Anuario de Estudios Medievales
52/1, enero-junio de 2022, pp. 185-207
ISSN 0066-5061
https://doi.org/10.3989/aem.2022.52.1.07

RECYCLING OF MATERIALS AND REUSE OF PRODUCTION LABOR RESIDUES IN LATE MEDIEVAL EUROPE*

RECICLAJE DE MATERIALES Y REUTILIZACIÓN DE RESIDUOS DE LABORES PRODUCTIVAS EN LA EUROPA BAJOMEDIEVAL

Ricardo Córdoba de la Llave
Universidad de Córdoba
https://orcid.org/ 0000-0003-0186-7290

Abstract: This work aims to address the recycling of materials and the reuse of production waste in late medieval Europe. It is divided into three sections; the first deals with the systems used to extend the use-life of different objects and materials; the second, with the methods used to recycle some of these by inserting them into a new production cycle, which allowed them to form part of new products; the third examines which were the main by-products of medieval industry, that is, waste materials that were reused for other production tasks. A brief assessment of the importance of these practices, both for society and for the medieval productive economy, closes the article.

Keywords: recycling; reuse; reemployment; industry; crafts.

Resumen: El trabajo tiene por objeto abordar el reciclaje de materiales y la reutilización de residuos generados en las labores productivas de la Europa bajomedieval. Está articulado en tres apartados, abordando primero los sistemas empleados para la prolongación de la vida útil de distintos objetos y materiales; en segundo lugar, los métodos usados para el reciclaje de muchos de ellos mediante inserción en un nuevo ciclo productivo, que les permitió formar parte de nuevas obras; y, por último, a examinar cuáles fueron los principales subproductos de la industria medieval, es decir, aquellos materiales de desecho que fueron reutilizados para otras labores de producción. Una breve valoración sobre la importancia de estas prácticas, tanto para la sociedad como para la economía productiva de época medieval, cierra el artículo.

Palabras clave: reciclaje; reutilización; reempleo; industria; artesanía.

Summary

* This work was undertaken within the framework of project "*Pruévalo e verás ques çierto*. Recetas y conocimientos de la sociedad medieval para el siglo XXI" (PID2019-108736GB-I00), funded by Agencia Estatal de Investigación, Ministerio de Ciencia e Innovación.

Citation / Cómo citar este artículo: Córdoba de la Llave, Ricardo, (2022), *Recycling of Materials and Reuse of Production Labor Residues in Late Medieval Europe*, "Anuario de Estudios Medievales" 52/1, pp. 185-207. https://doi.org/10.3989/aem.2022.52.1.07

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1. Introduction[1]

Some authors have adopted an ontological perspective within which the history of objects is approached as a sort of biography; objects undergo various transformations between their birth and their demise. In this way, although an object is a unique thing, it transforms in the transitions from the raw materials that constitute it to its production, use, repair, and discard. Unlike human beings, however, objects do not necessarily follow a single linear path; these changes that mark the object's life trajectory are what we term reuse or recycling, defined as a change of user, use or shape[2].

Michael B. Schiffer defines three types of reuse. The first is what he calls "lateral recycling", and is characterised by the recovery of matter, that is, the change of user or social unit of use of the object, without the shape or function of said object changing in any way (*e. g.* a handed-down garment or a Roman column reused for the same purpose in a medieval building); the second is referred to as *recovery*, and is the process whereby the constitutive materials of an object (metal, glass) are, after an initial period of use, transformed to make a new object (*e. g.* old cloth to make paper, glass cullet to make new glass vessels); and, the third is what he calls "deviation", which is giving an object a new use without substantially changing its shape (*e. g*. a Neolithic arrowhead used as an amulet in the Middle Ages)[3]. In this way, the use-life of things can be prolonged indefinitely, or their materials reborn in new forms; another means of prolonging their life.

Strictly speaking, "recycling" is the use of production waste as a raw material to create new objects or components that will later be used in other production processes. In modern Western society, the reuse of waste came to the fore after the oil crisis of 1973, which was followed by the contraction of the hydrocarbons sector and flagged the need for renewable energy sources. In parallel, and from at least 1990, society adopted a more ecological stance, contributed to by the historical sciences, with the emergence of physical and chemical methods to characterise materials, generally in the laboratory. Similarly, history is increasingly interested in past material culture and its interaction with social relations[4].

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[1] Abbreviations used: AHN = Archivo Histórico Nacional; AHPCO = Archivo Histórico Provincial de Córdoba; AMC = Archivo Municipal de Córdoba; LO = Libro de Ordenanzas (Statutes Book); PNCO = Sección de Protocolos Notariales de Córdoba (Notarial Records).

[2] Schiffer 1987, p. 28.

[3] Smail, Pizzorno, Hay 2020, p. 394.

[4] Ballet, Cordier, Dieudonné-Glad 2003, p. 9.

From an economic perspective, the logic of recycling relies upon the revalorisation of the object, putting waste to use as a way to save raw materials and energy, avoiding its accumulation and the associated pollution, and giving rise to new economic activities and employment. Within the realm of production, the revalorisation of matter, that is, using waste to replace another element, is particularly important. Therefore, "reuse" is the repeated use of an object for the purpose for which it was originally intended; "regeneration" is the transformation of the physical-chemical characteristics of matter to adapt it to a new use; and "recycling" is the use of waste generated by one production cycle in a different one (*e. g*. metal, pottery, glass, wood, textiles, paper)[5].

2. Prolongation of use-life and continuity in new uses

In the Middle Ages, people stretched the use-life of an object thoroughly before transforming it, either by repairing it or by putting it to a new use that did not demand changes to its external appearance or physical properties. This is an essential feature of preindustrial societies, and remains so in many societies today, where the cost of some objects or materials recommends this practice. As noted by Ellen Swift, prolonging the use-life of an object reflects its "value" to the owner, which may be economic but could also be a projection of emotional attachments or acquired habits. Although reuse is frequently defined in terms of the cost of replacing an object with a new one (and objects are used to the limit), in other instances the relevant factor is emotional and/or psychological: objects are frequently attached to memories, or are gifts from loved ones, so their value lies beyond the material realm, and is strictly personal[6].

To illustrate this with a few medieval examples, we can begin by recalling that mending, stitching up and patching textiles were very common practices in the domestic sphere. The prominent role played by occupations related to sewing (*e. g*. tailors, seamstresses), reinforcing seams and hems, mending cloth, etc. speaks for itself. This is a sector of which we know comparatively little, because most needlework was undertaken by women in domestic contexts. The majority of women could sew and spin, another activity that often took place in the context of women's household duties. Although no tapestry production is attested for Córdoba in the late 15th century, the use of sackcloth to repair French cloth and tapestries is well-known as an activity

[5] Dommanget, Loiseau, Masiero 1998, p. 5.
[6] Córdoba 1990, pp. 135-136; Swift 2020, pp. 426-427; Fennetaux 2015.

undertaken by specialist seamsters. Archaeology has identified several examples of this activity in earlier pieces[7].

Concerning leather, it was customary to reuse scraps of old footwear to mend shoes. Cobbling was a traditional trade, present in every medieval city and village, as indeed it is widely present today. In the Middle Ages, much of the cobbler's work consisted of taking still-usable scraps from old shoes to create patches or to reinforce worn out soles[8]. Véronique Montembault reports archaeological evidence for the reuse of shoe scraps to repair the vamps of other pieces of footwear. It appears to indicate that only children's shoes were not reused in this way, as the small amount of leather that they provided made the practice uneconomical[9].

In architecture, it was common to reuse old iron from old buildings. This was done in four different ways. The first was to reuse the iron without changing its form, so that it might serve the same function in the new building as the old, particularly in terms of dimensions and mechanical lode. The cost of this form of reuse was minimal (*e. g.* glass windows pieces applied to similarly-sized glass windows). The second involved cutting off part of the reused piece, a similarly low-cost operation. The third method was to solder two or more pieces together to adapt them to a new use, which was also a low-cost practice, as the only cost was the welder's wages. The fourth way was to blend several pieces together by heating and hammering, and this was the costliest operation of all[10]. Damaged or broken copper objects were repaired with plates attached by means of rivets, and hammered against a small anvil[11].

Pottery was recycled in many different ways. Often, the base or the walls of pots were cut in a circular shape (2 to 5 cm in diameter, although sometimes larger ones are found, up to the entire base) to be used as game counters[12]. Some examples cut from glazed vases were found in a 15th century context near the city wall in Ronda del Marrubial, Córdoba, and in Caliphate-period contexts also in Córdoba, as well as at the site of Pechina (fig. 1).

[7] Wild 2020, pp. 54 and ss.
[8] Woodward 2005, p. 197.
[9] Montembault 2020, pp. 389-390.
[10] Dillmann, L'Héritier 2020, pp. 160-161.
[11] Thomas, Saussus 2020, p. 359; Saussus 2019, pp. 136-143.
[12] Claude, Lefévre 2020, pp. 403-404.

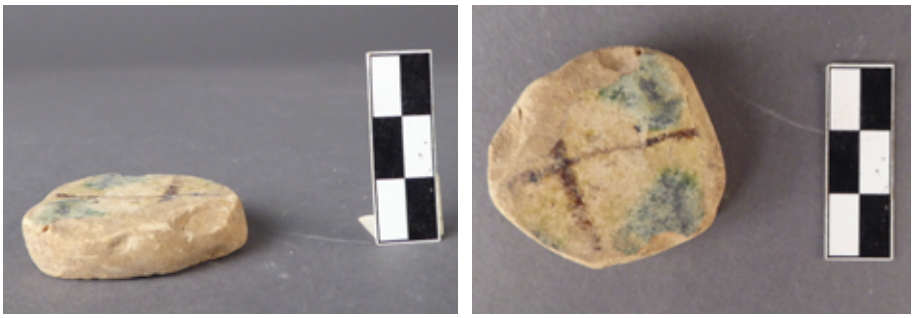

Fig. 1. Game counter cut from a polychrome glazed ataifor in Pechina (Almería), 10th century (image courtesy of Elena Salinas).

Closed containers were also cut through the middle, with the bottom half applied to various uses including as an open container to feed animals, as a charcoal brazier and as a lid. Some vases are known with a perforation drilled into the base after. The function of these is unclear, but they might have been used to roast chestnuts, store bread or preserve foodstuffs, or as a brazier or plant pot. Closed shapes with holes in the upper part may have been used to collect water from wells, with a string threaded through the holes[13].

The most common way to prolong the life of a broken ceramic vase was to assemble the pieces back together with glue or staples. The excavation of the north-western sector of Sacunda suburb, Córdoba, yielded 22 pots found *in situ* (where they were originally left, in two groups of fifteen and seven respectively), two lead staples and a ceramic fragment with a lead staple still attached. It seems that the employment of staples to prolong the use-life of vases was common practice (fig. 2)[14].

Ceramic vases were also used to fill vaults. Juan Bassegoda identified late 14thcentury records of the purchase of new amphorae and ceramic wasters to fill the vaults of Cordoba Cathedral among its *Libros de Obra* archive. Similar records have been attested in the *Libros de Obra* of Barcelona Cathedral, which uses the term *frentum*, from the Latin *fractum*; that is, broken, defective pieces for which only the transport costs were paid. The filling over the webbed vaults in the cloister at this cathedral consists of a layer of lime mortar and stones, one of amphorae mixed with mortar and another of smaller vases bound with mortar, all of which was covered by an external layer of brick. The use of ceramic vases as fillers makes perfect structural sense;

[13] *Ibidem*, pp. 406-408.
[14] Casal 2018, p. 127. Other ways of ceramic repair, Laire, Moitrel, Le Maho 2022, pp. 56-62.

they act as a light cement, which, being hollow, is extremely resistant without adding excessive weight to the ceiling. Although this cannot be considered an innovation of Gothic architecture, nor even a late medieval development (Roman, Byzantine and Romanesque examples are known), the use of defective ceramic vases in medieval vaults illustrates the ingenuity of the architects of the period, which were clearly aware of the technical and economic advantages of recycling (fig. 3)[15].

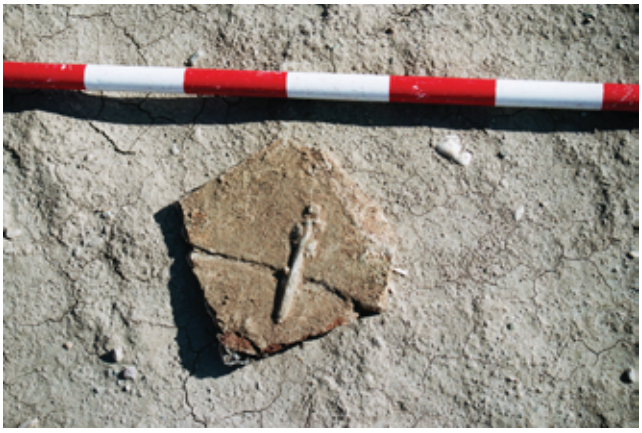

Fig. 2. Lead staple used to repair a pot from the excavation of the Emirate-period suburban district of Sacunda (Córdoba), 9th century (image courtesy of M.ª Teresa Casal).

Fig. 3. Vases used as fillers in the vaults of Vic's cathedral, 14th century (image courtesy of Judit Molera).

[15] Bassegoda 1989, pp. 135-137.

The excavation of pottery workshops has provided evidence for the frequent reuse of ceramic wastes, which far from being simply discarded were incorporated into walls or the structure of new kilns. Others were used in tombs, as candleholders, braziers to burn aromatic herbs or to protect grave goods. Stacked on top of one another, they were also used as ceramic alembics to distil vegetal oils, and some ended up as weights in fishing nets[16].

3. Recycling through reuse in a new production cycle

Broken and deteriorated elements that could no longer be used for their original purpose were recommissioned to produced new things, that could be similar in nature to the original object, or totally different from it. Recycling is to introduce matter into a new production cycle, either "internally", when a workshop reuses its own waste, or "externally", when useless or outmoded objects are made part of a new cycle. How common these practices were is often hard to establish[17].

Concerning external recycling, iron objects, which could not be fully melted owing to technological limitations, were reshaped by heating and hammering, as mentioned in multiple medieval and early modern documents from across Europe; this has led Donald Woodward to estimate that approximately 10 % of iron objects were recycled in 17thcentury England. The task fell to urban ironsmiths, and is documented chiefly in relation to building projects. The main purpose of this was to curb construction costs, and these practices may have systematically saved the builders between 30 % and 50 % in iron; in Rouen Cathedral, the iron frames of the 13th century windows were reused in new windows between 1430 and 1433, saving the builders approximately 40-45 % in iron costs[18].

Another way to identify iron recycling practices is through chemical analysis, which reveals the composition of the metal after it is reduced from the mineral. These analyses have revealed the reuse of old iron in combination with newer iron in the production of grilles, horseshoes, mining tools, knives, and all manner of objects for which reused iron is an obvious choice, although a scrap iron market, such as those emerging around textiles and glass, never crystallised in the Middle Ages[19].

The reuse of non-ferrous metals has been the usual practice in all historical periods. The characteristics of gold, silver, copper, tin and lead

[16] Claude, Lefévre 2020, pp. 410-412.
[17] Thomas, Saussus 2020, p. 356.
[18] Woodward 1985, p. 178; L'Héritier, *et al*. 2020, pp. 369-373.
[19] *Ibidem*, pp. 375-381.

allow them to be melted and remelted time and time again, with minimal loss of metal in each melting cycle. The raw materials were expensive, the exploitation of mines challenging, and mineral sources were frequently far from the point of consumption. In contrast, these metals were eminently recyclable and the objects themselves were less valuable than the material of which they were made. Therefore, throughout the Middle Ages and the Early Modern period, useless or out-of-fashion objects in copper-based alloys, for which a ready raw supply was not always guaranteed, ended as a rule at the bottom of a crucible, where they were turned into more useful or desirable things[20]. It is worth recalling that copper- and lead-based alloys can be remelted indefinitely, hence their constant recycling into new things or (in oxide form) as the paints used to decorate glazed pottery[21].

The reduction of freshly mined ore to extract the metal was a costly operation. The resultant metal had to be extracted, washed, refined and moulded before it could be made into an object, and each step involved capital, labour and transport costs. It is for this reason that the sources regularly make the distinction between old and new metal, between ingots and tableware and other objects for remelting. Urban regulations all over medieval Europe demanded retailers to make clear whether an object was made with new or old copper, and even that the work in each was undertaken by a different trade; clear evidence exists for the increasing importance of the second-hand market between the 13th and the 16th centuries. In addition, repairing objects with metal patches was also common practice, as noted above[22].

In the mint, masters not only used newly mined gold and silver, combined with new copper to achieve the necessary composition, but also reused the metal shavings that resulted from melting rods, cutting planchets, and stamping the coins, that is, all the metallic by-products generated during production in the mint. The 14th century Alloy Books (*Libros de aleaciones*) used in the Crown of Aragon's mints, record the melting together of fine silver, pure copper and silver shavings. After each batch, the workshop was carefully swept, recovering a mixture of the shavings, charcoal, dust and dirt. This was carefully washed to collect the precious metal. All the trimmings resulting from the cutting of the planchets were also collected and melted again, as studied by R. Córdoba or A. Estrada-Rius[23].

The reuse of precious metal was widespread in all sectors in which it was employed; the value of these metals was too high for the smallest frag-

[20] Thomas, Saussus 2020, p. 355.
[21] Pernot 1998, p. 124.
[22] Thomas, Saussus 2020, pp. 358, 361.
[23] Córdoba 2009, pp. 168-169, 201-202, 211-213; Estrada-Rius 2018, p. 364.

ment to be lost. Silversmiths and goldsmiths employed mercury, antimony and sulphur to extract the gold that remained attached to the cement during the refining process, cut the lipping that resulted from the whisking of gold and silver leaf, and carried out many other operations to collect even the smallest quantity of precious metal. Precious metal shavings were remelted to give shape to new objects or used to make gold and silver paints (glitter) and powders used by gilders in various decorative techniques[24].

Broken construction materials (bricks, rooftiles, tiles, mouldings) that could no longer be used for their original purpose were ground and used in mortars. Often, medieval builders laid floor tiles and wall linings on a layer of flexible material, referred to as *alcatifa* in 15th century construction contracts from Córdoba; this layer was composed of a lime and sand mortar with brick and tile fragments, which gave the mix greater stability[25]. Broken ceramic vases or wasters that could not be mended were frequently used in mortars, including waterproof lime mortars which set even in conditions of high humidity. In addition to slaked lime, these mortars included silica or alumina, metal scoria and ground brick or tile[26].

Broken and poorly fired pottery was often finely ground to make *chamota*, later used as grog temper in new pottery. When the clay used in pottery production is too plastic, this can be corrected with the addition of tempers, which are inert and non-hydrating materials that form a solid inner skeleton for the clay; common tempers that were added to the clay in the Middle Ages included ground stone, quartz-rich sand, and ground pottery (grog)[27]. These tempers can often be identified in the pottery, especially coarse wares, via optical microscopy. For example, Elena Salinas, working with a piece of kiln furniture found in the Andalusi site of Pechina (Almería) (Emirate period), was able to identify, in addition to changes in the colour of the clay, the remains of glazed pottery, which was very likely intentionally added as grog temper during the preparation of the clay (fig. 4)[28].

Glass shares with certain metals –including gold, silver, copper, lead and tin– the potential to be remelted almost indefinitely. Partially for this reason, the recycling of glass cullet was common practice in Antiquity and the Middle Ages, but there was a technical logic behind this too, as the introduction of glass cullet in a batch reduces the melting temperature of the raw materials used to make glass (silica and a flux). This is attested by

[24] Córdoba 2014, pp. 268-275.
[25] Córdoba 1996, p. 157.
[26] García de Miguel 1996, p. 44.
[27] Córdoba 1998, p. 164.
[28] Salinas, Pradell, Molera 2019, p. 204.

both the written and the archaeological records[29]. Danièle Foy points out that glass cullet was added to the batch in variable proportions, but never in excess of one third of the batch total. The practice was so common that recycling always needs to be taken into account in the interpretation of compositional analysis of archaeological glass. Similarly, the excavation of glass workshops often yields very few glass remains, because the material was used and recycled exhaustively[30]. According to Chloe Duckworth, the occasional accumulation of large assemblages of glass cullet in workshops (*e. g*. in the Iberian Peninsula Recópolis and Casón de Puxmarina, Murcia) is an indication of the systematic collection of old glass for recycling. Analytical data suggests that up to 50 % of glass fragments present chemical markers that could be indicative of recycling[31].

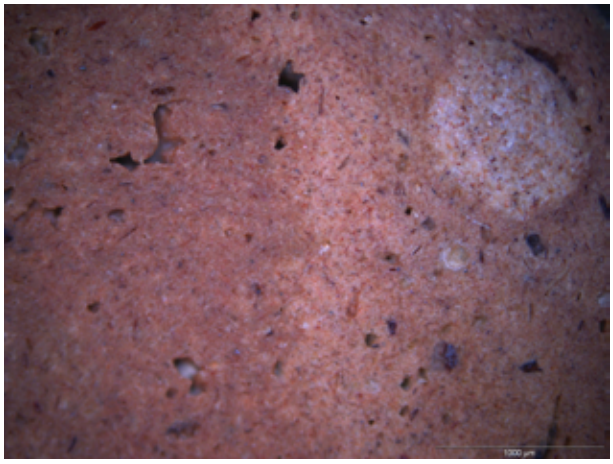

Fig. 4. Electron microscope image (dark field DF, 5x) of a fragment of *chamota* within the fabric of atifle PE3 from Pechina (Almería), 9th century (image courtesy of Elena Salinas).

Early medieval texts, for instance by Gregory of Tours and the monk Theophilus Presbyter, confirm the widespread nature of the practice. In 1331, Marseilles City Council passed strict norms to regulate the sale and recycling of glass cullet, and Miguel Ángel Capellà has found 14th and 15th century notarial records in Mallorca that attest that glass cullet was brought in from

[29] Foy 2003, p. 271.
[30] Foy 2018, p. 267.
[31] Duckworth 2020, pp. 313-317, 345.

Menorca and other places for recycling. For example, a Genoese ship was loaded, among other things, with *barrilia plena vitro coloris blavis*. A similar example is posed by a vessel stocked with glass setting sail from Mallorca to Bugia: both the container used and the price, barely 77 *sueldos*, strongly suggests that this glass was in the form of cullet for recycling[32].

Laboratory analyses of Carolingian glass have shown that a high sodium content in glass made with potash-rich plant ash reflects the continuous recycling of ancient glass[33]. In contrast, analyses carried out by David Govantes-Edwards with Spanish glass indicate that significant amounts of antimony, one of the most reliable markers of the recycling of Roman glass, are exceptional in the Iberian Peninsula, having been found only in Madīnat al-Zahrā and Málaga, and the same can be said about common colorants and opacifiers, such as copper, cobalt, tin and lead[34].

Chloe Duckworth has identified bangles and other similar glass objects as the final step in the life-cycle of glass, that is, they were objects made with glass which, after undergoing a large number of melting cycles, has accumulated impurities, especially heavy metals, that makes it less malleable and no longer susceptible to blowing. This is based on the presence in the glass of high concentrations, but not high enough to suggest a deliberate addition, of colorants, such as cobalt and copper, decolourisers, such as antimony, and opacifiers, such as tin and lead[35].

4. Use of industrial by-products

Other materials cannot be said to have been recycled, such as production waste, which could often be used as a raw material for different production processes. This waste was generally in the form of discard from raw materials processing, or the by-product of transformation processes. In the textile industry, for instance, the spinning of wool, flax and hemp left important residues that could be commandeered for other processes.

The preparation of wool cloth left what Claude Carrere and Dominique Cardon have referred to as "recovery wool"[36]. The operation of carding consisted of brushing the raw wool, which hung from a trestle, with cardon heads to remove fluff. Shearing consisted of the removal of excess fibres with large

[32] Foy 1988, pp. 781, 791.
[33] Foy 2003, p. 274.
[34] Govantes-Edwards 2021, pp. 395-398.
[35] Duckworth, *et al*. 2016, p. 162; Freestone 2015, p. 30; Paynter, Jackson 2016, p. 41.
[36] Carrere 1967, p. 436.

blunt-pointed shears. These processes, undertaken in the fulling mill, resulted in the *borra* or *tundizna*. Weaving processes yielded the *pezuelos* or *peçol*s, hanging threads, which were especially numerous at the head and at the tail of the piece of fabric. These materials, which would have been wasted otherwise, could then be reused. Most European urban regulations established that they must be used for domestic purposes and not sold, although their use was by no means forbidden[37].

The widespread use of this material is attested by numerous sale contracts from the city of Córdoba; *e. g*. in January 1494, Fernando de Córdoba, *mayordomo* of *regidor* Gómez de Aguayo, leased the *pelaire* Fernando López a fulling mill in the Guadalquivir River for six years, for an annual rent of 8500 mrs., 20 pounds of *borra*, 10 of *blanca* and 10 of *voltiza* (mixed) wool[38]. The famous manuscript of Naples, an Italian 15th century recipe book, mentions clay, ass's dung and *tundizna* as the ingredients of *luto sapiente*, a mixture used to seal ceramic vases that were to be put on a fire, and used regularly in metallurgy, coral-working and lapidary[39].

Concerning the processing of flax, hemp and wool fibres into cloth, it is well known that the raking of flax resulted in *estopa*, which could be spun and woven, just like the flax from which it came, although the *estopa* cloth was cruder than linen. The use of *estopa* was widespread in the Mediterranean, especially in the Iberian Peninsula in the 15th century. The maceration of hemp left the so-called *tascos de cañamazo* as a by-product. These thick fragments of the woody parts of the stalk were, like the *borra*, used as stuffing for cushions and mattresses.

The raking of hemp produced five different qualities of fibre. Maceration left the thicker fibres, also known as *estopa*, in the rake. *Chorrón* were the finer fibres detached after a second raking, while *canal* hemp was what remained of the hemp after the extraction of *chorrón* and *estopa*. This was of a higher quality than the first two, but inferior to *medio cerro* and *cerro*, the result of raking *canal* hemp a second and third time, respectively, once the hemp was completely free of loose fibres. Rope-makers made frequent use of these fibres, and their regulations, issued in Córdoba in 1496, forbid mixing *estopa* and *cerro*, or selling *estopa de canales* as *medio cerro*[40].

The reduction and refining of galena and the separation of lead and silver by cupellation resulted in litharge, a lead oxide known in 15th and

[37] Cardon 1999, pp. 109-111.

[38] 1494.01.25, AHPC, PNCO, leg. 13669P, f. 465r.

[39] "Bene lutari de bona argilla, bene speciata cum stercore asinino et cum zimatura pannorum" (Brunello 1975, p. 56).

[40] Rope-makers Regulation 1496, AMC, LO 1º, f. 87v (González, *et al*. 2016, p. 269; Córdoba 1990, p. 93).

16th century Castile as *almártaga*. Litharge was sold to potters for making glaze and to jewellers for making enamel, although it was occasionally remelted again for the cupellation of new lead. In December 1529, the galena mines belonging to the Count of Belalcázar and located in the town then known as Villanueva del Marqués (modern Villanueva del Duque, in the province of Córdoba), refined 36 *arrobas* of lead, which yielded two marks of silver and 32 *arrobas* of *almártaga*. A hundredweight of *almártaga* was generally sold for approximately one ducat, but it could sometimes fetch a higher price, between eight and fourteen *reales*, as was recorded for the *almártaga* bought by gunner Gonzalo Gómez in July 1544[41]. Some glasses present traces of the addition of metal slag, such as examples from Melle (Deux-Sèvres), the largest galena mine in operation during the Carolingian period. The use of litharge in glass is a clear example of the valorisation of the by-products of lead and silver mining. It is worth recalling that lead has fluxing properties, reducing the melting point of glass (which means substantial savings in fuel). There is circumstantial but firm evidence that glass from Madīnat al-Zahrā contain lead obtained by cupellation in the city's mint[42].

Some of the materials by-products from butcher's shops and slaughterhouses can also be regarded as industrial. If the main purpose of slaughtering livestock was to supply meat for human consumption, the skin of the animal, which cannot be used for that purpose and was sold to make leather, can certainly be regarded as such. The horns and bones of some animals, especially deer and bulls, were highly regarded by turners for their mechanical properties, which were like those of wood. They were used to make a wide array of everyday objects, including combs, awls, rods, and gaming counters. For example, the heads of ox femurs were often formed into spindle whorls, a universal tool for medieval women[43].

Butchers' shops were also a source of animal fat (tallow) for candles. Though inferior in quality to beeswax, tallow was a good deal cheaper. Fats were also employed to soften leather during tanning, and as lubrication for the axles of cutting machines, the sockets of grindstones, and more complex mechanical devices such as those found in fulling mills. Finally, animal entrails were used to make strings for musical instruments, such as vihuelas, and were used to form so-called *moldes* and *soldadas*. These were square-shaped patches of gut tissue used by gilders to sandwich fine sheets of precious metal before they were carefully hammered into gold leaf[44].

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[41] 1529.12.03, AHN, Osuna, leg. 3633, n.º 25, f. 14r (1 *arroba* = 11,5 kg. 1 hundredweight = 4 *arrobas* = 46 kg).

[42] Gratuze, Foy, Tereygeol 2003, p. 105; Govantes-Edwards, Duckworth 2020, pp. 40-42.

[43] Goret 2020, p. 37.

[44] Córdoba 1998, p. 167.

Tanners also discarded of all those parts of the animal hide that could not be turned into leather. This resulted, for instance, in what in Castile was known as *peladiza* or *de peladas* wool, which was not the by-product of the shearing of dead animals, but of the scraping in tanneries of the hides of animals slaughtered for food. These wools did not enjoy the best of reputations, because they broke easily, but they were widely traded in the Western Mediterranean, and Dominique Cardon estimates that up to 10 % of the wool in circulation could belong to this category. The processing of this wool was a major activity in urban centres of Languedoc (Perpignan, Toulouse) and the Crown of Aragón (Palma de Mallorca, Barcelona); the 15th century archival records from Barcelona are especially eloquent concerning the production and consumption of this type of wool[45].

This activity was only allowed during certain seasons due to the importance of wool fibre length in the textile industry. Obtaining *peladiza* wool from recently-shorn hides in April-May was frequently forbidden, as the resulting fibres would be too short, but the practice was recommended from September to April. This is set out in urban regulations such as those of Mallorca (1467), which forbid the commercialisation and use of this by-product between May and July, and Catalonia (1422), which extended the prohibition to late September[46]. In Córdoba, the first ordinance of bonnet-makers denounced bonnets made *with lana peladiza from the tannery, which is bad and false*, and established that *hereafter no bonnet is to be made with lanas peladizas from the tannery or elsewhere, but only with shorn wool*; later ordinances were more lax, in the sense that the use of this product was permitted between 1 September and 30 April[47].

The same method could be used to obtain goat hair. During the 13th century, urban regulations of Colliure, Barcelona and Valencia include numerous references to the use of goat and kid hair. In Gerona, ram and she-goat hair, spun and unspun, are mentioned in the *Libre del Mostassaf* (1367). In general, the regulations forbid the use of this material in the manufacture of fine cloths, but authorise them for coarse cloth, blankets (known as *de pelote*), and hats (although the animal whose hair was most often used for this purpose was, and remains to this day, the rabbit). Analyses of medieval cloth from London attest to the production of cloth made entirely from goat hair between the 11th and 17th centuries[48]. The aforementioned rope-makers' regulations from Córdoba

[45] Cardon 1999, pp. 97-99, 103-105.

[46] *Ibidem*, p. 100.

[47] Bonnet-makers Regulation 1497, AMC, LO. 1º, ff. 217r-v, 218v (González, *et al*. 2016, pp. 482-484).

[48] Cardon 1999, pp. 114-116.

(1496) establish that the saddle straps for beasts of burden must be of Castilian wool, and contain *no pelota, cabrita, repelón, or any other bad mix*[49].

Fig. 5. Scrapping of sheep and goat hides, depicted in *Hausbuch der Mendelschen*, f. 92r (15th century), and *De Arte Illiberalibus*, by Jost Amman (1568).

The tails, feet and other parts of the hide that could not be turned into leather were often used to make glues (in Spanish, the word *cola* is used to refer to both glue and the animal tail), adhesive pastes and similar substances, used in multiple production processes. In 1495, a group of tanners from Córdoba sold a clerk all the scraps of cow hide to come out of their workshop in the following year, for gluemaking. They agreed not to sell anything to *anyone else who makes glue*, but reserved the right to sell to saddle makers, who used glue to assemble the saddles, and painters, who used adhesive paste to prime the surface of altarpieces[50]. In April 1501, two embossers named Pedro de Soria and Juan de Palencia, from the parish of Santa María, Córdoba, formed a partnership for one and a half years: the contract establishes that Pedro de Soria was to *burnish, sew, apply paste and tie all the guadameciles* in exchange for the leather scraps. Finally,

[49] Rope-makers Regulation 1496, AMC, LO 1º, f. 88r (González, *et al*. 2016, p. 269).
[50] Córdoba 1998, p. 168.

an inventory made in a carpenter's shop in 1503 includes a *small pan with adhesive paste*[51].

Pyrotechnological activities that used firewood as fuel (bread ovens, glass furnaces and lime and pottery kilns) left abundant ashes, which were used to make certain varieties of soap and bleach. Although its market price was negligible, there was a market for this product, which was used in a large number of production activities, as the identification of numerous sales contracts between glassmakers and dyers has established[52]. In 1474, a *jurado* from Córdoba leased his bread oven to two married couples from La Rambla for 2.000 mrs. for the year and one *almud* of ash every Monday; in July 1503, Lope de Aguirre carried out a similar transaction, leasing his bread oven in Muchotrigo Street to Catalina Álvarez for 6 mrs. per day and one *celemín* of ash per week[53]. The scraps and filings of bone left by turners were, according to Theophilus, also used to make ash[54].

Almazaras returned so-called *aceite de remolidas*, a turbid oil that, being the result of the final pressing of the olives, was not apt for human consumption and was put to alternative uses. Large quantities of this oil were used to make soap, for which it was particularly suitable. Commenting upon its use in Mallorca, Margalida Bernat argues that there was no better vegetable fat to make liquid soap. Another widespread use was as fuel in lamps and other lighting devices; according to Rodríguez Molina the *remoledura* in the *almazaras* of Baeza was used to illuminate the mills themselves[55]. This oil was also used to soften leather and as lubricant in wooden machines, to mitigate the friction of rotating mechanisms.

Perhaps the most important by-product from *almazaras*, or at least the one for which the most information exists, is the *orujo* or *borujo*, formed by the crushed remains of olive pits, the high calorific value of which lent them to use in braziers, bedpans (*orujo* was used in traditional domestic braziers in Andalusia until the 1960s, when they were replaced by electrical models), and water boilers. J. Theodore Peña has demonstrated their frequent use in the Roman period, sundried in blocks or balls to facilitate transport, and Rodríguez Molina has shown that they were also used to heat the boiling water that was poured on the baskets in oil presses[56].

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[51] 1501.04.27, AHPC, PNCO, leg. 13671P, f. 184v and 1503.s.d., AHPC, PNCO, leg. 14142P, 2, f. 21r.

[52] Foy 2003, p. 275.

[53] 1474.02.01, AHPC, PNCO, leg. 13665P, 1, f. 14r; 1503.07.08; AHPC, PNCO, leg. 14142P, 8, f. 7r.

[54] Goret 2020, p. 37.

[55] Bernat i Roca 1991, p. 237; Rodríguez Molina 1991, p. 173.

[56] Peña 2020, p. 44; Rodríguez Molina 1991, p. 173.

In Córdoba, numerous sales contracts show that *orujo* was a popular choice among dyers to heat the water in the dying vats. In 1484, Bartolomé Sánchez sold Alfon Rodríguez, a dyer in the parish of Saint Peter, all the *borujo* collected in Martín Fernández's oil press for 5.000 mrs. In March 1502, Antón Ruiz del Alguacil sold a dyer from Córdoba 20 *cahices* of *borujo* from La Rambla, at 170 mrs. per *cahiz*, to be delivered in the month of April. In March 1503, Elvira Díaz sold the dyer Rodrigo Alfonso 20 *cahices* of *borujo of good local oil*, to be delivered in his *press, near Puerta de los Gallegos* on Saint John's Day, at 150 mrs. per *cahiz*'[57]. Finally, in 1513, a number of tile-makers from the suburban district of Santa María were documented buying *borujo*, no doubt to use as fuel in their kilns[58].

The importance of these by-products cannot be overemphasised. Let us take into consideration that 100 kg of olives yielded no more than 15 to 25 kg of oil, the remainder corresponding to *orujo* and other waste. A similar case exists for linseed oil, the processing of which left a solid residue called *torta*. When ground, *torta* could be used to make linseed bread or *bagazo*, which was used as animal fodder[59]. The by-products of crushed sugarcane were used as fertiliser or fuel[60].

5. Conclusions

All this waste which, far from being discarded, played a central role in other production processes suggests that we must not think of industrial waste only in terms of garbage, bad smells, infection and pollution; it was also regarded as a source of raw materials for which a use could be found, cancelling the negative connotations attached to the very notion of waste. And although it is true that these by-products were but a small proportion of the raw materials consumed by the production sector, we must view their significance in perspective; today, our cities still struggle with the management of waste and recycling, despite a much more widespread social awareness about the importance of these tasks. The repeated recycling of glass, copper and clay, the use of ceramic vessels to make church domes lighter, and the valorisation of textile fibres that appeared to be no good for anything, demonstrate the ingenuity of medieval craftspeople, as well as the economy-driven concern to

[57] 1483.03.14, AHPC, PNCO, leg. 13666P, f. 163v; 1502.03.10; AHPC, PNCO, leg. 14141P, 3, f. 33r; 1503.03.28, AHPC, PNCO, leg. 14142P, 4, f. 32r (1 *cahiz* = 666 l.).

[58] 1513.06.07, AHPCO, PNCO, leg. 11829P, ff. 107v, 108r.

[59] Alonso 1993, p. 49.

[60] Lobo 1996, p. 232.

preserve natural resources implied in the attempts to reduce production, labour, and transport costs.

Stretching the use-life of numerous objects to the limit and exploiting by-products are inescapable distinguishing features of medieval society, from the reuse of clothing (the most important articles of which were handed down from parent to child, becoming significant testamentary items), to the repair of cloth, shoes, cauldrons, furniture, and more; from the recycling of glass or metal to make new items to their use in entirely different production activities. Much unlike us in the modern West, medieval society was alien to *discard after use* mentalities.

This attitude was prevalent in every production sector (*e. g*. textiles, leatherwork, metallurgy pottery-making, agriculture), in all three varieties: prolonging the use-life of the object; recycling matter to produce either the same type of object or a different one (*e. g.* metal alloys, glass); and using by-products and waste from one activity as the raw materials for the same or for another production process. Construction is perhaps the sector in which these different approaches can be seen most clearly, with the reuse of old material (*e. g.* iron fragments from old churches, reshaped to be put to a new use; Roman columns and capitals used as construction material in medieval castles and cathedrals); and the recycling of others (*e. g.* ceramic wasters used as fillers; fragments of tile and brick as ingredients of mortar).

This issue also has an obvious social dimension. The availability of large quantities of by-products and waste was providential for social groups which could not afford silk garments and gold pendants, but only coarse cloth and glass bangles, which were largely based on by-products and waste; these were inferior in quality, but they were affordable for much wider swathes of the population. These same social groups were also behind the prolongation of the use-life of objects, a much more economical option than purchasing new ones, even if the symbolic and sentimental value of objects can be argued to have affected all social groups in equal measure. Family heirlooms, the pendant one wore on one's wedding day, a sword wielded in battle: all were objects whose value was use-dependent and unique for their owners, quite regardless of their economic worth.

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Fecha de recepción del artículo: junio 2021
Fecha de aceptación y versión final: abril 2022