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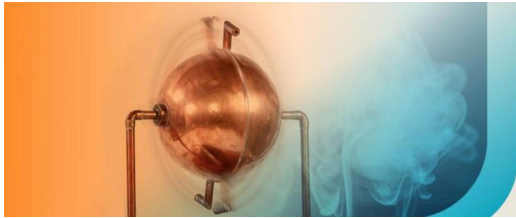
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The Board of Directors of the Association for Research on Ancient Greek and Byzantine Technology (EDABYΤ) undertook the posting on its website ([www.edabyt.gr](http://www.edabyt.gr)) of the papers presented at the 3rd International Conference on Ancient Greek and Byzantine Technology (Athens, November 19-21, 2024).

The papers had been subject to reviews and comments by the Scientific Committee. Additionally, further observations and comments were made during the discussion that followed their oral presentation at the Conference.

The papers are posted as submitted by the authors after the conclusion of the Conference. The authors are responsible for the content of their work, both in terms of their views and the accuracy and correctness of the data they present.



## REUSE AND RECYCLING IN THE GREEK WORLD

### Classical and Hellenistic Period

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#### Abstract

The present study investigates the philosophical, historical and archaeological origins and early forms of reuse and recycling in the Greek world; in particular, it focuses on the practices of reuse and recycling in the Classical and Hellenistic Period of materials, which were either valuable or of limited availability, such as metals, glass, marble, timber, textiles, papyrus and leather; on the other hand, clay products were recycled because of their abundance. In the Greek world, the various types of reuse/recycling were driven primarily by economical reasons, but also by socio-cultural considerations, political motivations and even aesthetic purposes. Archaeological finds in combination with literary and epigraphic testimonia provide evidence, although inconclusive, for the reuse/recycling of objects and materials. Sanctuaries, especially the Panhellenic sanctuaries of Delphi, Olympia and Delos, and the sanctuaries of the Acropolis contained substantial deposits of metal votives, which were reused and recycled in times of need. There are also archaeological finds, although sporadic, for the recycling of glass in the Hellenistic period. Unbroken ceramic vessels (e.g., amphorae) were reused for different commodities and in new applications, while potsherds found all kind of secondary uses. The reuse of architectural elements and sculpture has received broad archaeological and scholar interest; however, certain other types of reuse, such as lateral cycling, secondary reuse, mending, etc. leave no archaeological footprint and have received less consideration. Further, there are hardly any archaeological finds of organic items (textiles, wood, leather and papyrus), showing signs of reuse. The only available information come from literary and epigraphic sources. An effort was made to reevaluate representative archaeological finds and reinterpret literature sources through a proposed circular model, which takes into account the role of recycling and reuse in all its variations. An apart type of waste management in ancient Greece was the reuse and recycling of agricultural and pastoral byproducts resulting mainly from processing of cereals, olives, grapes and animal manure, which were used as fertilizers, food, pharmaceuticals, for pest control, in fishing applications and as building materials.

**Keywords:** Recycling, reuse, waste, Greek world, circular economy.

## 1. Introduction

Waste disposal has become an acute environmental problem of our modern societies. New manufacturing methods allow the mass production of goods leading to an increase in single-use products, especially of plastics, and the accumulation of huge amounts of waste. Current reclamation technologies used to reduce the pollution problem created by the disposed articles involve mainly controlled disposal (e.g., incineration/pyrolysis and security landfilling), recycling and reuse. Although the term 'recycling' was coined for the first time in 1924, the concept of recycling is much older. The ancient Greeks had not special words associated with the recycling or reuse of waste products. Discarded products were recycled and reused for economical, socio-cultural and political reasons. Nowadays, reclamation practices are driven by environmental and public-health concerns. Therefore, the trend to interpret ancient waste management practices with modern conceptual tools is risky and unreliable. Further, since different terms are often used in literature, it is a prerequisite for the analysis of archaeological data and ancient sources to redefine these terms.

Recycling is the process of turning an object into raw materials for a completely new product. In recycling, form and function are obliterated, and the object is reduced to its material (Kinney 2011, 3). Recycled materials are those that can be collected and either remelted (e.g. metals or glass) to form new objects or disaggregated and reformed into new materials (e.g., ceramics). In antiquity, materials that were recycled were those that were valuable (e.g., silver, gold) or of limited availability (e.g., bronze, iron and glass).

The philosophical origins of recycling can be traced in the ideas of Empedocles (490-430 BC). In the view of Empedocles,<sup>1</sup> the universe was an eternal recycling of four elements (earth, water, air and fire) in a kind of closed ecosystem. Although the recycling of elements proposed by Empedocles is of a different category from today's recycling of waste, his ideas offered the rudiments of a philosophical grounding for ecological thought (Hughes 2009).

Reuse refers to the practice of utilizing items, products, or materials again in their current form or for a different purpose. One of the early examples of reuse were the wax-coated tablets that could be smoothed and reused repeatedly. Herodotus<sup>2</sup> mentions the story of Demareteus, who sent from Susa to Lacedaemonians early intelligence of Xerxes' plans against Greece inscribed on a tablet covered with a layer of erasable wax.

Most of the studies of reuse and recycling in antiquity concern the Roman period (Duckworth and Wilson 2020; Freestone 2015; Furlan and Andreatta 2023; Peña 2007; Wild 2020), and only a few are dedicated to ancient Greece (Lindenlauf 2000 and 2003, Rous 2016).

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<sup>1</sup> Empedocles, fragment 8.

<sup>2</sup> Herodotus, The Histories, 7.239.

## 2. Inorganic Materials

The practice of recycling and reuse of inorganic materials such as metals, clay and glass is aptly attested in the Greek world. Metals and glass were recycled because of their value and/or shortage of materials. Clay products were recycled because of their abundance.

### 2.1. Ceramics

Ceramic objects were made of kiln-fired clay, which is of low value and practically indestructible. Ceramic products were manufactured in a massive scale. The produced pottery objects were widely used in antiquity for the storage and transport of goods and discarded freely providing an abundance of potsherds in almost all the archaeological sites of Greece. Although most damaged or broken pots were discarded, potsherds found multiple uses.

Potsherds were a cheap source of writing material. They were used as voting tokens, called 'ostraca' (ὄστρακα), for the well known ostracism held every year in the assembly of 5th century BC Athens. The Athenian citizens would write on ostraca the names of people they thought would threaten democracy. The writing was done by scratching the glazed surface of the potsherd. A large number of such ostraca have been found in the Athenian Agora (see Figure 1).



Figure 1. Inscribed potsherds (ostraca) used in voting to expel (ostracize) famous politicians. Museum of the Ancient Agora of Athens

Potsherds were also used to take notes, send messages, write inscriptions and make lists. Diogenes Laertius<sup>3</sup> reports that the Stoic philosopher Cleanthes (c. 330 BC – c. 230 BC) used to write down Zenon's lectures on potsherds and the shoulder blades of oxen because he could not afford to buy papyrus (χαρτία).

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<sup>3</sup> Diogenes Laertius, Lives of Eminent Philosophers, 7.174.

Geoponica<sup>4</sup> describes a trick of making wine seem old by throwing potsherds from vessels that have been filled with old wine in an amphora filled with new wine.<sup>5</sup>

Potsherds were used as amulets by Greek farmers in religious and ritual practices for the protection of crops. Geoponica<sup>6</sup> describes the use of potsherds painted with images of Heracles for the protection of crops from invasive weeds.

At the Adonia, an annual festival held in summer and celebrating with lamentations the death of Adonis, Athenian women planted fast-sprouting seeds (celery and fennel) in pots or potsherds and left them on the roof of their houses, wherein the shoots would wither and die before growing in full-sized plants as Adonis did. Figure 2 shows a lekythos depicting a woman on a ladder, turning round to receive from Eros a funnel-shaped vase filled presumably with earth to place on a roof. A receptacle with sprouting plants is on the ground, mounted on a stand. A youth (Adonis) sits by the ladder, watching the scene and behind Eros is a woman, perhaps Aphrodite (Richter 1936, 219).



Figure 2. Terracotta squat lekythos (mid-4th century BC) depicting a scene from the Athenian festival of Adonia. The Metropolitan Museum of Art

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<sup>4</sup> Geoponica is a 20-book compilation including texts from various Greek and Latin writers on agriculture and husbandry. It was written by an unknown writer in the 10th century for the Byzantine emperor Constantine VII Porphyrogenitus.

<sup>5</sup> Geoponica: Agricultural Pursuits, 7.24.

<sup>6</sup> Geoponica Agricultural Pursuits, 2.42.2.

Potsherds were used as child's play in games such as 'ostracinda' (οστρακίνδα) and 'efentinda' (έφεντίνδα).<sup>7</sup> They were also used to make spindle whorls, fishing weights, waterproof plaster or cut to size to serve as mosaic tesserae. Ground potsherds were reintroduced into crude clay to temper it before making new ceramic ware. On Minoan Crete, this ceramic powder, known as grog, was also used to manufacture mudbricks (Devolder and Lorenzon 2019).

Potters reused occasionally pithoi, after removing the narrow lower part, as walls for the firing chamber (e.g., the Hellenistic workshop at Paros). The pithos, having already been fired, was ideal in this place, because of its shape and its capability to provide heat insulation (Hasaki 2002, 89 and 90). In Corinth were found a pithos and a kantharos of the Hellenistic period that were repaired with lead clamps, as well as amphorae that were reused as parts of water installations and sewer systems (Slane, Lawall and Lund 2011, 96 and 101).

Emptied imported amphorae were used as containers for different commodities. Chemical and DNA analysis of traces of substances in the interior of some amphorae found in Greek shipwrecks in combination with graffiti labelling on their exterior provide evidence, although inconclusive, that wine amphorae have been reused for different products such as olive oil and honey (Foley *et al.* 2012, Lawall 2000).

Herodotus<sup>8</sup> records an unusual reuse of amphorae in a battle between the Phoceans and the Thessalians (c. 510-480 BC) wherein the Phoceans dug a deep trench across the advance line of their enemy, filled it with empty wine amphorae and covered them with earth. The Thessalian cavalry riding at full gallop fell in the trap, and the horses broke their legs.

There is evidence that valuable or hard to replace ceramic vessels were repaired in antiquity. Figure 3 depicts an amphora that was broken and extensively repaired. One handle was reattached with staples, and the neck of the amphora was replaced with one taken from another amphora. Lead staples were set in carved grooves and joined the two parts. It could be said that the amphora was restored instead of repaired (Dooijes and Nieuwenhuyse 2007, 20). Figure 4 depicts a red-figured kylix that was also broken and repaired. A thin sheet of bronze, only as wide as the interior diameter of the cup stem, was welded onto a bronze disk, which fit snugly into the opening at the base of the stem. When this device was in place, the mender drilled a hole through the stem of the kylix and the bronze sheet within, above the line of the break. He then threaded a bronze pin through these holes to anchor the pieces together (Elston 1990, 55-57).

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<sup>7</sup> Julius Pollux, *Onomasticon*, 9.110-12, 117.

<sup>8</sup> Herodotus, *Histories*, 8.28.





Figure 3. Herakles being escorted by Athena to Olympus in a chariot. Attic Black-Figure Neck-Amphora, 530–520 BC. Nicknamed the “Bareiss painter.” The J. Paul Getty Museum



Figure 4. Scenes of reveling men and youths. Attic red-figure Kylix, c. 450 BC. Attributed to the Euaion painter. The J. Paul Getty Museum

## 2.2 Metals

Iron, copper, lead, silver and gold were the metals used in antiquity for the manufacture of tools, weapons, ornaments, statues, coins and other objects. Each metal was used on its own or in combination with the others, or with zinc or tin to form alloys. Metal objects of iron and copper corrode with time. Bronze, an alloy of copper and tin, is only mildly subject to corrosion and is highly recyclable. Because of its alloyed nature, smiths and artisans living in areas far away from



a source of either copper or tin ore recycled bronze objects. Bronze was an expensive material, and the surviving bronze statues are rare in comparison with those made of stone. A characteristic example is the Charioteer of Delphi of the 5th century BC, the only partly surviving statue of the many tens of bronze statues that once surrounded the sanctuary of Apollo which in the long run were remelted or discarded. It is estimated that the sanctuary of Olympia housed up to 1,000 bronze statues and monuments when Pausanias visited the place in the 2nd century AD (Mattusch 1988, 109).

It has long been known that the remelting of obsolete metal objects was a labor-saving way to create new ones. Even today, the cost of metal extraction, refining and manufacture is still high enough that metal recycling remains one of the most profitable of all material recycling industries (Amick 2015, 7).

Greek sanctuaries, especially the Panhellenic sanctuaries of Delphi, Olympia and Delos, and the sanctuaries of Acropolis contained substantial deposits of metal votives, which were recycled in times of need, based on archaeological, epigraphic and literary evidence. Actually, the only form of recycling mentioned in the ancient sources is the melting of metal offerings. The verb, which is used in the sources to denote the recycling of a metal object is *καθαίρω*, which means that the object is destroyed and repurposed (Lindenlauf 2003, 30). The recycling and reuse of metal votives were driven by religious, economical, political, and artistic reasons.

Recycling old metal votives for religious reasons:

Temple treasuries, such as those from the Athenian Acropolis and Delos, record the recycling of older or damaged metal dedications that could be melted and repurposed. As Hellenistic inscriptions show, the recycling of sanctuary dedications was a common practice, often recording that the material held more importance than the object. According to Linders (1989, 284) votives were regarded as such as long as the material existed.

Two decrees, namely *IG II<sup>3</sup>, 1 1154* (220/19 BC) and *IG II 2 840* (2nd century BC), contain orders of the Assembly and Council of Athens, respectively to melt down and recast old dedications in the sanctuary of 'Heros Iatros' (*Ἡρώς ἱατρός*) to make an 'oinochoe' (*οἰνοχόη*) for the god.

Another decree, *IG VII 303* (late 3rd century BC), contains an order of the people of Oropos, a member of the Boeotian confederacy, to melt down and recast old dedications to make 'phialai' (*φιάλαι*). The procedure followed in all three cases can be summarized as follows: if some metals have become worn out of use, ad/or the offering of new objects is recommended, the melting and recasting of old dedications is decided. Therefore, a special committer is appointed, so that he compiles an inventory of the old objects, recording the weight of each object and the details of the dedicator. Repairs are made, if possible; otherwise, the objects are melted down to make new ones. Finally, inventories of both the melted objects and the new ones are published, along with the decrees describing the procedure (Lupu 2004, 32).

Metal votives recycled for economical reasons: In 434 BC, Pericles<sup>9</sup> spoke of the possibility of using gold and silver offerings, sacred vessels and other ritual equipment in order to finance the

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<sup>9</sup> Thucydides, *The Peloponnesian War*, 2.13.4, 5.

war with the Spartans. In 407/6 BC, the Athenians were obliged to melt down seven of the eight Nike statues, which were raised at the Parthenon as tributes to military valor, for the war effort. Each of these Nike statues weighed c. 2 talents of gold; by melting also other votives from the Acropolis, the Athenians must have used about 17 gold talents in order to mint staters and fractions —equivalent to 204 silver talents following a 12:1 ratio of silver to gold. With these resources the city managed to meet its military needs and its fleet emerged victorious from the battle of Arginousae (406 BC). The impact of the gold coinage is attested both in literary texts<sup>10</sup> and in a later inscription<sup>11</sup> preserving that the dies employed for the minting of the gold coins were still kept in the Parthenon just after 385/4 BC (Stoyas 2008).

According to Pausanias,<sup>12</sup> the Phoceans removed and melted down the golden tripod — dedicated to Apollo by the Greeks from the spoils taken at the battle of Plataea (379 BC) — during the Third Sacred War (356–346 BC). Plutarch<sup>13</sup> reports that the neighboring Opuntian Locrians collected these coins and melted them down to make a hydria. An Athenian inscription<sup>14</sup> records that the Athenians made two ‘phiales’ from the drachmas of ‘Stephanephoros.’

Metal objects recycled for political reasons:

While the recycling of old metal objects was socially acceptable, the melting down of treasuries by enemies to pay soldiers, or even for personal ambitions, was considered an act of sacrilege or impiety (Lindenlauf 2003, 15). Demosthenes<sup>15</sup> condemns Androtion (355/4 BC) for melting down the votive golden crowns (*στεφάνοι*) of the Acropolis and recasting them as paterae or bowls (*φιάλαι*) and inscribing his own name on them.

Lycurgus (c. 390 – c. 325 BC), in his speech against Leocrates<sup>16</sup> (330 BC), claims that the bronze stele displayed on the Acropolis was made by melting down Hipparchos’ statue, when he was sentenced to death for treason in 487 BC. The name of Hipparchus and his accomplices were inscribed on this stele too.

Strabo<sup>17</sup> reports that after Demetrius of Phalerum was overthrown as dictator of Athens (307 BC), all but one of his 300 statues were reportedly melted down and made into chamber-pots.

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<sup>10</sup> Aristophanes, *Frogs*, 720: the new gold coinage.

<sup>11</sup> *IG II<sup>2</sup>*, 1408.

<sup>12</sup> Pausanias, *Description of Greece*, 10.13.9.

<sup>13</sup> Plutarch, *Moralia*, *Why the Pythian priestess no longer gives oracles in verse*, 16.

<sup>14</sup> *IG II<sup>2</sup>*, 1028.

<sup>15</sup> Demosthenes, *Against Androtion*, 73.

<sup>16</sup> Lycurgus, *Against Leocrates*, from *Minor Attic Orators*, volume 2.

<sup>17</sup> Strabo, *Geography*, 9.1.20.

Bronze statues from the spoils of war:

The Colossus of Rhodes, one of the seven wonders of the ancient world<sup>18</sup> (Haynes 1957), was a statue of the sun god Helios, c. 33m high, constructed by Chares of Lindos between 292 and 280 BC, comprised a wooden skeleton stabilized by filling it with blocks of stone, and was said to be covered with hammered bronze plates (see Figure 5). The bronze plates were made largely from the weaponry which Demetrius Poliorcetes left behind when he gave up the siege of Rhodes in 305 BC. At the time, the island of Rhodes was the most important Greek center for casting bronze. The statue stood next to the harbor for only 56 years; in 226 BC, an earthquake caused it to fall into the water. When the Oracle of Delphi was consulted, the Oracle forbade the recovery of the statue from the water. In the 7th century AD, the Arabs raided Rhodes and dismantled any remnant of the statue and sold the bronze as scrap metal (Conrad 1966).



Source gallica.bnf.fr / Bibliothèque nationale de France

Figure 5. The Colossus of Rhodes, from the French book *Voyage Aux Sept Merveilles Du Monde* by Lucien Augé de Lassus, 1878

There is archaeological evidence that scrap metal objects including fragmented bronze statues were transported by ship for trading purposes. It has been suggested that the entire cargo of a shipwreck found in 1982 off the Israeli coast at Megadim, dating from c. 140-130 BC, consisted of scrap metal. From the vessel was recovered a Rhodian amphora containing c. 100kg of various types of scrap metal: pieces of bracelets, parts of fittings and arrowheads, as well as coins and

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<sup>18</sup> Seven Wonders of the World. The book is attributed to Philo of Byzantium, (*Φίλωνος Βυζαντίου περί τῶν ἑπτὰ θαυμάτων, δ' ὁ ἐν Ρόδῳ κολοσσός*).

the tools of a jeweler. In the shipwreck were also found fragments of statues, vessels, furniture details and nails. The ship may have been sailing from one port to another buying and selling supplies of scrap metal to be recycled (Misch-Brandl and Galili 1985, Treister 1996, 358).

The Porticello shipwreck found in the Straits of Messina, Italy, contained a mixed cargo of amphorae, lead ingots and bronze statue fragments when it sank c. 400 BC. Isotopic analyses made on samples from these objects indicate that lead in the ingots and nuggets all came from the mines of Lavrion. Other lead items recovered included portions of lead anchor stocks of mixed isotopic composition, which is common to ores from both Italy and the Levant. It seems that the lead anchor stocks may have been composed of scrap lead from several different sources, which had been melted down and mixed together.

Reworking of slags and low-grade ores:

At the end of the 2nd and the beginning of the 1st century BC, much of the silver from the exhausted mines of Lavrion in Attica was recovered from the reworking of slags and low-grade ores on stockpiles without real mining going on. Strabo<sup>19</sup> (63 BC – AD 23) describes in a passage the remelting of old refuse or dross.

Reuse of metal votives:

At the sanctuary of the Kabeiroi at Thebes in Boeotia were found at least three dedicated bronze bulls showing signs of reuse (Bedigan 2008, 162, Roesch 1985, 144, Table). Two bulls from c. 625 BC have inscriptions which date to the late 6th or early 5th century BC, and another bull dated to c. 650 BC has an inscription which places it at 500-450 BC (Schmaltz 1980: 56, no 193, 158 no 211). The significant difference in date of production, style and date of inscription, indicates reuse. Figure 6 depicts a bronze bull with inscriptions: On the right side of the body is engraved, in Boeotian alphabet, the feminine name 'XSENYLIS', and on the left side of the body is engraved 'TO PAIDI' (ΤΟΙΠΑΙΔΙ), meaning The Child. According to the inscriptions, Xsenylis dedicated the figurine to the divine Child, while surviving traces of letters below the inscription state that initially the bull was assigned to god Kabiros (KAVIRO), but at some point the assignment was changed to his son the Child (Athanasopoulou 2023).

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<sup>19</sup> Strabo, Geography, 9.1.23.



Figure 6. Bronze bull with inscriptions, c. 550-500 BC. Provenance: Sanctuary of the Kabiroi in Thebes. National Archaeological Museum. Metalwork Collection, inv. no. X 10552

A decree from Lindos<sup>20</sup> describes a practice of reusing old metal statues of Zeus Polieus (*Ζεὺς Πολιεύς*) and Athena Lindia (*Ἀθηνά Λινδία*) for economical reasons. The boule of the city auctioned off the right to rededicate iron and bronze statues stored in the 'neokoreion' of the sanctuary on the acropolis of Lindos by reinscribing their limestone or marble bases, which had become worn out or illegible (Lupu 2004, 33).

Dio Chrisostom<sup>21</sup> (AD c. 40 – c. 115) condemns the Rhodians for their habit of changing the names on statues erected to benefactors to different honorees.

Reuse of coins:

There are also cases where coins were reused. Several Greek cities countermarked old coins by striking them on reused flans and putting them afresh into circulation. The practice of countermarking old coins served political and economical purposes including saving time and cost of minting new coins.

### 2.3 Glass

There is no single ancient Greek word for the material known today as glass. The most common Greek term to be translated into English as "glass" is 'hyalos' (*ὑάλος*), although 'kyanos' (*κύανος*) and 'lithos chytos' (*λίθος χυτός*) may also refer to glass and glass-like substances (Larson 2023, 2).

One of the earliest glassmaking techniques practiced in Greece was core-forming. Core-forming is the technique of forming a vessel by winding molten glass around a core supported by a rod. After its formation, the object is removed from the rod and annealed. After its annealing, the core is removed by scraping. The most ubiquitous glass vessels of the Greek world were core-

<sup>20</sup> I. Lindos II 419/ LSS 90 (AD 22).

<sup>21</sup> Dio Chrisostom, Orations, 31.

formed. The second technique of glassmaking involved the use of open molds, either by heating chips of glass or sagging flat panels into a mold. Glass blowing, invented during the 1st century BC, enabled glass to be made more cheaply, efficiently, and quickly than had previously been possible. Two poems from the Roman imperial period written in Greek describe the processes of glass working (Reitz-Joosse 2024, 136-142). The first poem is written by Mesomedes of Crete<sup>22</sup> (early 2nd century AD). The second poem by an anonymous author depicts the various steps of glass blowing.<sup>23</sup> Major producers of glass in Greece were Rhodes and Macedonia (Larson 2023, abstract).

The recycling of glass may have been as important an innovation as glass blowing for the affordability of glass vessels and objects. In ancient times glass could be recycled only a limited number of times before a fresh batch had to be added, as the loss of sodium at high temperatures would cause the viscosity of the melt to become too high, thus making the material too stiff for processing. Secondary workshops would have had the capacity to recycle glass, as the temperatures needed to melt and mix the glass were in principle no higher than those required for glass working. Glassworkers recycled broken glass by adding glass cullet<sup>24</sup> into a glass batch while melting it, or mixing crushed or ground glass with scrap glass and, then melting them together (Franjić and Freestone 2018, 147).

Scientific analysis of ancient glass has detected compositionally mixed glasses, which suggests that the recycling of glass was already occurring during the Hellenistic period (Connolly *et al.* 2012, 96). Broken glass itself may have emerged as a commodity, collected for recycling, around this time, given the increasing availability of broken glass in urban and domestic settings as glass became more commonly used (Larson 2016, 337 and 338).

During the excavation of an ancient building in the Hellenistic city of Rhodes (1966/7), a large amount of debris from a glass workshop was recovered (Triantafyllidis 2001). The glass debris included workshop remnants and failed products of glass working in the form of cullet, fragments, scraps or deformed objects; and also recyclable glass products of glass making, mainly pieces of semi-melted or glass transformed raw glass and colored or colorless chunks (Τριανταφυλλίδης 2014).

Excavations in the Hellenistic city of Pherai, Thessaly revealed a large number of finds including glass objects dated from the end of the 3rd to the 1st century BC. Most of the analyzed glass was produced at a single, possibly regional glass making center. Among the analyzed glass samples (20) was one sample having a slightly elevated concentration of lead oxide (PbO). Two previously analyzed colorless glass vessels from Rhodes (Τριανταφυλλίδης 2000, 118) have comparable

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<sup>22</sup> AG 16.323 = 2.13 Regenauer.

<sup>23</sup> APHex 1.15 = P. Oxy. L 3536 late 2nd or early 3rd century AD.

<sup>24</sup> Cullet is defined as recycled broken or waste glass used in glassmaking, and furnace-ready cullet is uniform in size, free of contaminants and often sorted by color. Cullet creation is the form of glass recycling that saves large quantities of energy and toxic emissions.



concentrations of PbO, and the majority of colorless glass samples from Vergina, Greece contain somewhat higher PbO concentration (Brill 1999, 65), at concentrations too low to be considered deliberate addition. It is suggested that the presence of PbO is the result of recycling, presumably through contamination of the glass with colored cullet (Connolly *et al.* 2012, 94 and 96).

Game counters and gaming pieces found in the area of Pydna/ Macedonia were made probably from recycled glass scraps and debris (Ignatiadou 2013, 330).

## 2.4 Stones

Architectural members, sculptures and their parts were reused for the construction of buildings and/or of fortification walls. Some characteristic cases of stone reuse in ancient Athens are:

The Themistoclean city wall: The Themistoclean city wall running through the Kerameikos is one of the earliest and most widely-known examples of large-scale stone reuse in Athens. Thucydides<sup>25</sup> describes how in the winter of 479/8 BC, at Themistocles' behest, the returning Athenians re fortified their polis, using the vandalized funerary monuments (tombstones, stelai and sculpture) as fill or part of the substructure.

The North Acropolis Wall: The North Acropolis Wall was constructed largely of material from the temples destroyed by the Persians in 480 BC (Figure 7). The purpose of North Acropolis Wall was to function as a war memorial by displaying the reused marble and the damage it suffered (Rous 2016, 55).



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<sup>25</sup> Thucydides, *The Peloponnesian War*, 1.93.1.



Figure 7. Column-drums from the temples destroyed by the Persians in 480 BC incorporated into the North Wall of the Acropolis (photo Gary Todd)

The Temple of Ares: The temple of Ares was originally erected at Pallene c. 430 BC and dedicated to Athena Pallenis (Ἀθηνά Παλληνίς). The whole temple was moved to the Athenian Agora in the late 1st century BC. According to Rous (2016, 75 and 93) the translocation of the temple constitutes an example of upcycling. The reuse of a then 400 year old temple in its entirety in a new context in combination with many changes and additions brought in a short time, made the act of reuse invisible.

The Mycenaean bastion and the sanctuary of Athena Nike: The reuse of the Mycenaean bastion beneath the classical sanctuary of Athena Nike at the entrance of the Acropolis after the Persian wars incorporated upcycling in all of its phases (Rous 2016, 146, 147, 150 and 292).

The Southeast and Southwest temples: The so-called Southeast and Southwest temples in the Athenian Agora were built with architectural members taken from the Ionic temple of Athena Sounias (Ἀθηνά Σουνιάς) and the Doric double stoa at Thorikos, respectively, which were reused as upcycled material (Rous 2016, 97). Further, several of the marble votive reliefs from the Athenian Agora show signs of ancient repair (Agathe Tyche, Asklepios, Hygeia, Persephone) (Lawton 2017, 13).

It was a common practice to reuse old statues by reinscribing new dedications on their limestone or marble bases or giving new names to them. Pausanias records three cases where the original inscription on a statue base was replaced with a new one:

*τὰς γὰρ Μιλτιάδου καὶ Θεμιστοκλέους εἰκόνας ἐς Ῥωμαῖόν τε ἄνδρα καὶ Θρᾶκα μετέγραψαν.*<sup>26</sup>

For the likenesses of Miltiades and Themistocles have had their titles changed to a Roman and a Thracian.

*Τοῦ ναοῦ δὲ οὐ πόρρω Ποσειδῶν ἐστὶν ἐφ' ἵππου, δόρυ ἀφίεις ἐπὶ γίγαντα Πολυβώτην, ἐς ὃν Κώοις ὁ μῦθος ὁ περὶ τῆς ἄκρας ἔχει τῆς Χελώνης: τὸ δὲ ἐπίγραμμα τὸ ἐφ' ἡμῶν τὴν εἰκόνα ἄλλω δίδωσι καὶ οὐ Ποσειδῶνι.*<sup>27</sup>

Not far from the temple is Poseidon on horseback, hurling a spear against the giant Polybotes, concerning whom is prevalent among the Coans the story about the promontory of Chelone. But the inscription of our time assigns the statue to another, and not to Poseidon.

*Τούτου δὲ εἰσὶν εἰκόνας ἐφεξῆς χαλκαῖ: τὰς Προΐτου θυγατέρας λέγουσιν εἶναι σφᾶς, τὸ δὲ ἐπίγραμμα ἐς γυναῖκας ἄλλας εἶχεν.*<sup>28</sup>

Next after this are bronze portrait statues, said to be the daughters of Proetus, but the inscription I found referred to other women.

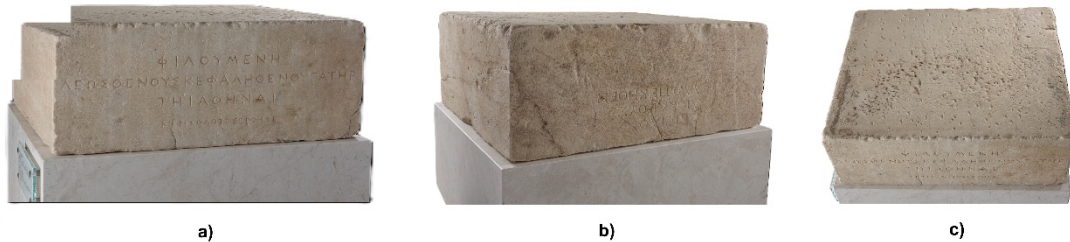
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<sup>26</sup> Pausanias, Description of Greece, 1.18.3; translated by H. L. Jones, Harvard/Heinemann 1924. <https://topostext.org/work/144>.

<sup>27</sup> Pausanias, Description of Greece, 1.2.4.

<sup>28</sup> Pausanias, Description of Greece, 2.9.8.

Figure 8 depicts the reinscribed marble base of a statue originally attributed to Kephisodotos the Younger, son of Praxiteles. The marble base was reused at least three times in a time span of c. 500 years.



a) **ΦΙΛΟΥΜΕΝΗ ΛΕΩΣ ΘΕΝΟΥΣ ΚΕΦΑΛΗΘΕΝ ΘΥΓΑΤΗΡ ΤΗΙΑΘΗΝΑΙ. ΚΗΦΙΣΟΔΟΤΟΣ ΕΠΟΗΣΕ** (after 350 BC)

b) **Δ[Ε]ΙΦΙΛΟΝ ΔΙΟΚΛΕΟΥΣ ΑΛΩΠΕΚΗΘΕΝ** (2nd century BC, the base was turned upside down)

c) **ΦΙΛΟΣΕΡΑΠΙΣ** (3rd century AD, the base was turned over and reinscribed on its upper side)

Figure 8. Reinscribed marble base of a statue with a dedication. Collection inv. no Ακρ. Υ 3627. Kephisodotos the Younger, son of the sculptor Praxiteles. The Acropolis Museum

Other sources of reused stones were from the demolition of old buildings, faulty and/or damaged pieces. The cost of retrieving stones from their original context and reusing them in a new environment was lower than the quarrying, transport and processing of new stones. A large number of marble sculpture was lost in antiquity or the Byzantine period, particularly because marble was often burnt in kilns to make lime for mortar. The reuse of architectural members and stone sculpture are known as spolia.<sup>29</sup>

### 3. Organic Materials

Organic materials such as textiles, papyrus, timber and leather generally are not preserved, since they tend to decompose with time due to moisture and other conditions of the air and soil, while they are likely to be retained in the archaeological record only in a small number of circumstances, mostly in dry conditions.

#### 3.1 Textiles

Textiles are generally made of organic materials such as plant and animal fibers. The manufacture of textiles was a laborious and expensive process involving the steps of plant cultivation, sheep

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<sup>29</sup> The word 'spolia' was first coined in the early 16th century AD in the antiquarian circle that included Raphael (Kinney 2001, 143).

breeding, carding spinning and weaving. Due to their high cost, cloths were repaired and reused for a long time. Second-hand clothes were sold in market places. A papyrus from Oxyrynchus<sup>30</sup> mentions a cloak (*φαινόλη*) that was initially purchased for 10 drachmae, and was later repaired for 1.5 obols.<sup>31</sup> Dealers and traders of second-hand articles, including cloths, are well known in ancient written sources as *γρυτοπῶλαι*<sup>32</sup> (or *κρυτοπῶλαι*) (Bogensperger 2014).

Cloths, which were beyond repair, were either torn in pieces and used as patches, or were remade into another cloths or repurposed as rags, bandages, sanitary or personal items. A rag that was used to patch up torn cloths was called *κέντουκλον/κεντόνιον* (from Latin *cento/centunculum*) (Liu 2009, 63). Rags were typically used for cleaning and waterproofing purposes, e.g., for caulking ship hulls (Nosch 2015, 112), and as makeshift tools for various production processes, namely as tarring tools in pottery.

Although the repair and mending of textiles and cloths was a common practice, there is scarcity of evidence in the archaeological record because the textiles are rarely preserved. One of the rare examples is a bleached textile fragment found at the settlement of Tell Iḏḏabba of Seleucid Nysa-Scythopolis (Beth Sh'ean), which is likely to have originally been part of a garment and later became a purse (Shamir, Lichtenberger and Tal 2022, 235).

The wearing of worn out cloths was considered as an indication of poverty. Homer<sup>33</sup> presents in several instances Odysseus dressed in rags (*ράκος/ράκη (ράκεα)*) and in Greek theater, rags are used to symbolize suffering and deprivation. Euripides has the tendency of presenting his heroes and heroines in rags (e.g., Electra,<sup>34</sup> Hecuba<sup>35</sup> and Helen<sup>36</sup>). Aristophanes in *Acharnians*<sup>37</sup> and *Frogs*<sup>38</sup> mocks Euripides for dressing kings in rags. Aeschylus in his *Persians*<sup>39</sup> describes the return of the defeated Xerxes, who is dressed in rags.

Among the women's dedications of clothing as thank offerings to Artemis in the sanctuary of Brauron (second half of the 4th century BC) there are and some rags. The paganistic custom of hanging rags (*τζάτζαλα*) on trees in the courtyards of rural chapels for the healing of patients continues to this day (Μουτσόπουλος 2000).

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<sup>30</sup> *P. Oxy.*, 4 736, c. 30 BC – c. AD 14.

<sup>31</sup> Six obols make up a drachma.

<sup>32</sup> *IG XII,4 2:635*, line 5. Bilingual dedication to the emperor Augustus as Hermes.

<sup>33</sup> Homer, *Odyssey*, 4.340, 6.175, 14.345, 14.512, 18.67, 18.74, 19.507, 21.221, 22.1, 22.489.

<sup>34</sup> Euripides, *Electra*, 185, 501.

<sup>35</sup> Euripides, *Hecuba*, 240.

<sup>36</sup> Euripides, *Helen*, 416, 1079, 1204.

<sup>37</sup> Aristophanes, *Acharnians*, 412–34.

<sup>38</sup> Aristophanes, *Frogs*, 841, 1055, 1066, 1393.

<sup>39</sup> Aeschylus, *Persians*, 832.

Rags were also used as menses pads. Hippocrates<sup>40</sup> recommends the use of two separate folded rags, both for day and for night, for the flow of menstruation. There is also a story in Suda about Hypatia<sup>41</sup> the philosopher, who in order to discourage a young suitor, she threw her feminine rags before him, showing him the signs of her unclean origin.

### 3.2 Papyrus

Papyrus was manufactured by placing two layers of fibers perpendicularly to each other.<sup>42</sup> Papyrus scrolls were usually written on one side only, where the fibers were horizontal and more suitable for writing, while the other side with vertical threads was usually left blank. In times of need, scribes reused the more inconvenient side of scrolls (see Figure 9). The practice of writing on the reverse of ancient Greek texts has sometimes saved classical works which would otherwise have been lost. A less common technique was to wash away the original text. Since the inks applied from reed pen were water soluble, the writings on the surface of papyrus was sponged or rubbed off and then reused.



Figure 9. A page of Euclid's book Elements reused in a 9th-century manuscript containing a Syriac translation of a Greek theological text, Add MS 17211, f. 49v. British Museum

Scrap written papyri were used in the Ptolemaic period (305-30 BC) for the manufacture of cartonnage for the protection of the head, breast and feet of mummies. Pieces of waste papyri were cut and dampened with water to make them flexible and form the required shape of

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<sup>40</sup> Hippocrates, Diseases of Women, 1.11.

<sup>41</sup> Suda, Lexicon, Adler number: upsilon, 166.

<sup>42</sup> Pliny the Elder, Natural History, 13.69.

cartonnage using layered plaster or animal glue as adhesive (Wendelbo 1978). The practice was introduced during the reign of Ptolemy II Philadelphus as replacement of gummed linen and plaster because of the cheap price of scrap papyri (Salmenkivi 2020, Thompson 2008, 27-36). Cartonnage mummy casings made from discarded papyri were found at the following archeological sites of Middle Egypt (Yassin and El-desokey 2023, 196-198):

- the crocodile cemeteries at Tebtunis (modern, Umm al-Baragāt) in Fayoum;
- the Ptolemaic Necropolis of al-Hība/Hībeh (ancient, Ankyronpolis, Ἀγκυρων πόλις), on the east bank of the Nile;
- the Ptolemaic Necropolis of Abū Sīr al-Malaq (ancient Busiris, Βούσιρις) of Herakleopolite nome in Middle Egypt. Most of those papyri texts were written in Herakleopolite nome, and date back to the Late Ptolemaic period (1st century BC);
- excavations in 2018 at the tombs of Tuna el-Gebel, Minya revealed two cartonnage mummy masks date to the Late Ptolemaic period.

### 3.3 Timber, Wood Structures

The use of timber from discarded wood structures, such as ships, buildings and furniture, for repair works was a common practice in antiquity. However, there are no archaeological finds, because wood decomposes in the ground. The only evidence of reuse of wood structures comes from literature and epigraphic sources. Wood was used almost exclusively for Greek beds (κλίνας) until at least the middle of the 4th century BC, based on the lack of references to metal furniture in literary sources (Kyrieleis 1969). There is epigraphic evidence of the 4th and 3rd century BC for the repair of planked beds and tables in the sanctuary of Delos.<sup>43, 44, 45, 46</sup> (Andrianou 2006, 236).

A different issue was the refurbishment of decayed or damaged wood structures with new timber. Known is the story of Theseus and the Minotaur quoted by Plutarch (AD c. 46-120). After killing the Minotaur, Theseus and his men returned to Athens in a wooden ship with thirty oars, which was preserved in the harbor by the Athenians, who replaced the old planks as they decayed with new and stronger timber (see Figure 10). The story gave rise to the so-called Theseus's Paradox, a philosophical problem as to whether an object remains the same after having had all of its original components replaced over time:

*τὸ δὲ πλοῖον ἐν ᾧ μετὰ τῶν ἡϊθέων ἔπλευσε καὶ πάλιν ἐσώθη, τὴν τριακόντορον, ἄχρι τῶν Δημητρίου τοῦ Φαληρέως χρόνων διεφύλαττον οἱ Ἀθηναῖοι, τὰ μὲν παλαιὰ τῶν ξύλων ὑφαιρούντες,*      The ship on which Theseus sailed with the youths and returned in safety, the thirty-oared galley, was preserved by the Athenians down to the time of Demetrius Phalereus. They took away the

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<sup>43</sup> IG XI,2 144, line 65; shortly before 301 BC.

<sup>44</sup> IG XI,2 199, line 27; 273 BC.

<sup>45</sup> ID 290, line 160; 246 BC.

<sup>46</sup> ID 104, 143-146; 364/3 BC.

ἄλλα δὲ ἐμβάλλοντες ἰσχυρὰ καὶ συμπηγνύντες οὕτως ὥστε καὶ τοῖς φιλοσόφοις εἰς τὸν αὐξόμενον λόγον ἀμφιδοξούμενον παράδειγμα τὸ πλοῖον εἶναι, τῶν μὲν ὡς τὸ αὐτό, τῶν δὲ ὡς οὐ τὸ αὐτὸ διαμένει λεγόντων.<sup>47</sup>

old timbers from time to time, and put new and sound ones in their places, so that the vessel became standing illustration for the philosophers in the mooted question of growth, some declaring that it remained the same, others that it was not the same vessel.



Figure 10. Fragment of François Vase depicting the Ship of Theseus, via Center for Hellenic Studies, Harvard

#### 4. Agricultural and Pastoral Byproducts

An apart type of waste management is the reuse and recycling of agricultural and pastoral byproducts resulting mainly from processing of cereals, olives, grapes and animal manure. Foxhall (1998, 35 and 36) argued that farming in ancient Greece was dependent on these byproducts.

##### 4.1 Cereal Byproducts

The processing of cereal crops (threshing, winnowing, and grinding) yields a number of byproducts, which were known in ancient Greece as:

*κάλαμος*: stubble, the stalks of the cereal plant left standing in the field. Xenophon reports that the stubble may be burnt with advantage to the land, or thrown on the manure heap to increase its bulk.<sup>48</sup>

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<sup>47</sup> Plutarch, Life of Theseus, 23.1; translated by Bernadotte Perrin (1847-1920), from the Loeb Classical Library edition of 1914 <https://topostext.org/work/156>.

<sup>48</sup> Xenophon, Oeconomicus, 18.2.

ἄχυρα: chaff, the components of the cereal ear other than grain, also straw. Chaff was used for feeding livestock and pack and draught animals. It was also used as building material. Grain-rich chaff could have been used as poor-quality human food for poor or for slaves.

πίτυρον / πίτυρα: husk, bran of wheat or barley. Bran was a major byproduct of the wheat flour milling and was, and still is used as a livestock feed.

ἄχνη: fluffy chaff. It was produced during winnowing.

αἶρα: invasive weeds.

There are also other leftovers (trailings) and some grain.

## 4.2 Olive Processing

The main byproducts of olive processing are olive-mill wastewater and olive cake.

### 4.2.1 Amorge

Olive-mill wastewater, known as 'amorge' (ἀμόργη) in ancient Greece is the watery byproduct obtained when the oil is drained from compressed olives. The term amorge is used by several Greek authors (Hippocrates,<sup>49</sup> Theophrastus,<sup>50</sup> Dioscorides, Philo of Byzantium and in *Geoponica*). Amorge had multiple uses in antiquity. One of the earliest known references of amorge (amurca in Latin) is attributed by Pliny the Elder<sup>51</sup> to Democritus, and it is a remedy for the control of blight by sprinkling the infected plants (vines) with unsalted amurca. Dioscorides<sup>52</sup> proposes the use of amorge for medicinal purposes. Philo of Byzantium describes the use of amorge for preserving peas (ἄρακος),<sup>53</sup> and for the protection of granaries and warehouse from birds and animals.<sup>54</sup> *Geoponica* gives instructions on how to apply amorge on the field:

- and men of experience advise to pour amurca, that is made of olives, that are not sprinkled with salt, over the roots of trees (*Geoponica*, Book 2.10.8).

- the month of December is also a seasonable time to dig round them (olive trees) and other trees, and to apply a sufficient quantity of goats dung or twenty cotylae<sup>55</sup> of amurca to the trees that are weak (Book 3.15.6).

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<sup>49</sup> Hippocrates, *Aphorisms*, 7.45.

<sup>50</sup> Theophrastus, *On the Causes of Plants*, 1.19.3, 6.8.3.

<sup>51</sup> Pliny the Elder, *Natural History*, 18.45.1.

<sup>52</sup> Dioscorides, *On Medical Material*, 1.134.

<sup>53</sup> Philo of Byzantium, *A treatise on Mechanics* B, 3; edited and translated by Garland, Y. 1974. *Recherches de poliorcétique grecque*: 1-423, xxii, 424 pages of plates. Ecole française d'Athènes.

<sup>54</sup> *Ibid.*, B, 10.

<sup>55</sup> Cotyla or cotyle, unit of volume of liquids and solids in ancient Greece whose value varied from one place to another in the range of 210-330 cm<sup>3</sup>.



- concerning the care of vine cut off what is redundant in vines just planted, smear the cut with fresh amurca that has been boiled (Book 5.21.2).

- concerning the care of lachrymal vines,<sup>56</sup> make an incision on the trunk and rub the cuts with amurca boiled to half its original quantity, and cooled (Book 5.38.2).

- you will render the olive-trees more thriving, and more flourishing, and exceedingly fruitful, if, after digging round the roots, you pour over each root two cotylae of amurca, from olives that have not been salted, equally mixed with river water (Book 9 .10.1).

- grafting pomegranates by besprinkling a flexible stem with amurca (Book 10.37.1).

- the fig-tree retains its fruit, if you dig trenches around it about the Pleiades, and having mixed an equal quantity of amurca and water you pour it on the trunk (Book 10.48.4).

- you will also destroy the existing caterpillars, if you mix urine and amurca in equal quantities, and boil them over the fire, and then let them cool, and so irrigate the herbs (Book 12.8.3).

- ants will not touch plants, if you smear their stems with bitter lupines pounded with amurca (Book 13.10.7).

- you will keep off ants by mixing bulls gall and pitch with amurca, and smearing the stem of a plant (Book 13.10.14).

- you will also destroy your bugs, if, having boiled amurca with bollocks gall, you mix it with oil, and sprinkle it over them (Book 13.14).

- and so does amurca (kills the fleas), when constantly poured on the paved floor (Book 13.15.5).

Amorge was used for the treatment of various diseases of animals:

- concerning unknown diseases of animals, the best and the most wholesome thing is amurca, given gradually with their water (Book 17.14.6).

- concerning the loathing of provender, you are to sprinkle the provender (dry food for domestic animal) with a sufficient quantity of amurca; and, having mixed a proportionable quantity of resin, or of turpentine, smear the beast's horns to the roots (Book 17.28).

- but it is better to smear them (the wounds of the sheep that are made in shearing) with an equal quantity of wine and amurca...for this is a preventive against the mange, and an impediment to ulceration (Book 18.8.3).

- concerning the mange of sheep after shearing: Fresh amurca is percolated, and the water in which bitter lupines have been macerated, and the lees of white wine, an equal quantity of each being mixed, are warmed in a vessel, and the sheep being anointed remains for a couple of days (Book 18.15.2).

- you are also to destroy the fleas of a dog by anointing its body with amurca, for this will cure such as have the mange (Book 19.3.2).

Amorge was also used for the protection of buildings from invasive pests:

- Anatolius says, if you put some amurca in a brazen dish and get it in the middle of the house in the night, you will bring all the mice together (Book 13.4.9).

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<sup>56</sup> Lachrymal vines, literally vines that shed many tears; see Lacryma Christi or "Tears of Christ, native vine unique to the area of Vesuvius

- concerning the laying of threshing floor: It is of utility to sprinkle amurca over the threshing floor from time to time, and to level it with a cylinder, for then ants will not injure it (Book 2.26.5).

- concerning the granary, and the care and preservation of corn. It is better to sprinkle amurca over the sand mortar, for this destroys all noxious animals, and it makes the corn more firm and more dense; some persons therefore, having boiled amurca to half its quantify, sprinkle it over the walls; then suffering it to dry, they lay in their corn (Book 2.27.7).

Amorge was also used for the preservation and transport of wine:

- concerning the stopping of the wine amphorae, after the pitching of the amphorae and a short time before the tunning of the must, smear the lids with amurca only (Book 6.9.2).

- to carry wine over sea: Having percolated amurca through a cloth, and having boiled it to half its quantity, pour it with Attic honey into the jar, before the wine is poured in; for it keeps thus a very long time (Book 7.17).

#### 4.2.2 Olive cake

Olive cake or pomace (*στέμφυλα*) resulting from the pressing of olives for the production of oil was used as food:

*αὐτοπυρίταισὶ τ' ἄρτοις καὶ λιπῶσι στεμφύλοις.*<sup>57</sup> loaves of whole-meal bread and pressed-olives  
oozing with oil

*οὐ ταύτόν ἐστιν ἀλμάδες καὶ στέμφυλα*<sup>58</sup> salted olives are not the same as pressed-olives

*ἦν δέ ποτ' εἰς ἀγρὸν οὔτος ἀπελθὼν εἰρηναῖος* But if he ever takes off for the countryside and lives in  
*διατρίψῃ, καὶ χῖδρα φαγῶν ἀναθαρρήσῃ καὶ* peace there, regaining his fortitude by munching wheat  
*στεμφύλω ἐς λόγον ἔλθῃ,*<sup>59</sup> cakes and saying hello to his pressed olives,

Olive cake was, and still is used as fuel (Forbes 1966, 2nd edition).

#### 3.4 Leather

Leather was used to make shoes (e.g., sandals, boots), garments, upholstery, harnesses, straps, containers, armor and personal items (e.g., purses). The use of leather implements of war are mentioned in the Iliad, including the use of leather coverings for shields.<sup>60</sup> Leather was an expensive material and its manufacture from animal skins and hides involved several treatments,

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<sup>57</sup> Phrynichus, quoted by Athenaeus in *Deipnosophists*, 3.75; translated by Ch. B. Gulick (1868-1962) from the Loeb Classical Library edition of 1927-41. <https://topostext.org/work/218>.

<sup>58</sup> Aristophanes quoted by Athenaeus in *Deipnosophists*, 2.47.

<sup>59</sup> Aristophanes, *Knights*, 805-806; translated by I. Johnston, Faenum Publishing, Oxford Ohio.

<sup>60</sup> Homer, *Iliad*, 12.20.

the most important of which was the tanning to prevent decay. Tanners (*σκυτοδέψες, βυρσοδέψες, σκυλοδέψες*) and shoemakers (*σκυτοτόμοι, σκυτεῖς*) in ancient Athens and elsewhere (e.g., in Mytilene)<sup>61</sup> established separate and highly exclusive leather guilds. Because of their high cost, many worn out leather items were not discarded but repaired in order to extend their usable life.

There are no archaeological finds of reused and/or repaired leather items from Greek sites. The only available information comes from literary sources and concerns the shoe sector. It was part of the shoemaker's job to repair worn out or damaged shoes, and cobblers refurbished, repaired and remade old shoes before selling them.<sup>62</sup>

Figure 11 shows the upper part of an inscribed stele with relief depicting a scene in a cobbler's workshop. Four men sit on chairs with curved legs, making or repairing shoes. A small boy sits in the lower left cutting something, presumably leather (Lawton 2017, 89 (I, 7936), plate 27).



Figure 11. Scene in a cobbler's workshop. Athenian Agora 89 (I 7936)

The Greek word for mending, repairing, cobbling and resoling of old shoes was *καττίειν*.<sup>63</sup> The patching of shoes was called *παλίμπηξις* and the adjective *παλίμπηγα* was applied to cobbled

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<sup>61</sup> *IG XII,2* 109; see also: *SEG 26:891*, l.10-17.

<sup>62</sup> Plato, *Meno*, 91d, e.

<sup>63</sup> Plato, *Euthydemus*, 294b.

shoes (Bryant 1899, 71). Theophrastus calls the wearer of patched or cobbled shoes in a derogative comment as *ἀνελεύθερος*, meaning literally unfree:

(ὁ δὲ ἀνελεύθερος τοιοῦτός τις...), καὶ τὰ ὑποδήματα παλινπήξει κεκαττυμένα φορεῖν καὶ λέγειν, ὅτι κέρατος οὐδὲν διαφέρει.<sup>64</sup> He will wear his shoes patched with cobbler's work, and say that it is as strong as horn.

It seems that the new shoes were made only with sewing (Bryant 1899, 70 and 71). It was a sign of poverty to wear cobbled shoes with nails in them. Teles (*Τέλης*, c. 235 BC) says:

τότε μὲν γὰρ ἐξ ἀνάγκης ἔδει ὑπόδημα ἔχειν καὶ τοῦτο ἀκκάπττον ἤλους οὐκ ἔχων<sup>65</sup> and then out of necessity, he should have uncobbled shoes without nails

Tanners repaired also leather items. Theophrastus speaks of a *σκυτοδέμης*, who repairs a torn leather flask:

καὶ ἐὰν μῦς θύλακον ἀλφίτων διαφάγη, πρὸς τὸν ἐξηγητὴν ἐλθὼν ἐρωτᾷν τί χρὴ ποιεῖν, καὶ ἐὰν ἀποκρίνηται αὐτῷ ἐκδοῦναι τῷ σκυτοδέμῃ ἐπιρράψαι, μὴ προσέχειν τούτοις, ἀλλ' ἀποτραπείς ἐκθύσασθαι.<sup>66</sup> If a mouse gnaws through a meal-bag, he will go to the expounder of sacred law and ask what is to be done; and, if the answer is, "give it to a cobbler to stitch up," he will disregard the counsel, and go his way, and expiate the omen by sacrifice.

### 3.4.1 Parchment

Parchment was used as a replacement for papyrus. Parchment is based on prepared untanned animal skins, in particular cows and sheep. The Greek name for parchment was 'pergamene' (*περγαμηνή*), but the usual term was 'difthera' (*διφθέρα*). The preparation of parchment was labor intensive and expensive. A technique was developed, where the original ink was scraped away and the clean parchment, called 'palimpsest' (*παλίμψηστο*), was reused in a context different from that of the original text. If the parchment was reused only for a structural purpose, such as for the binding or protection of the body of the manuscript, the text was often not removed although it no longer was to be read.

### 4.3 Grape Processing

The main byproducts of grape processing are grape pomace and wine lees.

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<sup>64</sup> Theophrastus, *Characters*, 22.12; translated by R. Claverhouse Jebb. <https://topostext.org/work/632>.

<sup>65</sup> Teles, *Stobaeus' Anthology, Florilegium*, 97.31.

<sup>66</sup> Theophrastus, *Characters*, 16.6.

### 4.3.1 Grape Pomace

The grape pomace is the residue originated after the pressing of grapes to produce must or wine. It is composed of stems, skins, and stones (seeds or kernels) of grapes. The grape pomace was also called *στέμφυλα* as the olive cake. The difference is highlighted in Geoponica:

*Είδέναι δὲ χρή, ὅτι στέμφυλα οὐχ ὥς τινες νομίζουσι τῶν ἐλαιῶν μόνων εἰσὶ πυρῆνες, ἀλλὰ καὶ τὰ τῶν σταφυλῶν γίγαρτα. ἔαν οὖν τὸ ἀκούσης στέμφυλα, πρὸς τὸ ὑποκείμενον νόει, ποτὲ μὲν γίγαρτα σταφυλῆς, ποτὲ δὲ ἐλαίας τὴν καλουμένην πυρίνην.<sup>67</sup>*

It is indeed proper to know that the 'stemphyla' are not the insides (kernels) of the olives only, as some persons think, but they are also applied to the refuse of the grapes. If therefore you hear the word, bestow attention on the subject, as indeed the grape stones are sometimes so called, and sometimes the inside (kernel) of the olive is thus denominated.

Geoponica describes various uses of grape stones:

- the refuse (*στέμφυλα*), that is, the stones (*γίγαρτα*), are immediately to be thrown out after the draining of the must, and they are to be put into casks, and to be trodden down; for the inferior wine from these, which they provincially call 'thamna' (*θάμνα, τρύξ, στεμφυλίτης*) is not an unpleasant drink for the laborers, and the kernels that are remaining will afford proper nourishment to dumb (*ἄλογος*) creatures (Geoponica, Book 6.13.2).

- grape-stones also make compost for vines (Book 5.26.7).

- it is also proper to throw in a handful of parched grape-stones into each trench, the grape-stones of white grapes indeed to the black kinds and of black grapes to those that are white (Book 5.9).

### 4.3.2 Wine Lees

Lees or dregs of wine (*τρυγία*) are the residues formed at the bottom of wine vessels after fermentation during storage. They are often referred to as an important agricultural waste product with potential to be used in pharmaceutical, food and cosmetic applications. Geoponica gives instructions on how to apply the lees of wine on the field:

- in October is of utility to dig round the vines, and to apply to the roots the lees of wine, (Geoponica, Book, 3.13).

- they (shoots of palm trees) also flourish with more vigor when manured with the lees of old wine (Book 10.4.3).

- palm-trees flourish and grow high, when the lees of old wine are percolated and poured on the roots (Book 10.6.1).

- and they pour the lees of old wine on the roots (of the apple trees), thus rendering the fruit sweeter (Book 10.18.4).

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<sup>67</sup> Geoponica: Agricultural Pursuits, 6.11.7; translated from the Greek by the Rev. T. Owen, 1805.

- by pouring the lees of old wine on the roots (of pear trees) (Book 10.23.6).
  - when the time of planting (lilies) comes, macerate the stems in lees of old wine (Book 11.20.1).
- There are also instructions for the preservation of fruits in lees of wine:
- others likewise lay them (the pears) in the lees of sweet wine, at some distance from each other (Book 10.25.2).
  - quinces put in must keep, being preserved by the lees (Book 10.28.1).
- There are described recipes of lees of wine to be used as medicine for humans and animals:
- lees of wine are used in a recipe for the treatment of joints (Book 16.17).
  - lees of wine are used in a recipe for the treatment of mange of sheep (Book 18.15.2).
- There are also instructions on how to make fish baits from lees of wine:
- lees of wine are used to make fish bait recipe to be thrown before casting the nets (Book 20.4, 20.5).
  - lees of wine are used to make fish bait recipe to catch cuttle-fish (Book 20.43).

#### 4.4 Manure and Compost

The practice of storing and spreading manure (*κόπρος*) over the agricultural fields as fertilizer was known since Homer's times.<sup>68</sup> Xenophon<sup>69</sup> advised farmers to fertilize the soil both with manure and with burned crop stubble plowed back into the fields or to gather weeds and allow them to rot in water to create a compost to spread on the soil.<sup>70</sup>

The Greeks fertilized vineyards and olive groves with water that contained dissolved manure. There was also a practice of discarding domestic vessels, probably pottery onto manure piles as alluded in a passage of Epictetus.<sup>71</sup> It is suggested that the addition of potsherds to manure has the advantage of aerating and moisturizing the soil (Bintliff 2012, 275).

Theophrastus<sup>72</sup> lists six types of manure in order of strength: human, swine, goat, sheep, ox and pack animals. Human excrement and urine were a significant contribution to the farm's manure. In the same passage, Theophrastus speaks of 'syrmatitis' (*συρματίτις*), which is translated as 'litter manure,' which derives from the noun 'syrma' (*σύρμα*), meaning organic refuse; most probably the word syrmatitis refers to a compost derived from a wide range of sweepings (Forbes 2013, 569).

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<sup>68</sup> Homer, *Odyssey*, 17.7.b

<sup>69</sup> Xenophon, *Oeconomicus*, 18.2.

<sup>70</sup> Xenophon, *Oeconomicus*, 20.11.

<sup>71</sup> Epictetus, *Discourses*, 2.4.4; *Epicteti Dissertationes ab Arriano digestae*. Epictetus. Heinrich Schenkl. editor. Leipzig. B. G. Teubner. 1916.

<sup>72</sup> Theophrastus, *Enquiry into Plants*, 2.7.4.

## 5. Collection

The discarded objects and materials were not collected in a systematic and organized manner. The waste products were disposed in pits (apothetes), wells, cisterns, store rooms,<sup>73</sup> in open depots or collected in heaps in the backyards of sanctuaries, workshops and houses, from where they could be reclaimed at a later stage. Fragments of old dedications were found in various wells within the sanctuary of Olympia (Kindt 2012, 151, note 130).

Scavengers collected worn out cloths, glass fragments, pieces of metals, broken pottery and whatever was useful and could be sold. Scavengers, who collected human and animal wastes (*λύματα, κόπρος*) from the streets and cesspits of Athens were called 'koprologoi' (*κοπρολόγοι*); they sold the content to farmers as fertilizer to be used in agricultural fields. The Council of Athens enacted an ordinance requiring scavengers to dispose of the wastes they collected at least one mile from the city walls (Downs and Medina 2000). Aristotle<sup>74</sup> reports that it was the duty of city wardens (*ἀστυνόμοι*) to prevent the koprologoi of disposing the wastes they collected within 10 stadia (1.766m) of the city walls.

## 6. Circular Economy

Circular Economy is one of the promising tools that could be used to analyze and interpret archaeological data and literary sources. The circular economy gives emphasis to the reuse and recycling of objects and materials and the extension of the life cycle of products. Archaeologists and scholars still rely on the linear economic model (production – distribution – consumption) for the evaluation of ancient artifacts. However, the linear approach has some serious drawbacks. It downplays the contribution of reuse and recycling in the waste management of materials. As a result, some archaeological finds and literary and epigraphic sources can go unnoticed or underestimated. In particular, it is difficult to detect recycled metal artifacts, while there are practical difficulties in recognizing reused articles. Further, archaeological finds of organic materials (textiles, papyrus, timber and leather) are rare, and, even then, to find objects showing traces of reuse and repair is challenging; possibly the only exception are the palimpsests.

In the Greek world, the products were produced in a closed-loop reminiscent of the basic principles of the modern economic model of circular economy, where discarded goods are reused continuously, by minimizing waste and reducing pollution. There can be distinguished various types of reuse including repair, mending, remanufacture or spoliation, refurbishment, restoration and upcycling. Repair is the process by which a faulty or damaged product or component is brought back to a usable state to fulfil its intended use. Mending is the process of fixing an object by sewing and stitching and it applies mostly to old clothes and shoes. Remanufacture or spoliation is the process of reusing ancient architectural and/or funerary elements in a new structure. Refurbishment implies a process of cleaning, equipping, or retrofitting. Restoration is

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<sup>73</sup> Strabo, Geography, 9.3.8.

<sup>74</sup> Aristotle, Constitution of Athens, 50.



usually associated with notions of value, authenticity and exclusivity of an object (Dooijes and Nieuwenhuys 2007, 20). Upcycling refers to the process of bringing a change in the purpose or cultural significance to a discarded object based on some aspect of its previous life history; it can be compared with the narrower term 'spoliation' (Rous 2019, 215) (e.g., the North Acropolis Wall and the Temple of Ares in the Athenian Agora).

Reclamation (or salvation) is the process of collecting and often reprocessing discarded objects for reuse. The activity of reclamation was linked to that of scavenging, that is to the recovery of items and materials from waste from a large variety of sites (Duckworth and Wilson 2020). Scavenging has been proposed as the most common way of reclaiming materials for which there was a shortage, such as metals, glass and cloths.

In a circular economy, composting can be used to convert food byproducts and other biodegradable materials into compost, which can be used as a soil enhancer.

Various models of circular economy have been proposed for the reevaluation of archaeological materials and written sources of the Roman period (Bavuso *et al.* 2023, Duckworth and Wilson 2020, Furlan 2023). However, there are no corresponding studies for the Classical and Hellenistic period. Figure 12 depicts a proposed circular model for the Classical and Hellenistic period built by the study of representative archaeological finds and literature sources of reused and recycled materials and artifacts.

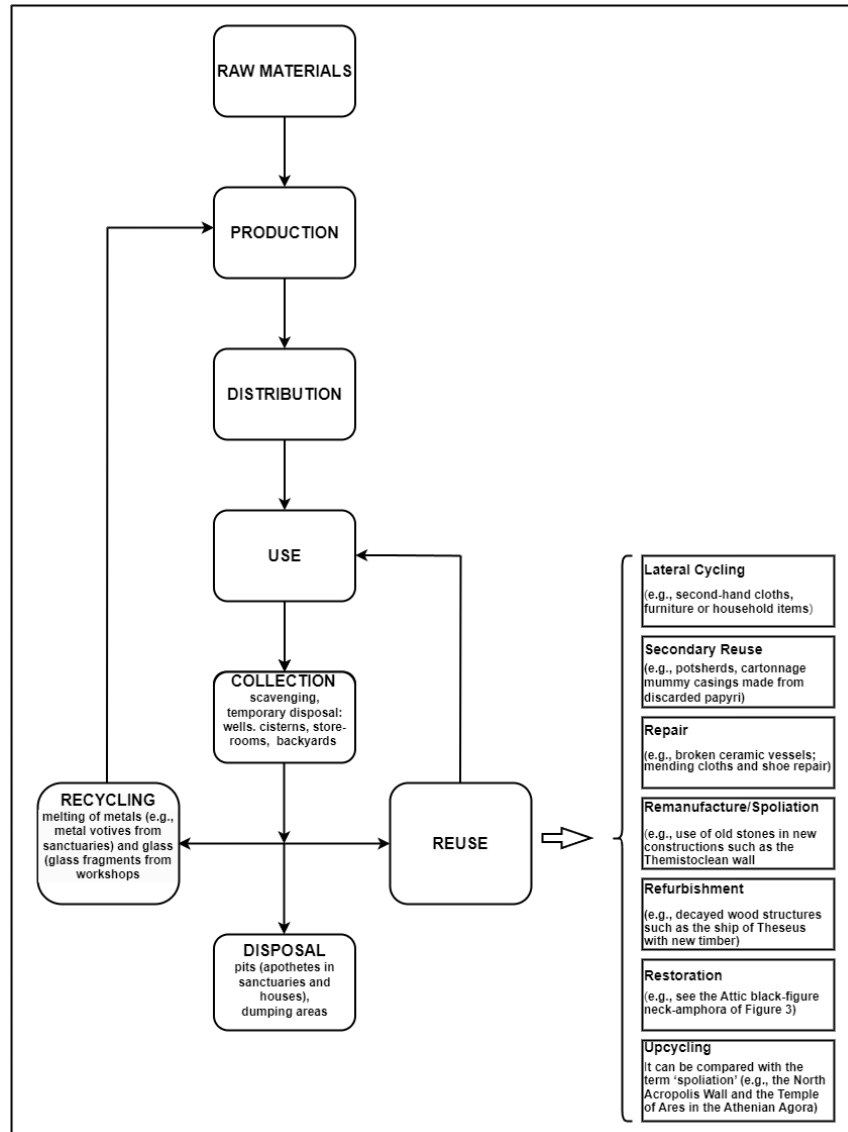


Figure 12. Flow chart of a proposed circular economy model for the Classical and Hellenistic period built of representative archaeological finds and literature sources of reused and recycled materials and artifacts.

## 7. Conclusion

While most of the evidence for the reuse and recycling of objects and materials come from the Roman period, there is an increasing number of studies showing that reuse and recycling took place in the Classical and Hellenistic period. Archaeological finds in combination with literary and epigraphic testimonia provide evidence, although inconclusive, for the reuse/recycling of objects and materials in the Greek world. However, the extent of reclamation is unknown.

Materials that were reused and recycled were those that were either valuable or of limited availability and included metals, glass, marble, timber, textiles, papyrus and leather. The recycling

of metal artifacts is the most well documented activity. The most information about the recycling of metals come from the Panhellenic sanctuaries (Olympia, Delphi and Delos) and the sanctuaries of Acropolis and involved mainly metal votives. The role of sanctuaries in the recycling of metal artifacts (bronze, silver and gold) was pivotal.

The recycling of glass was known to Greeks of the Hellenistic period (city of Rhodes and Pherai, Thessaly). However, the available information are fragmentary and sporadic and do not show a systematic recycling of glass.

Reuse of architectural elements and sculpture has received broad archaeological and scholar interest. Whole temples were translocated to and rededicated in a new environment. On the other hand, certain reuse practices such as lateral cycling, secondary reuse, mending, etc. leave no archaeological footprint.

Further, there are hardly any archaeological finds of reused and/or repaired organic items (textiles, wood, leather and papyrus) from Greek sites. The only available information come from literary and epigraphic sources.

The agricultural and pastoral byproducts constituted an indispensable part of ancient farming. However, with the exception of the *Geoponica* and some isolated ancient sources, the contribution of these byproducts to the rural economy is relatively unknown and understudied.

Recycling and reuse in the Greek world were driven primarily by necessity and scarcity of natural resources. Nowadays, recycling and reuse aim at the conservation of natural resources and protection of the environment. The recognition of recycled and reused artifacts in the archaeological record is a difficult, but necessary procedure for understanding the extent of exploitation of the resources and the contribution of reuse and recycling to ancient Greek economy.

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ΑΙΓΙΔΑ

ΕΛΛΗΝΙΚΗ ΔΗΜΟΚΡΑΤΙΑ  
Υπουργείο Πολιτισμού

ΧΟΡΗΓΟΙ



ΤΕΧΝΙΚΟ  
ΕΠΙΧΕΙΡΗΤΗΡΙΟ  
ΕΛΛΑΔΑΣ



ΟΜΙΛΟΣ ΤΕΕ ΤΕΡΝΑ

ΥΠΟΣΤΗΡΙΞΗ



ΜΕΓΑΡΟ  
ΜΟΥΣΙΚΗΣ  
ΑΘΗΝΩΝ