *nummularii* (money changers), or merchants, or from municipal administrations, perhaps offering a favorable rate of exchange or levying threats of fines and/or demonetization with a view to encouraging participation in the initiative.

### *Textile craft goods*

It is unclear how great the demand for recycled textiles might have been, and it seems possible that most or all of the material required for the patching of garments, the stuffing of various items such as cushions, and so forth, was obtained from supplies of used garments and other textile items that households, specialized garment menders, and tailors kept on hand, or through the acquisition of material of this kind through what appears to have been a robust second-hand clothing market.<sup>91</sup> That it was also a common practice to scavenge discarded textiles from refuse middens, however, is suggested by the passage in the *Mishnah* alluded to above (Kelim 27.11)

---

<sup>90</sup> Butcher and Ponting (2014: 35–38).

<sup>91</sup> For the evidence for the buying and selling of second-hand clothes see Liu (2009: 71–3).

that considers the recovery of pieces of textile of varying sizes from dung heaps, and it seems possible that a significant amount of the material employed was obtained in this way.

It is important to keep in mind in this connection that the prominence of rag-picking as an activity and of rag collectors as recycling workers in Europe and later in the Americas from the twelfth through the early twentieth century, and, in particular, during the nineteenth century — circumstances that doubtless have shaped the views of many scholars who have considered the recycling of textiles in the Roman world (see below) — was determined primarily by the demand for textiles in vegetal fiber (chiefly cotton, though also linen) that was generated by the paper industry, which required this material in massive amounts for the manufacture of rag paper. This specific form of recycling would have had no close analog in the Roman world. Although the decline of rag picking in modern Europe and the Americas was determined by the complex intersection of several factors (the expansion of public assistance to the poor, the growth of concerns about the link between refuse treatment/disposal and public health, the introduction of standardized, closed containers for the storage of refuse for collection), first among these was the introduction of practical techniques for the manufacture of paper from wood pulp that occurred during the final third of the nineteenth century, which had the effect of reducing quite radically the demand for used textiles.

With this observation in mind we can now turn our attention to the category of workers known as *centonarii*. This occupational title, formed on *cento*, a word that was used to refer to a patch, a patched garment, a heavy or coarse textile or an item made from such a textile,<sup>92</sup> has been widely

---

<sup>92</sup> For uses and meanings of *cento* see Liu (2009: 63–9, 395–8).

assumed in the scholarship to designate rag men.<sup>93</sup> This inference was an easy one for scholars to make, given the similarity of this occupational title to those employed to indicate rag collectors in early modern and modern Europe and the Americas (*cenciaiolo* in Italian, *chiffonnier* in French, *Lumpensammler* in German, *trapero* in Spanish, and rag and bone man in English).

*Centonarii* are widely attested in the epigraphic record, with a corpus of at least 234 inscriptions referring to this occupational title.<sup>94</sup> The attestations in the Latin literary sources are decidedly less plentiful, being limited to one in Petronius' *Satyricon* (45.1) (written *c.* third quarter of first century AD), where Echion, one of the guests at Trimalchio's dinner, is identified as a *centonarius*, and three entries in the *Codex Theodosianus* (12.1.162 [AD 399]; 14.8.1 [AD 315]; 14.8.2 [AD 369]), which refer in one instance to a *collegium* and in two to a *corpus* of *centonarii*. This evidence demonstrates the presence of occupational organizations of *centonarii* — usually referred to as a *collegium*, though in a few cases as a *corpus* — in at least 84 municipalities in Italia and several of the western provinces, with a particular concentration of these in central and northern Italia and in Gallia Narbonensis.<sup>95</sup> The earliest attested of these organizations is the one at Rome, which already existed in the time of Augustus. The latest of the three references in the *Codex Theodosianus* demonstrates that some of these organizations continued to operate in Italia down to the end of the fourth century, and most probably as late as the time of this work's compilation in the AD 430s. In a strikingly large number of cases a *collegium centonariorum* was

---

<sup>93</sup> See, for example, Joshel (1992: 14, 177); Whittaker (1992: 279); Nin and Leguilloux (2003: 160).

<sup>94</sup> For the epigraphic corpus relating to *centonarii* see Liu (2009: 331–83, 391–4).

<sup>95</sup> Liu (2009: 29–55).

associated in some undefined and unclear way with a *collegium* of the *fabri* (builders), and in a more limited number of cases with a *collegium* of the *dendrophori* (carpenters or wood cutters) or *utriclarii* (wagon drivers?).<sup>96</sup>

The specialist literature regarding Roman occupations and occupational organizations has long doubted that *centonarii* were, in fact, rag collectors or workers in some related occupation, such as menders and/or sellers of second-hand clothing, in large measure due to the apparent high socio-economic status of some members of their occupational organizations, who in a handful of instances were *Augustales* and perhaps in a few cases enjoyed equestrian status.<sup>97</sup> It has thus been argued that the *centonarii* were, rather, men who served in municipal fire brigades, with this designation referring to the heavy mats that they wielded to smother fires. Most recently, Liu has undertaken a comprehensive review of the large and complex body of evidence regarding the *centonarii*,<sup>98</sup> concluding that they were ‘primarily tradesmen and/or manufacturers engaged in the production of low- or medium-quality woolen textiles and clothing, including felt and its products’.<sup>99</sup> This is not the place to engage in a detailed evaluation of her conclusions regarding the activities of the *centonarii*. It should be pointed out, however, that although Liu devotes an

---

<sup>96</sup> For the relationship of the *collegia/corpora* of the *centonarii* to these other organizations see Liu (2009: 50–4, 384–90).

<sup>97</sup> For overviews of the scholarship see Perry (2006: 7–18); Liu (2009: 1–4, 125–60). For the social status of members of the *collegia/corpora* of the *centonarii* see Liu (2009: 161–212).

<sup>98</sup> Liu (2009), especially 63–75.

<sup>99</sup> Liu (2009: 69).

entire chapter of her study to the refutation of the view that the *centonarii* were fire fighters,<sup>100</sup> she nowhere similarly evaluates the assumption that they worked as rag collectors or as menders or sellers of second-hand clothing, but rather acknowledges this to be a possibility at one point in her discussion without further addressing the question.<sup>101</sup> Also worth noting is the fact that Liu adduces cross cultural evidence that demonstrates that, contrary to what is commonly assumed, involvement in rag collecting and related occupations need not necessarily equate in every instance with low socio-economic status.<sup>102</sup> It may thus be the case that rag collectors did represent some portion of the membership of the *collegia centonariorum*.

One striking aspect of the evidence regarding *centonarii* is the paucity of texts that refer to this occupational category that are not in some way related to one of the *collegia centonariorum*.

There is, for example, no known epitaph of an individual who is characterized as a *centonarius*

---

<sup>100</sup> Liu (2009: 126–60).

<sup>101</sup> Liu (2009: 70): ‘But perhaps there is no need to push for homogeneity among them [i.e., the *centonarii*]. The same occupational title in antiquity might refer to workmen doing very different things, from a modern point of view .... It would not be surprising if the *centonarii* were also involved in collecting, mending, reusing, and reselling secondhand textiles, even though, according to our sources, these recycling functions were distributed among various other professionals and were often done domestically.’

<sup>102</sup> Liu (2009: 64–5).

that does not refer to his membership in one of these organizations.<sup>103</sup> We thus know little about how this occupational title might have been employed – if much at all – outside its use as the name for a category of occupational organization.

### *Water craft*

Although the significance of shipbreaking (the dismantling of ships and the recovery of elements of these for recycling) as an industry increased exponentially with the advent of iron- and then steel-hulled vessels in the nineteenth century, in many cases wooden hulled ships have been subjected to systematic stripping or dismantling for the recovery of various materials for recycling in modern times.<sup>104</sup> It is reasonable to assume that similar efforts were made on a more or less regular basis in the Roman world. The incidence of this practice might well have increased in the Late Empire, when mortice and tenon, shell-first construction techniques were being replaced by frame first techniques, which involved the more extensive use of iron and copper alloy bolts and nails.<sup>105</sup>

Work of this kind presumably would have been carried out for the most part at ports, where many ships doubtless came to be abandoned when they were judged to be no longer worthy of repair. Some of this work may have been done by workers whose main occupation was the repair

---

<sup>103</sup> An epitaph from Aquileia dating to the first century AD commemorates a probable imperial freedman who is styled a *vestiarius centonarius* (seller of patched (i.e., used?) garments) (*CIL* 5.50 = *AE* 2003.696).

<sup>104</sup> Bowen (c. 1930s).

<sup>105</sup> For this development see Pomey, Kahanov and Rieth (2012).

of watercraft, although less skilled workers, such as stevedores, many of whom might have had only seasonal employment, could have undertaken many of the necessary operations.

### *Animal bone*

The various scholars who have addressed the question of the supply of animal bone to workshops that manufactured items in this material have generally been of the opinion that, as fresh bone is superior in several regards for this purpose to bone that has been cooked (even though fresh bone, unlike cooked bone, may require degreasing), and as these workshops in many cases would have required particular bones and/or intact bones of a large size, it is probable that these establishments obtained their raw material directly from butcher's shops, with the butchers deliberately setting aside particular bones for this purpose. We can thus posit that the acquisition of this material involved a direct supply arrangement similar to the one suggested above for the supply of recyclate to construction crews for use as fill in concrete and similar applications.

The same considerations would not have held in the case of bone destined for boiling for the extraction of collagen for the production of glue, and though the convenience of having a fixed source of supply might have meant that the establishments that undertook this work also obtained their raw material from butchers, it is possible that cooked bone recovered from refuse deposits was employed for this purpose.

### *Human excrement*

It is widely assumed by scholars concerned with the management of solid waste in Roman towns that the task of emptying cesspits was undertaken by specialized workers who disposed of the excrement that they collected either by dumping it onto refuse middens outside the town or

providing it to those who wanted to employ it as fertilizer, either for gardens located somewhere inside the town or on farms situated somewhere outside the town.<sup>106</sup> The practice of emptying latrines for payment is attested by a graffito from Herculaneum (*CIL* 4.10606), which records a charge of 11 *asses* for such an operation.

There is some uncertainty about the occupational title employed to refer to those who undertook this work. The general assumption is that in the Latin-speaking parts of the Roman world these individuals were known as *stercorarii*, a title formed on *stercus* — the word employed in Latin to refer to organic waste and, to some extent, to waste more generally,<sup>107</sup> and in the Greek speaking part as *κοπρόλογοι*, a title based on *κόπρος*, the word employed in Greek to refer to excrement. As a substantive noun, however, *stercorarius* is attested only once, in a graffito executed on the exterior of a building in *Insula* 5.6 at Pompeii (*CIL* 4.7038), in which the person indicated as such is instructed to proceed to the city wall in order to avoid paying a fine.<sup>108</sup> Given the graffito's context, it seems probable that here this term was employed to refer to a person intent on defecating, or perhaps to a person intent on discarding refuse, rather than to a worker whose occupation was that of emptying cesspits. Julius Firmicus Maternus, in his *Matheseos libri VIII* (8.20.1) (written *c.* AD 334–337), an astrological treatise that mentions 264 different occupations, refers to persons whose work involved the emptying of cesspits and the removal of their content simply as *quicumque ... baiulabunt stercora; latrinas cloacasque purgabunt*

---

<sup>106</sup> Scobie (1986: 413–4); Flohr and Wilson (2011: 147–8); Koloski-Ostrow (2015: 89).

<sup>107</sup> For the uses and meaning of the word *stercus* see Cordier (2003: 20–2).

<sup>108</sup> For this graffito see Flohr and Wilson (2011: 148).

(whoever ... will haul away *stercus*; will clean cesspits and sewers.). This raises the possibility that there was no generally accepted occupational title in Latin to designate these workers.<sup>109</sup>

The *Lex Iulia municipalis*, as represented in the *Tabula Heracleensis* (*CIL* 1<sup>2</sup>.593) (issued c. 88–45 BC?), exempts *plostra... stercoris exportandei causa* (wagons for the removal of *stercus*) from a ban on the entry of wagons into Rome between sunrise and the tenth hour. It is not entirely clear that this passage refers to the removal of excrement rather than refuse more generally. If it does refer to excrement, however, then it would appear that, as we might expect, those who undertook this work at Rome (and presumably certain other towns in the Roman world at that time) regularly employed wagons for the removal from the settlement of the material that they collected.

#### *Human and animal urine*

Scholars have long thought on the basis of a small number of passages in Latin literature and some archaeological evidence that was thought to corroborate these, that fullers collected the urine that they required for their operations by setting out ceramic jars in public places so that male passers-by could urinate into these. Flohr has recently reviewed the relevant textual and

---

<sup>109</sup> Elsewhere in this work (8.19.12) Maternus refers to *quicumque ... latrinas semper cloacasque mundabit, vel ad opus publicum damnabitur sententia iudicantis* (whoever will regularly clean cesspits and sewers, or will be condemned to public labor by the ruling of a judge), raising the possibility that in the passage under consideration he was referring not to regular occupations, but rather to duties imposed by municipal authorities as a form of community service.

archaeological evidence and concluded that it does not support this notion.<sup>110</sup> Among other considerations, he points out that this practice would have meant that fullers would not have been in a position to prevent the adulteration of the urine with various foreign substances. In Flohr's view, the most probable way that fullers obtained the urine that they required was by collecting it at home.

### *Pomace*

Pomace would have been generated in very considerable amounts across the large portion of the Roman world in which oleoculture was practiced.<sup>111</sup> In these regions rural farmsteads of widely varying sizes would have pressed olives for the extraction of oil, yielding substantial amounts of pomace. In regions in which there was intensive oleoculture the amounts of this substance generated would have been particularly great. Pomace that was collected with the intent that it be used as fuel was probably in many cases shaped into bricks or balls that were then set out to dry in the sun to facilitate its storage, handling, and transport.<sup>112</sup> Pomace that was not formed into a brick or ball might also have been transported in ceramic containers, skin containers, or casks, or simply piled on the bed of a cart or wagon.<sup>113</sup>

---

<sup>110</sup> Flohr and Wilson (2011: 151–3).

<sup>111</sup> Rowan (2015: 477) estimates that across of the whole of the Roman Empire the pressing of olives would have resulted in the annual production of between 951,000 and 1.9 million tons of pomace.

<sup>112</sup> Rowan (2015: 466).

<sup>113</sup> Rowan (2015: 476).

As the pressing of olives presumably took place almost exclusively in rural areas, the utilization of pomace by craft production establishments, baths, and households in towns — to the extent that this was not an instance of self-supply by elites — must have involved a distribution system of some kind. More probably than not, pomace was treated simply as another agricultural product, and its transport to towns and distribution in these entrusted to the same set of arrangements that served for the marketing of farm produce. In cases in which manufacturing establishments employed significant amounts of pomace on an ongoing basis, we can imagine a direct supply arrangement of some kind such as those conjectured above for the supply of various kinds of fill for use in construction. This would have been particularly likely to have been the case in the instance of establishments such as pottery workshop or lime kilns that were located in rural areas on or in proximity to estates that produced large amounts of olive oil.<sup>114</sup> It has long been conjectured, for example, that pomace was regularly employed for the firing of African Sigillata, much of which was manufactured in rural areas that also supported intensive oleoculture.<sup>115</sup>

#### *Town-based waste pickers*

For most of the categories of recyclate discussed in the preceding sub-sections we know little if anything about the individuals who were responsible for collecting the recyclate at its source and then transferring it either to a middleman or to the end user, and no idea whether the small and isolated glimpses that we do possess of such activities might be representative of broader patterns in recycling practice. In towns it seems possible that in many instances these operations

---

<sup>114</sup> For the locating of lime kilns in rural areas prior to the late empire see Munro (2016: 51).

<sup>115</sup> Rowan (2015: 471).

were carried out by more or less specialized waste pickers, that is, persons who scavenged the materials from refuse deposits. Waste picking has been a regular feature of town life in many parts of the world from early modern times to the present, as it represents a means whereby unskilled, economically (and often socially) marginal persons can either earn a living or supplement the income that they obtain through other activities.<sup>116</sup> The World Bank, for example, has estimated that in the countries of the developing world roughly one percent of the population, or roughly 15 million people, earns a living through some form of waste picking.<sup>117</sup> In the Mediterranean region, waste pickers today play an important role in the management of refuse in some of the largest and most important cities, including Cairo, with its *zabbaleen* (literally garbage people or garbage collectors),<sup>118</sup> and Istanbul, with its *eskicis* (literally dealers in old or second-hand items).<sup>119</sup>

There is, however, no clear evidence for the presence of waste pickers in the Roman world, and it is not clear whether this reflects the absence or near absence of persons who undertook

---

<sup>116</sup> For an overview of contemporary waste pickers in the developing world see Medina (2007).

<sup>117</sup> Medina (2009: vii). National organizations of waste pickers have been formed in many countries — in Latin American, in particular — to advocate for the interests and promote the welfare of their membership. In 2008 organizations representing waste pickers in over 30 different countries in Latin American, Asia, and Africa came together to form the Global Alliance of Waste Pickers. For this organization's website see <http://globalrec.org/>.

<sup>118</sup> For the *zabbaleen* see Zelenková (2015); Furniss and Tastevin (2017).

<sup>119</sup> For the *eskicis* see French (2011); Garrett (2017).

activities of this kind or the fact that the persons who earned a living in this way simply have left no clear textual or archaeological footprint.<sup>120</sup> In the modern world there is a negative correlation between the prominence of waste picking as an occupation and the availability of public assistance for the poor,<sup>121</sup> and it may be that the *clientela* system that operated in some parts of the Roman world at particular times, and, in Rome, itself, the dole, to some extent had the effect of depressing activity of this kind.<sup>122</sup> Still, given the probability that there was a significant presence of poor persons in Roman towns and the utility and potential value of various kinds of recyclables that regularly wound up in refuse deposits in quite substantial amounts, it would be surprising if there was no waste picking as a regular feature of economic life in Roman towns.

Based on a consideration of the approaches adopted by waste pickers in the modern context and what has been noted above regarding Roman practices of refuse discard, we can surmise that in Roman towns waste pickers might have employed either or both of two different approaches, namely mobile waste picking inside the settlement, and waste picking at extra-settlement refuse middens.<sup>123</sup> The first of these two approaches may have represented a viable undertaking only in

---

<sup>120</sup> For the problem of the visibility of the poor in Rome see Morley (2006: 27–36).

<sup>121</sup> Medina (2007: ix).

<sup>122</sup> For the impact of patronage and the dole in the lives of the Roman poor see Whittaker (1993: 291–6); Morley (2006: 34).

<sup>123</sup> For the various modes of operation employed by waste pickers in the developing world see Medina (2007: 33–37).

instances in which there was some provision for regular refuse collection, as this would have meant that substantial amounts of freshly discarded refuse were exposed for scavenging on a regular basis at well established, publicly accessible locations inside the town. With regard to the second approach, we do possess a slight amount of textual evidence for the scavenging of useful items from what are characterized as dung heaps — presumably meaning large, extra-settlement refuse middens or some similar kind of feature.<sup>124</sup> These include the passage in the *Mishnah* (Kelim 27.11) referred to above that considers the recovery of pieces of textile of various sizes from a dung heap and a passage in Arrian's *Dissertationes ab Arriano digestae* (2.4.4) (written c. AD 108), which suggests that the retrieval of still-useful items such as a (pottery?) vessel from a dung heap would have represented a normal practice.<sup>125</sup> However, these may well refer to casual scavenging by individuals rather than to some sort of organized, ongoing activity, such as that of professional waste pickers.

In order to gain some idea of how Roman town-based waste picking might have been organized we can consider one representative group of modern practitioners, the *chiffonniers*, the rag men of nineteenth century Paris.<sup>126</sup> I have chosen this group due to the fact that their activities are well documented and they dealt in a suite of recyclables that in certain regards was similar to those that would have been present in the refuse stream in Roman towns.

---

<sup>124</sup> For the evidence for the recovery of infants exposed on dung heaps see Harris (1994: 3–11).

<sup>125</sup> For this passage see Peña (2007: 309).

<sup>126</sup> For the *chiffonniers* see Paulian (1885); Barles (2005: 24–65); (2017: 109–19); Jousselin, Cena, and Turrents (2009); Compagnon (2017).

Parisian *chiffonnage* of what is regarded as its golden age — roughly the 1820s to the 1880s — emerged from earlier activity of this kind carried out on a less structured, often part-time basis. Its expansion in the nineteenth century was driven by the establishment and growth of a paper industry in the city. The classic *chiffonnier*, known as a *chiffonnier piquer*, was an adult (either male or female) who worked on foot, making his or her rounds after dark, employing a hook known as a *crochet* or *biffe* to root through the refuse piled along the sides of the streets for collection by the municipal collection service, extracting material of value. The principal focus of this work was rags manufactured in vegetal fiber — cotton and linen — which were recycled for the production of paper. The *chiffonniers* also collected a wide variety of other kinds of refuse, however, including animal bone (which in terms of their remuneration represented the second most important class of item that they recovered), woolen rags, objects in metal, glass, ceramic, and whale bone, scraps of leather, paper, cardboard, corks, sponges, snail shells, sardine cans, candle stumps, cigar butts, and stale baguette.<sup>127</sup> The *chiffonnier* placed these items in his/her *hotte*, a wicker hamper worn on the back. When he/she had filled the *hotte* they returned home to sort their take, often assisted by the members of their family.<sup>128</sup> When the *chiffonnier* had accumulated a certain amount of one kind of recyclate (rags, glass, animal bone) he/she or a family member visited a middleman who specialized in the bulking of that particular kind of

---

<sup>127</sup> For a table that lists the principle materials collected by the Parisian *chiffonniers* in 1860 and the prices paid for these by middlemen see Barthes (2005: 61 table 9).

<sup>128</sup> Following the construction of the Thiers fortifications in the mid-1840s the *chiffonniers* came to occupy the 300-meter wide strip immediately outside the walls in which there was a ban on development. See Jousselin, Cena, and Turrents (2009).

material. The middleman purchased the material and resold it to an establishment that required it for some productive process. With the passage of time the system became more elaborate, with master *chiffonniers*, who employed several *chiffonniers piquers*, and the emergence of the *chiffonnier placier*, a more elevated form of the occupation, comprised of men and women who struck agreements with wealthy households to gain access directly to the refuse that they generated rather than scavenging in the street, using a wagon to move about the city. Although many *chiffonniers* were destitute, it was possible to earn a respectable living even as a *chiffonnier piquer*,<sup>129</sup> and some of the master *chiffonniers* and the middlemen involved in the system were able to amass a not inconsiderable fortune. Interestingly, the *chiffonnier* became a romanticized figure of fascination for the artistic world in Paris, and came to be represented in numerous nineteenth-century Parisian works of art and literature.<sup>130</sup>

One interesting aspect of Parisian *chiffonnage* was the extent to which municipal government sought to regulate it. Beginning in 1828 *chiffonniers* were required to register with the police. Upon registration they were issued a copper identification plaque that they were required to carry on their person.<sup>131</sup> One side of this was inscribed with the *chiffonnier's* name and registration number, the other with the year, the *chiffonnier's* age, and his or her physical characteristics. Thanks to the registration system we possess detailed information regarding the number of *chiffonniers* active in some years and their breakdown by age and sex. In 1829, for example, the

---

<sup>129</sup> It was possible, for example, for a *chiffonnier piquer* to earn more than a carpenter. See Jusselin, Cena, and Turrents (2009).

<sup>130</sup> Jusselin, Cena, and Turrents (2009); Compagnon (2016).

<sup>131</sup> Barles (2005: 59); (2017: 110).

second year of the system, the number of *chiffonniers* registered with the police — presumably some fraction of the total number of persons actually involved in this activity — came to 1,841, including 1,201 males and 640 females.<sup>132</sup> A very small number of these were children, both boys and girls, under the age of 10. Quite sizable portions consisted of persons between the ages of 10 and 20 (predominantly males), and of individuals above the age of 60 (more evenly divided between males and females), with some of these older than 70.

Making sense of the available data regarding the number of persons who worked in *chiffonnage* in Paris at various points over the course of the nineteenth century is difficult, as these do not appear to represent a uniform approach to defining or counting the target population.<sup>133</sup> What is clear, however, is that the number of persons who earned their living in one way or another through this occupation was in constant increase through to the late 1880s or early 1890s. Thus, in 1872 the number of *chiffonniers* registered in the city came to 11,767, a more than six-fold increase in respect to the number registered in 1829, and it has been estimated that the true number of persons who earned their living through *chiffonnage* in Paris at that time in fact came to between 30,000 and 40,000.<sup>134</sup> Data collected during the early 1890s indicate that in Paris no fewer than 84,795 persons earned their living in one way or another through *chiffonnage*, and that nearly 295,000 did so across the whole of France.<sup>135</sup> As the country then had a population of

---

<sup>132</sup> For these figures see the histogram at Barles (2017: 110).

<sup>133</sup> Barles (2005: 58–9).

<sup>134</sup> Barles (2017: 111); Compagnon (2017: 81).

<sup>135</sup> Barles (2017: 118).

c. 38.4 million, we can calculate that roughly 0.75 percent of its inhabitants were engaged in work of this kind.

Two developments set in train the decline of Parisian *chiffonnage*. The first has already been noted — the introduction in the 1870s of the technique for the production of paper from wood pulp, which led to a radical decline in the demand for rags. The second was the adoption of a package of ordinances in 1883 and 1884 that required Parisians to set out their refuse in a standardized type of closed container that came to be termed a *poubelle*, the name of the administrator who instituted the system and a word that remains to this day the French term for refuse bin. This innovation greatly complicated the task of rooting through refuse for useful materials and rendered the *chiffonnier's* work less profitable and more unpleasant than had already been the case. In the decades that followed the introduction of synthetic materials of various kinds and the reconfiguration of streets to accommodate automobiles further reduced the profitability and complicated the exercise of *chiffonnage*, which also came to be regarded as something of a nuisance and a threat to public health, and in 1946 the practice was outlawed in Paris.

Six aspects of Parisian *chiffonnage* are of potential interest with regard to recycling in the Roman world:

1. Waste picking in a large city with refuse roughly analogous to that in a Roman town supported a small, though not insignificant portion of the population.
2. This activity offered employment to persons of both sexes and all ages.

3. Although this activity focused on a single recyclable, practitioners also recovered a wide array of other recyclables.
4. This activity involved a complex system that included waste pickers of different kinds and middlemen specialized in the bulking and supply of particular kinds of recyclables.
5. Although most practitioners were economically marginal, the size and hierarchical nature of the system permitted some to earn a substantially more remunerative living.
6. Municipal administration was interested in and regulated this activity.

To be sure, the circumstances in which Parisian *chiffonnage* emerged, expanded, and thrived were different in certain basic regards from those that would have existed anywhere in the Roman world. The main focus of collection — rags for the manufacture of paper — had no analog in the Roman case; between the disestablishment of the Catholic Church and the dismantling of its charitable initiatives in the French Revolution and the rise of the French welfare state in the period from the 1880s to the 1930s there was little in the way of social assistance for the Parisian poor, leaving participation in waste picking as an attractive, and, in some cases, the only economic option for many;<sup>136</sup> and, while there had been a municipal refuse collection service in Paris since the eighteenth century,<sup>137</sup> it is by no means certain that a service of this kind ever existed in Roman towns.

---

<sup>136</sup> Bottini (2013).

<sup>137</sup> La Berge (1992: 230).

Despite these important differences, we can conjecture that groups of waste pickers may have existed in many Roman towns and that they shared some of the characteristics of the *chiffonniers*, such as a broad-based approach to the recovery of recyclables that at the same time focused to some greater or lesser extent on one or two kinds of more profitable materials, such as metals or glass;<sup>138</sup> participation by persons of all ages and perhaps also both sexes; and, in the larger cities, at least, a hierarchical organization that included low- and high-level waste pickers and middlemen, with those at lower levels earning a marginal income and a restricted number at the higher levels substantially more. If there was, in fact, no arrangement for municipal refuse collection in Roman cities and towns, we can posit that these workers operated not as mobile waste pickers within the settlement, as did the *chiffonniers*, but rather focused their activity on the extra-settlement refuse middens that represented the locus of definitive discard for much of the refuse generated by the community, as do many groups of waste pickers in the contemporary developing world. Unless these workers are subsumed under the *centonarii* (in which case they would have had as their primary focus the scavenging of textiles), correspond to Martial's *ambulator* and/or *proxeneta* (both linked to the recycling of glass), or are the individuals referred to as *scrutarii* (perhaps linked specifically to the recycling of metals), they remain entirely without mention in the surviving bodies of literary, epigraphic, and papyrological texts. Given

---

<sup>138</sup> There is some evidence that waste pickers active in Paris c. 1500 and in Rome in the seventeenth century— well before the explosive growth in the use and manufacture of paper that began in Europe during the late eighteenth century— focused to some extent on the recovery of metal, raising the possibility that this also might have been the case in Roman towns. For Paris see Jousselin, Cena, and Turrents (2009 <http://www.mheu.org/fr/chiffonniers/cris-de-paris.htm>). For Rome see Manacorda (2000: 70).

the extremely low profile of the urban poor and their day-to-day activities in the textual record, that these workers pass completely unmentioned or nearly so seems a distinct possibility.<sup>139</sup>

To date, little research has been carried out that has involved the characterization of refuse deposits associated with Roman towns with a view to evaluating the extent to which recycling activities resulted in the systematic removal of various categories of recyclables from the waste stream. In some cases, however, researchers have noted a dearth of glass in a deposit, suggesting that this may be the result of the systematic, intensive collection of glass as recyclate.<sup>140</sup> Most deposits for which data are available contain substantial amounts of various categories of recyclate, indicating that the recovery of these materials from the refuse stream was anything but thorough. This is particularly striking in the case of refuse deposits from sites in Egypt, such as Karanis<sup>141</sup> and Mons Claudianus – Wadi Umm Hussein,<sup>142</sup> and Quseir al-Qadim,<sup>143</sup> in which

---

<sup>139</sup> For Roman recognition of and attitudes towards the poor and workers in marginal occupations see Larsen (2015); Bond (2016: 1–20). We might ask whether the fact that Martial, Juvenal, and Statius all made passing mention of the recycling of glass represents an interest in these kinds of activities on the part of late first-century AD Rome literati akin to that of the artistic and literary world of nineteenth century Paris.

<sup>140</sup> Keller (2005: 68).

<sup>141</sup> Van Minnen (1994: 229–232).

<sup>142</sup> Maxfield and Bingen (2001: 89, 109–16).

<sup>143</sup> Peacock and Blue (2006: XXX).

organic materials are preserved, as these contain substantial amounts of potentially useable and perhaps also valuable organic recyclables, such as textiles and papyrus. It would thus appear that, whatever the role played by town-based waste pickers, Roman towns were far from being — as Rodríguez Almeida argued would have been the case with Rome — ‘*città* self-cleaning’,<sup>144</sup> — that is, settlements that were largely spared from having to confront and manage problems stemming from the accumulation of refuse on account of its extensive and intensive recycling.

### *Rural peddlers/recyclate collectors*

As noted above in connection with the recycling of glass, it seems possible that in rural areas recyclables were collected by more or less specialized itinerant recyclate collectors or peddlers/recyclate collectors, who consigned the materials that they obtained either to middlemen or to end users, such as craft production establishments. Given the challenges raised by the need to carry this material over long distances, it seems probable that workers of this kind would have focused their efforts on relatively light materials, such as glass and textiles, rather than heavier ones, such as metals.

## **Conclusions**

This preliminary review of the evidence demonstrates that the Romans recycled a wide array of materials, including construction materials, glass, metals, textiles, leather, ceramics, papyrus, elements of furniture, wheeled vehicles, and ships, animal bone, various kinds of industrial and agricultural waste, including organic ash, shell, and slag, and olive pressings, and human and animal excrement and urine. The presence of substantial amounts of many of these materials in

---

<sup>144</sup> Rodríguez-Almeida (2000).

refuse deposits demonstrates that the recovery and recycling of these materials was at best only very partial.

The methods that were employed to recover this material and to transfer it from the point where it was collected to the point where it was employed in a productive process remain largely obscure. We can posit that in some cases establishments that generated large amounts of industrial or agricultural waste (organic ash, shell, slag, olive pressings) provided this material directly to other establishments that required this in large quantities for some productive process through an ongoing, direct arrangement of some kind. In the case of construction materials, there is some evidence for the existence of demolition specialists who might have assembled the material recovered from buildings and provided it to middlemen, who would have sold it to end users. In the case of glass and metals, there is evidence for the operation of a complex system perhaps specialized in the collection of that kind of material that involved middlemen and occasionally, at least, the long-distance transfer of significant amounts of recycle by ship. Workers known as *centonarii* may have been involved in the collection of textiles for recycling, although here the evidence is less than compelling. There is literary evidence to the effect that workers were paid to empty latrines, and it seems probable that they either transferred the excrement that they collected to extra-settlement middens for dumping or provided it to urban horticulturalists and/or rural farmers for use as fertilizer.

Given this dearth of evidence for how recycling was accomplished, we can conjecture that there existed in Roman towns groups of waste pickers who recovered various kinds of recyclables from refuse deposits and provided these to middlemen and/or end users. This might have involved the recovery of materials from temporary deposits of relatively modest size regularly created inside the settlement in anticipation of collection by a regular municipal refuse collection

service of some kind, their recovery from refuse middens located immediately outside the settlement where large amounts of refuse were deposited in definitive discard, or operations of both kinds. Some aspects of this work may have resembled Parisian *chiffonnage* of the nineteenth century or waste picking at urban dump sites in some parts of the contemporary developing world. In rural areas, itinerant peddlers/recyclate collectors may have collected some kinds of recyclables, particularly low-weight materials such as glass and textiles, providing these to middlemen and/or end users.

There appear to be three paths forward for advancing our understanding of recycling in the Roman world, all archaeological in nature: the analysis of objects manufactured wholly or partially from recyclate in order to better understand the nature and scope of the practices and methods involved; the study of specific archaeological contexts that relate in a direct way to recycling, including caches of material assembled for use as recyclate, processing facilities for recyclate, and facilities at which recyclate was utilized in a productive process, as these come to light in the course of excavations; and the quantitative and qualitative characterization of refuse deposits of various kinds in order to better understand patterns in the removal (and non-removal) of specific categories of recyclables from the refuse stream.<sup>145</sup> Ongoing research of these three kinds will doubtless improve our understanding of certain aspects of Roman recycling.

---

<sup>145</sup> A research project that I currently direct at Pompeii that is aimed at elucidating the life history of objects in the town — The Pompeii Artifact Life History Project (PALHIP) — is in the process of studying, among other things, both intra- and extra-settlement refuse deposits with this aim in mind. For this project see Peña (2014), (2016), (forthcoming); Peña and Cheung (2015).

Particularly welcome will be any research results that position us to better understand quantitative aspects of Roman recycling, about which we can say very little at present. The dearth of textual evidence that bears on Roman recycling means that our understanding of the specifics of the ways in which recycling operations were organized and the identities of the persons who undertook these will remain decidedly partial and uneven. By evaluating the extensive body of evidence regarding the ways in which recycling workers have operated in the modern period in various parts of the world, however, it will be possible to fill in these gaps to some extent by employing this information to formulate informed conjectures regarding how various recycling operations might have been organized and carried out in the Roman case.

## References

Ballet, P, Cordier, P, and Dieudonné-Glad, N. (eds) (2003). *La ville et ses déchets dans le monde romain: rebuts et recyclages. Actes du colloque de Poitiers (19–21 Septembre 2002)* (Archéologie et histoire romaine 10). Montagnac.

Barker, S. (2012). *Demolition, salvage and re-use in the city of Rome 100 BC–AD 315*. D.Phil. thesis, University of Oxford.

Barker, S. and Marano, Y. (2017). ‘Demolition laws in an archaeological context: legislation and architectural re-use in the Roman building industry’, in P. Pensabene, M. Milella, and F. Caprioli (eds), *Decor. Decorazione e architettura nel mondo romano* (Thiasos Monografie 9). Rome, 833–50.

- Barles, S. (2005). *L'invention des déchets urbaine: France: 1790–1970*. Seyssel. Barles, S. (2017). 'Gestes et métiers du métabolisme urbain'. in Chevallier and Tastevin (2017), 109–19.
- Bernard, J.-F. (2008). 'À propos de l'architecture antique comme source d'approvisionnement en métaux', in J.-F. Bernard, P. Bernardi, and D. Esposito (eds), *Il riempiego in architettura: recupero, trasformazione, uso* (ColLEFR Rome 418). Rome, 40–50.
- Biró Mária, T., Choyke, A., Vass, L., and Vecsey, A. (2012). *Bone objects in Aquincum* (Az Aquincumi Múzeum Gyűjteménye 2). Budapest.
- Blue, L., Whitewright, J., and Thomas, R. (2011). 'Ships and ships' fittings', in Peacock and Blue (2011), 179–209.
- Boetto, G., Carsana, V., and Giampoala, D. (2009). 'Il porto di Neapolis e i suoi relitti', in X. Nieto and M. Cau (eds), *Arqueologia nàutica mediterrànea* (Monografies del CASC 8). Girona, 467–70.
- Boetto, G., Carsana, V., and Giampoala, D. (2010). 'I relitti di Napoli e il loro contesto portuale', in S. Medas, M. D'Agostino, and G. Caniato (eds), *Archeologia, storia, etnologia navale. Atti del I convegno nazionale Cesenatico - Museo della Marineria (4–5 aprile 2008)*. Cesenatico, 115–22.

Bond, S. (2016). *Trade & taboo: disreputable professions in the Roman Mediterranean*. Ann Arbor.

Bottini, F. (2013). 'The rise of the French welfare state'. *Jurisprudence* 2/1: 643–62.

Bowen, F. C. (c. 1930s) 'The shipbreaking industry'. <http://www.naval-history.net/WW1NavyBritish-Shipbreak.htm> (accessed 18 December 2017).

Brems, D. and Degryse, P. (2014). 'Trace elements in sand raw materials', in Degryse (2014), 69–85.

Brems, D., Ganio, M., and Degryse, P. (2014). 'The Sr–Nd isotopic fingerprint of sand raw materials', in Degryse (2014), 51–67.

Butcher, K. and Ponting, M. (2014). *The metallurgy of Roman silver coinage*. Cambridge.

Carreras Monfort, C. (2011). 'Urbanismo y eliminación de residuos', in Remolá and Pérez (2011), 17–26.

Chevallier, D. and Tastevin, Y.-P. (eds) (2017). *Vies d'ordures: de l'économie des déchets*. Paris.

Choyke, A. (2012a). 'Bone workshop from the area of the church of San Lorenzo', in O. Brandt (ed.), *San Lorenzo in Lucina: the transformations of a Roman quarter* (Skrifter utgivna av Svenska Intututet Rom 4<sup>o</sup> 61). Stockholm, 335–46.

Choyke, A. (2012b). 'Skeletal elements from animals as raw materials', in Biró Mária, Choyke, Vass, and Vecsey (2012), 49–53.

Ciccirelli, C. (1996). 'La ceramica commune da Terzigno: nota preliminare', in M. Bats (ed.), *Les céramiques communes de Campanie et de Narbonnaise (Ier s. av. J. - C. - IIe s. ap. J. - C.): la vaisselle de cuisine et de table* (Collection du Center Jean Bérard 14). Naples, 157–71.

Compagnon, A. (2014). 'Le moment du chiffon', in Chevallier and Tastevin (2014), 79–81.

Compagnon, A. (2016). 'Les chiffonniers littéraires: Baudelaires et les autres'. *College du France*. <http://www.college-de-france.fr/site/antoine-compagnon/course-2015-2016.htm> (accessed 24 December 2017).

Cordier, P. (2003). 'Les mots pour le dire: le vocabulaire des rebuts et leurs représentations', in Ballet, Cordier, and Dieudonné-Glad (2014), 19–26.

Croxford, B. (2016). 'Metal sculpture from Roman Britain: scraps but not always scrap', in Kristensen and Stirling (2016), 27–46.

Degryse, P. (2012). 'Archaeometric applications', in F. Vanhaecke and P. Degryse (eds). *Isotopic analysis: fundamentals and applications using ICP-MS*. Weinheim, 373–90.

Degryse, P. (ed.) (2014). *Glass making in the Greco-Roman world* (Studies in archaeological sciences 4). Leuven.

Degryse, P., Ganio, M., Boyen, S., Blomme A., Scott, B., Brems, D., Carremans, M., Honings, J., Fenn, T., and Catting, F. (2014). 'Primary glass factories around the Mediterranean', in Degryse (2014), 97–112.

Delfino, A. (2013). 'Contesti ceramici da due *domus terinee* del Foro di Cesare', in M. Ceci (ed.), *Contesti ceramici dai Fori Imperiali* (BAR-IS 2455). Oxford, 129–38.

Dicus, K. (2014). 'Resurrecting refuse at Pompeii: the use-value of urban refuse and its implications for interpreting archaeological assemblages', in *TRAC 2013: Proceedings of the Twenty-Third Annual Theoretical Roman Archaeology Conference, London 2013*. Oxford, 65–78.

Downs, M. and Medina, M. (2000). 'A short history of scavenging', *Comparative civilizations review* 42: 23–45.

Dupré Raventós, X. and Remolà, J.-A. (eds) (2000). *Sordes urbis: la eliminación de residuos en la ciudad roman* (Biblioteca itálica 24). Rome.

D-Waste. (no date). *Waste atlas*. <http://www.atlas.d-waste.com/> (accessed 22 December 2017).

Fant, J. C., Russell, B., and Barker, S. (2013). ‘Marble use and reuse at Pompeii and Herculaneum: the evidence from the bars’, *PBSR* 81: 181–209.

Flohr, M. and Wilson, A. (2011). ‘The economy of ordure’, in Jansen, Koloski-Ostrow, and Moorman (eds), *Roman toilets: their archaeology and cultural history*. Leuven, 147–57.

French, D. (2011). ‘What the Turks can teach us about recycling’. *Mises Institute*.  
<https://mises.org/library/what-turks-can-teach-us-about-recycling> (accessed 22 December 2017).

Furniss, J. and Tastevin, Y.-P. (2017). ‘Collecte de déchets au Caire’, in Chevallier and Tastevin (2017), 132–7.

Garrret, P. (2017). ‘Une tournée de récupération à Istanbul’. in Chevallier and Tastevin (2017), 138–41.

Gelichi, S. (2000). ‘L’eliminazione dei rifiuti nelle città romane del nord Italia tra antichità ed alto medioevo’, in Dupré Raventós and Remolà (2000), 13–23.

Gianfrotta, P. (2000). ‘I rifiuti sommersi’, in Dupré Raventós and Remolà (2000), 25–35.

*Global Alliance of Waste Pickers*. (no date). <http://globalrec.org/> (accessed 22 December 2017).

Harl, K. (1996). *Coinage in the Roman economy, 300 B.C. to A.D. 700*. Baltimore.

Harris, W. V. (1994). 'Child-exposure in the Roman empire'. *JRS* 84: 1–22.

Harrison, G. (1987). 'Martial 1. 41: sulphur and glass'. *TAPhA* 37/1: 203–7.

Hobbs, L. and Siddall, R. (2011) 'Cementitious materials of the ancient world', in Å. Ringbom and R. Hohlfelder (2011), 35–65.

Joshel, S. (1992). *Work, identity, and legal status at Rome: a study of the occupational inscriptions*. Norman.

Jousselin, C., Cena, O. and Turrents, G. (2009). 'Les chiffonniers'. *Musée historique environnement urbain*. <http://www.mheu.org/fr/chiffonniers/> (accessed 24 December 2017).

Keller, D. (2005). 'Social aspects of glass recycling', in *TRAC 2004 Proceedings of the Fourteenth Annual Theoretical Roman Archaeology Conference which took place at the University of Durham 26-27 March 2004*. Oxford, 65–78.

Koloski - Ostrow, A. O. (2015). *The archaeology of sanitation in Roman Italy: toilets, sewers, and water systems*. Chapel Hill.

Kristensen, M.T. and Stirling, L. (eds) 2016. *The afterlife of Greek and Roman sculpture: late antique responses and practices*. Ann Arbor.

La Berge, A. (1992). *Mission and method: the early-nineteenth-century French public health movement*. Cambridge.

Lancaster, L. (2015). *Innovative vaulting in the architecture of the Roman Empire*. Cambridge.

Larsen, M. R. (2015). *The representation of poverty in the Roman Empire*. Ph.D. thesis, University of California, Los Angeles.

Lewis, C.T. and Short, C. (1956). *A Latin dictionary*. Oxford. (accessed at: <http://www.perseus.tufts.edu/hopper/resolveform?redirect=true&lang=Latin>)

Liboiron, M. (2010). *Discard studies: social studies of discard, pollution, & externalities*. <https://discardstudies.com/> (accessed 15 December 2017).

Liboiron, M. (2012). 'Recycling', in Zimring and Rathje (2012), 735–8.

Liddell, H.G. and Scott, R. (1940). A Greek-English lexicon. Oxford. (accessed at:

<http://www.perseus.tufts.edu/hopper/text?doc=Perseus%3Atext%3A1999.04.0057&redirect=true>

)

Liebeschuetz, W. (2000). 'Rubbish disposal in Greek and Roman cities', in Dupré Raventós and Remolà (2000), 51–61.

Liu, J. (2009). *Collegia centonariorum: the guilds of textile dealers in the Roman west*. Leiden.

Loomis, I. (2017). 'Expedition finds South Pacific plastic patch bigger than India', *Science news for students*. September 15, 2017. <https://www.sciencenewsforstudents.org/article/expedition-finds-south-pacific-plastic-patch-bigger-india> (accessed 16 December 2017).

Lucas, S. (2012). 'Culture, values, and garbage', in Zimring and Rathje (eds), 164–8.

Manacorda, D. (2000). 'Sui "mondezzari" di Roma tra antichità e età moderna', in Dupré Raventós and Remolà (2000), 63–73.

Marano, Y. (2015). ‘Il riempiego a Roma tra tarda Repubblica e alto Impero: evidenza archeologica e fonti giuridiche’, in M. Centanni and L. Sperti (eds), *Pietre di Venezia. Spolia in se, spolia in re. Atti del convegno internazionale (Venezia, 17-18 ottobre 2013)*. Rome, 159–72.

Margary, I. (1965). *Roman ways in the Weald*. London.

Marinazzo, A. (ed.) (2010). *I bronzi di Punta del Serrone. Dal mare al Museo Provinciale di Brindisi*. Bari.

Marzano, A. (2013). *Harvesting the sea: the exploitation of marine resources in the Roman Mediterranean*. Oxford.

Maxfield, V. and Bingen, J. (2001). ‘The southern seabakh’, in V. Maxfield and D. P. S. Peacock (eds) *Survey and excavations Mons Claudianus 1987 – 1993 vol. 2 Excavations part 1 (FIFAO 43)*. Cairo, 87–125.

Medina, M. (2007). *The world’s scavengers: salvaging for sustainable consumption and production*. Lanham.

Morley, N. (2006). 'The poor in the city of Rome', in M. Atkins and R. Osborne (eds) *Poverty in the Roman world*. Cambridge, 23–39.

Munro, B. (2011). 'Approaching architectural recycling in Roman and late Roman villas', in D. Mladović and B. Russel (eds), *TRAC 2010: Proceedings of the Twelfth Annual Theoretical Roman Archaeology Conference*. Oxford, 76–88.

Munro, B. (2016). 'Sculptural deposition and lime kilns at Roman villas in Italy and the western provinces in late antiquity', in M. T. Kristensen and L. Stirling (2016), 47–67.

Nenna, M.-D. (2007). 'Production et commerce du verre à l'époque impériale: nouvelles découvertes et problématiques', *FACTA* 1: 125-47.

Nin, N. and Leguilloux, M. (2003). 'La gestion des déchets à Aix-en-Provence dans l'antiquité', in Ballet, Cordier, and Dieudonné-Glad (2003), 133–63.

Pancierà, S. (2000). 'Nettezza urbana a Roma. Organizzazione e responsabili', in Dupré Raventós and Remolà (2000), 95–105.

Pasqui, A. (1897). 'La villa pompeiana della Pisanella presso Boscoreale'. *Monumenti antichi* 7. Milan, 398–554.

Paulian, L. (1885). *La hotte du chiffonnier*. Paris.

Pavolini, C. (ed.) (1993). *Caput Africae: indagini archeologiche a Piazza Celimontana (1984 – 1988)*. *La stora, lo scavo, l'ambiente*. Rome.

Peacock, D. P. S. and Blue, L. (eds) (2006). *Myos Hormos – Quseir al-Qadim. Roman and Islamic ports on the Red Sea*, vol. 1: *The survey and report on the excavations 1999–2003*. Oxford.

Peacock, D. P. S. and Blue, L. (eds) (2011). *Myos Hormos – Quseir al-Qadim. Roman and Islamic ports on the Red Sea*, vol. 2: *Finds from the excavations 1999–2003*. (BAR-IS 2286). Oxford.

Peña, J. T. (2007). *Roman pottery in the archeological record*. Cambridge.

Peña, J. T. (2014). 'The Pompeii Artifact Life History Project: conceptual background and first season's results'. *RCRFActa* 43: 297–304.

Peña, J. T. (2016). 'The Pompeii Artifact Life History Project (PALHIP)'. *RES ROMANAE*. <http://resromanae.berkeley.edu/node/1109> (accessed 22 December 2017).

Peña, J. T. (forthcoming) 'Evidence for pottery production from the Torre VIII/Porta di Nola refuse middens at Pompeii'. in L. Toniolo and M. Osanna (eds) *Fecisti Cretaria. Produzione e*

*circolazione ceramica a Pompei. Stato degli studi e prospettive di ricerca.*

Peña, J. T. and Cheung, C. (2015). 'The Pompeii Artifact Life History Project: conceptual basis and results of first three seasons'. in C. Gambardella (ed.). *Heritage and technology. Mind, knowledge experience. Le Vie degli Mercanti XIII Forum Internazionale di Studi* (Fabbrica della conoscenza 56), 2115–23.

Pérez-González, J. (2017). 'Purpurarii et vestiarii: El comercio de púrpuras y vestidos en Roma', *Studia antiqua et archaeologica* 22/2: 149–94.

Perry, J. (2006). *The Roman collegia: the modern evolution of an ancient concept*. Leiden.

Pollard, A. M. and Bray, P. (2014). 'Chemical and isotopic studies of ancient metals.' in B. W. Roberts and C. P. Thornton (eds). *Archaeometallurgy in global perspective*. New York, 217–38.

Pomey, P., Kahanov, J., and Rieth, E. (2012). 'Transition from shell to skeleton in ancient Mediterranean ship-construction: analysis, problems, and future research', *IJNA* 41/2: 235–314.

Ponting, M. and Levene, D. (2015). 'Recycling economies, when efficient, are by their nature invisible: a first-century Jewish recycling economy', in M. Geller (ed.) *The archaeology and material culture of the Babylonian Talmud* (IJS studies in Judaica 16). Leiden, 39–65.

Profita, C. (2017). 'Recycling chaos in U.S. as China bans "foreign waste"'. *National public radio*. December 9, 2017. <https://www.npr.org/2017/12/09/568797388/recycling-chaos-in-u-s-as-china-bans-foreign-waste> (accessed 16 December 2017).

Rahtje, W. and Murphy, C. (2001). *Rubbish! The archaeology of garbage*. Tucson.

Remolá, J.-A. (2000). 'Sobre la interpretación arqueológica de los vertederos', in Dupré Raventós and Remolà (2000), 107–21.

Remolá, J.-A. and Pérez, J. (eds) (2011). *La gestión de los residuos urbanos en Hispania* (Anejos de archivo de español de arqueología LX). Mérida.

Ringbom, Å. and Hohlfelder, R. (eds) (2011). *Building Roma aeterna: current research on Roman mortar and concrete*. (The Finnish Society of Sciences and Letters 128). Helsinki.

Robinson, O. E. (1992). *Ancient Rome: city planning and administration*. London.

Rodet-Belarbi, I. (2003). 'Répartition spatiale de dépotoirs de boucherie bovine dans les agglomération gallo-romaines. Première approche', in Ballet, Cordier, and Dieudonné-Glad (eds), 197–217.

Rowan, E. (2015). 'Olive oil pressing waste as a fuel source in antiquity', *AJA* 119/4: 465–82.

Schiffer, M. (1987). *Formation processes of the archaeological record*. Salt Lake City.

Schwartz, J. (2006). “Reduce, reuse and recycle” Prolegomena on breakage and repair in ancient Jewish society: Broken beds and chairs in Mishnah *Kelim*, *Jewish studies on internet journal* 5: 147–80.

Scobie, A. (1986). ‘Slums, sanitation, and mortality in the Roman world’, *Klio* 68/2: 399–433.

Siddall, R. (2011). ‘From kitchen to bathhouse: the use of waste ceramics in Roman mortars’, in Ringbom and Hohlfelder (eds), 152–68.

Sidebotham, S. (2011). *Berenike and the ancient maritime spice route*. Berkeley.

Spelman, E. (2016). *Trash talks*. Oxford.

Taylor, M. (2017). ““Total monster”: fatberg blocks London sewage system”. *The Guardian*. September 12, 2017. <https://www.theguardian.com/environment/2017/sep/12/total-monster-concrete-fatberg-blocks-london-sewage-system> (accessed 16 December 2017).

Thomas, R. (2011), ‘Roman vessel stoppers’, in Peacock and Blue (2011), 11–34.

Toniolo, A. (2008). ‘I vetri da riciclare del relitto Grado I’, *Aquileia nostra* 79: 481–500.

United States Environmental Protection Agency. (no date). 'Municipal solid waste'.  
<https://archive.epa.gov/epawaste/nonhaz/municipal/web/html/> (accessed 22 December 2017).

van Minnen, P. (1994). 'House-to-house inquiries: an interdisciplinary approach to Roman Karanis'. *ZPE* 100: 227–51.

Vecsey, A. (2012). 'Utilization of animal skeleton elements', in Biró Mária, Choyke, Vass, and Vecsey (2012), 67–71.

Whitehead, P. J. (2017). 'Eli Whalley & Company'. *The industrial heritage of Britain*.  
<http://www.pittdixon.go-plus.net/donkey-stones/donkey-stones.htm> (accessed 16 December 2017).

Whitewright, J. (2011). 'Wooden artifacts', in Peacock and Blue (eds), 167–78.

Whittaker, C. R. (1992). 'The poor', in A. Giardina, A (ed.), *The Romans*. Chicago, 272–99.

Zelenkova, B. (2015). 'Zabbaleen – the garbage collectors'. *The ethnologist*.  
<http://ethnologist.info/2015/08/28/zabaleen-the-garbage-collectors/> (accessed 22 December 2017).

Zimring, C. and Rathje, W. (eds) (2012). *Encyclopedia of consumption and waste: the social science of garbage* vols. 1-2. Los Angeles.