

Recycling and Waste Management in Greco-Roman Egypt

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Abstract: Despite that Recycling is a modern approach for sustainable development, it might have been practiced in Greco-Roman Egypt. This research seeks to illustrate the origins of recycling concepts through its social economic significant in Ptolemaic and Roman Egypt and argue the waste management ways followed during this period. Thus, research objectives are: identifying recycling practices in ancient times; classifying the different categories of material/archaeological evidence of recycling; clarifying the waste management ways that applied; demonstrating the motivations and techniques of papyrus and glass recycling (as two case studies); documenting papyrus and glass recycling practices from archaeological and textual evidences; discussing the new approaches in papyrus and glass recycling, through new excavations. One of the challenges in researching recycling and reusing is that it might be difficult to distinguish the two in some cases. Additionally, some materials arrive in their final product form with no information regarding their manufacturing process. To address this, the research will use a two-tiered approach; analyzing primary and secondary historical resources; and interpreting archeological and textual evidence through theoretical frameworks. Both case studies were practiced widely. While, glass recycling might have been implemented either in all this period or might have national income during Greco-Roman Egypt.

Keywords: Recycling – Waste Management – Greco Roman Egypt – Papyrus recycling – Glass recycling.

Introduction:

Recycling implies the process of turning an object into raw materials for a completely new product. Reusing, on the other hand, refers to reusing an item as it without treatment. In modern times, Recycling is one of the fundamental elements of Circular Economy¹, which plays a vital role in achieving UN sustainable development goals (SDGs).² Especially, the SDG indicator (12.5.1) aims to minimize waste generation and maximize the recycling of waste.³ Although, there is an opinion that the earliest known example of recycling was in Japan in 1031 AD⁴, or beyond during medieval

¹ Shi, L. (2021). Industrial Circular Manufacturing. In: Lerwen Liu and Seeram Ramakrishna (eds.), *An Introduction to Circular Economy*. Springer, 77-94; Brandao, M., Lazarevic, D., and Finnveden, G. (eds.). (2021). *Handbook of the Circular Economy*. UK and USA: Edward Elgar publishing.

² Swain, R. B. and Sweet, S. (2021). *Sustainable Consumption and Production: Introduction to Circular Economy and Beyond*. Vol. II. Ranjula Bali Swain and Susanne Sweet (eds.). Palgrave Macmillan, pp. 1-16.

³ United Nations Environment Programme (UNEP), United Nations Statistics Division (UNSD), United Nations Institute for Training and Research (UNITAR). (31 Mars, 2023). *SDG indicator metadata: Indicator 12.5.1: National recycling rate, tons of material recycled*. Retrieved from: <https://unstats.un.org/sdgs/metadata/files/Metadata-12-05-01.pdf> (15 August 2023, 4:33 pm).

⁴ Cleveland, C. J. and Morris, C. (2014). *Handbook of Energy*. Vol. II: Chronologies, top ten lists and word clouds. Elsevier, p. 461.

periods.⁵ It is possible that recycling as a process might have been practiced in Greco-Roman Egypt. Despite the fact that there has historically been a great deal of recycling and reuse of materials and objects in ancient times, economic models seldom incorporate these practices, and even less frequently do they make any attempt to assess their scope. Growing scholarly interest in the subject has also resulted in a rise in the acceptance of these practices by those who use more traditional methodological techniques, which are occasionally combined with innovative archaeological theory.⁶

This paper aims to explore the origins of recycling concepts in Ptolemaic and Roman Egypt, as well as the waste management practices and impacts of the time. Thus, research objectives are: identifying recycling practices in ancient times, especially in Greco-Roman Egypt; classifying the different categories of material/archaeological evidence of recycling in Greco-Roman Egypt; clarifying the waste management ways that were applied during Greco-Roman Egypt; demonstrating the motives and techniques behind papyrus and glass recycling (as two case studies); documenting papyrus and glass recycling practices from archaeological and textual evidence in Egypt; discussing the new approaches in papyrus and glass recycling appeared in this time, through new excavations. But, one of the research obstacles is that it is difficult to distinguish between the two in some cases. Furthermore, some materials came to us in their final product without any information about process they passed, which need some advanced technologies to determine that they were recycled or not. Research draws on a two-tiered methodological approach. First, it will analyze primary and secondary sources. Then, it will interpret archeological and textual evidences through theoretical frameworks, to understand recycling practices and their social-economic impacts during Greco-Roman Egypt.

One of the most important research literature on this subject is that "*Recycling and Reuse in the Roman Economy*".⁷ This book is very valuable and is the first specific one to cover this subject, as its editors said.⁸ This book covers a wide geographical range, from Britain to North Africa and the Eastern Mediterranean, with a primary concentration on the Roman imperial and late antique world. Thus, for this paper, it is very important to focus on Egypt with more searching about some special cases that were avoided in this book.

⁵ Ryley, H. (April 2017). "Constructive Parchment Destruction in Medieval Manuscripts." In: *Book 2.0* (7) 1: 9-19.

⁶ Duckworth, C. N. and Wilson, A. (2020). Introduction: Recycling and Reuse in the Roman Economy. In: Duckworth, Chloë N., and Andrew Wilson (eds.), *Recycling and Reuse in the Roman Economy*. Oxford Studies on the Roman Economy. Oxford University Press, p. 1.

⁷ As part of the (Oxford Roman Economy Project) <http://www.romaneconomy.ox.ac.uk/> accessed (16 August 2023, 1:00 am), a conference on "Recycling and the Roman Economy" was held at All Souls College, Oxford, on 22-23 September 2017. As a result of this conference, a volume of collective genuine papers was published in 2020, entitled "Recycling and Reuse in the Roman Economy" which was edited by Chloë N. Duckworth and Andrew Wilson, in a series of Oxford Studies on the Roman Economy.

⁸ Duckworth, C. N. and Wilson, A. *Introduction: Recycling and Reuse in the Roman Economy*, p. 2.

Recycling in ancient Egypt

Historically, reusing and recycling were practiced in ancient civilizations. Potentially, people have reused their things, not because they cared about the environment, but rather because they had no other option. When everything was handcrafted prior to the Industrial Revolution, individuals lacked the time or resources to produce or purchase a replacement when an old item is worn out. They made many things out of scrap metals by melting and mending their clothes and shoes. They considered these actions to be making do with what they had rather than recycling.⁹

According to archaeological evidence, metallurgy dates back to 3000 B.C., when metal scrap and obsolete metallic items may have been melted down and recycled.¹⁰ In ancient Egypt, for instance, once the Deir el-Medina workmen's copper chisels decomposed, they were restored and weighed for recycling.¹¹ Soon after pottery was developed, pieces of shattered pottery were also reused or recycled, as the Archaeological excavations conducted at the Temple of Millions of Years of king (Thutmosis III) between the years 2013 and 2014 revealed a number of materials related to the recycling of pottery.¹² Furthermore, wood recycling was practiced in ancient Egypt. Many ship timbers or parts were found at (Wadi Gawasis, Red Sea), a seasonal harbour for marine trips to Punt, has revealed new insights on the context of wood waste and recycling at naval repair/way stations.¹³ Also, during the third intermediate period, Egyptians often buried their mummies in recycled wood coffins. Dowels, pegs, and holes are examples of this; however they have no structural use when re-used for a coffin. The British Museum has a stunning 22nd Dynasty example of this: (EA29577), which comprises Djedameniufankh's mummy in a cartonnage case and one wooden coffin.¹⁴ [Figs, 1 and 2]



Fig. 1. The British Museum lid of wooden coffin of Djedameniufankh, EA29577. (Cartwright, C. *Re-using wood in ancient Egyptian coffins*, fig. 1-3)

⁹ Byers, A. (2018). *Reuse it: the history of modern recycling*. The history of conservation: preserving our planet. New York: Cavendish Square Publishing, p. 11.

¹⁰ Downs, M. and Medina, M. (2000). "A Short History of Scavenging", *Comparative Civilizations Review*, 42 (42) 4, p. 25.

¹¹ Mahmud, M. F. (June 2022). Environmental Sustainability in Ancient Egypt "I Have Never Stopped the Flow of Water". *Journal of the Faculty of Tourism and Hotels-University of Sadat City*, 6 (1/2), p. 223.

¹² Fernández, J. J. P., Chapon, L. & Cortés, F. C. (2018). Reuse and Recycling in the Temple of Millions of Years of Thutmosis III (Luxor, Egypt): Archaeological Evidence of a Pottery Workshop. *Near Eastern Archaeology*, 81 (4): 228–237.

¹³ Creasman, P. P. (2013). Ship Timber and the Reuse of Wood in Ancient Egypt. *Journal of Egyptian History* (6): 152–176.

¹⁴ Cartwright, C. (2020). Re-using wood in ancient Egyptian coffins. *Newsletter Scientific Research* (6). The British Museum, p.2.

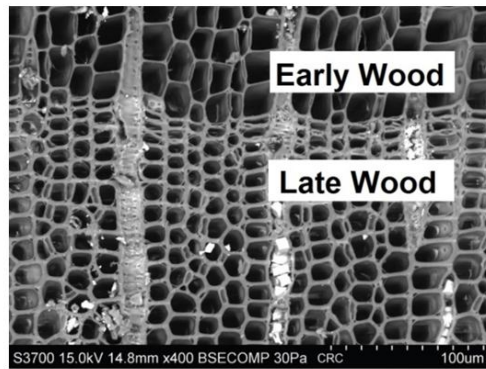


Fig. 2. Scanning electron microscope image a transverse section of cedar of Lebanon wood from EA29577. (Cartwright, C. *Re-using wood in ancient Egyptian coffins*, fig. 1-3)

Recycling in Greco-Roman period

Greeks and Romans reused and recycled a variety of materials: in 1992, Italian archaeologists uncovered a sunken ship in the Adriatic Sea carrying parts and pieces of Roman bronze sculptures. The bronze shipment was dated between (4th century BC – 3rd century AD), and is thought to be the earliest physical indication of trade in the recycling of old bronzes. These bronzes were most likely destined to be melted down and repurposed into new goods, as Martin Medina mentioned.¹⁵

Pliny the Elder reported in his works in the first century A.D. the reuse of waste copper and the fabrication of bronze mirrors in Brindisi (Pliny, *Natural History*. 34.160).¹⁶ There is a scarcity of literary evidence for recycling in the Roman world, and most of what we do have is uninformative. The few passages in Latin and Greek literary texts dealing with recycling mostly do little more than point to the use of specific types of recyclables (metals, ceramics, glass, excrement, urine) for some application that is often known to us through material evidence or could be inferred based on natural considerations, and could only provide little or no information regarding the organizing of recycling practices.¹⁷ Further, the Epigraphical texts that relate to professions or professional organizations are very important. May be, these involve information about persons who practiced recycling activities.

It is challenging to research recycling practices in ancient civilizations, especially with the existence of a great difference between reusing and recycling practices, while the later one (recycling activities) depended on the raw materials of the things to produce new products or sometimes in new forms. Thus, researching recycling activities in ancient societies through archeological evidence needs high technologies and

¹⁵ Medina, M. (2007). *The World's Scavengers: Salvaging for Sustainable Consumption and Production*. Rowman Altamira Press, p. 20-21.

¹⁶ Downs, M. & Medina, M. *A Short History of Scavenging*, p. 27; Pliny the Elder. *Natural History*. Book 34, Translated by H.Rackham (1952), with some minor alterations. Retrieved from: https://www.attalus.org/translate/pliny_hn34b.html (August 29, 2023. 6:00 pm).

¹⁷ Peña, J. T. (2020). Recycling in the Roman World: Concepts, Questions, Materials, and Organization. In: Duckworth, Chloë N., & Andrew Wilson (eds.). *Recycling and Reuse in the Roman Economy*. Oxford Studies on the Roman Economy. Oxford University Press, p.16.

sometimes damaging effects of physicochemical analysis. Further, many of the materials often recycled were perishable organics, which means they are likely to be retained in the archaeological record only in a small number of circumstances, mostly in dry conditions. J. Theodore Peña (2020) sets many categories of archaeological evidence of recycling during Greco-Roman period, as following:¹⁸

- Buildings and other constructions that have been stripped of one or more of their elements, or more thoroughly deconstructed, for recovering materials for recycling.
- Workshops that included furnaces of processing the recyclables materials, such as melting of glass or metal, or for the calcination of limestone and/or marble.
- Archeological Evidence of materials deposits that would have been collected for recycling as raw materials. For example: some broken glass sorted by color in discovered shipwreck cargo.
- Archeological artifacts and structures could be identified as certainly or possibly recycled. For example, firstly: Cartonnage mummy masks made from recycled papyrus; pottery containing ceramic temper; embedded architectural elements in other buildings, *etc.* Secondly: artifacts that are manufactured in various metals, metal alloys, and glass.
- Refuse deposits of various kinds may contain waste products from the reprocessing and/or use of recyclates.
- Some coin hoards that by chemical analysis may give us information related to coinage recycling.

As such, before demonstrating recycling in Greco-Roman Egypt, it is significant to illustrate how waste and waste management were processed during this period.

Waste management in Greco-Roman Egypt

Although, data on waste management during Greco-Roman period are in shortage, varied and complex, it refers to the existence of an efficient waste management system during that period. J. Theodore Peña discusses the differences of waste disposal ways in towns and rural areas.¹⁹ In towns, waste amounts were discarded in/on the grounds of dwelling or manufacturing installations, in separated rooms or in unroofed areas, particularly, by being thrown into cesspits. These were temporary waste deposits to be collected outside the city in a waste stream, while, these pits should have been emptied of waste over time. In villages, most waste could have been discarded in any suitable open spaces, while, some organic waste was used as fertilizer for land.

A papyrus (*P.Oxy.* XLVIII 3386, 28 March 338 CE) of a house lease; involves a formula of stipulations specifying that the renters should clean the house from any waste before departure. Anne Marie Luijendijk suggests that this formula is standard common phrase in many lease contracts during that period.²⁰

Further, one of the duties of city police agents (*ἀστυνόμοι*) that they forbid the waste collector to deposit any waste within (10 *stadia*) from the city walls, according to a

¹⁸ Peña, J. T. *Recycling in the Roman World*, p. 14-16.

¹⁹ Peña, J. T. *Recycling in the Roman World*, p. 17-18.

²⁰ Luijendijk, A. M. (2019). "On Discarding Papyri in Roman and Late Antique Egypt Archaeology and Ancient Perspectives". In *Proceedings of the 28th International Congress of Papyrology, Barcelona 2016*. Barcelona. *Scripta Orientalia* (3), p. 732.

papyrus (*P.Lond.* I. 131, Hermopolis).²¹ Despite the police agent's efforts to prevent waste disposal inside the city, some cases refer to the existence of dung or waste heaps around the houses inside the cities or villages. A papyrus (*P.Ryl.* II 162, dated 30 March 159 CE)²² of sale of a house and courtyard in Socnopaei Nesus, reveals that the house was surrounded by a dung or waste heap from the north side, while the house plot was enclosed by other houses and public road.

In a papyrus (*P.Fay.* 110, 94 CE) from Fayoum as an agricultural area, "Lucius Bellenus Gemellus" ordered his (perhaps) nephew "Epagathus"; (to have the manure there banked up in order to make the store place that you speak of, [...], and take away the manure to the manure heap, [...]).²³ In order to understand the second step after collecting waste or some partial waste, apparently, some waste was burned, as it is found in a third century CE papyrus, (*P.Oxy.* 42.3066) from Oxyrhynchus. In which, Apollonius orders Sarapammon some agricultural instructions involved with the method that he should follow to burn some waste; as follows: "and how the rubbish (filth, dirt) should be burned" (καὶ ὅπως καῖ ἡ δεῖσα).²⁴

Anna Boozer suggests that organic waste (such as: vegetables scraps, eggshells, pits, seeds and so on) may have been fed to domestic animals in the houses, as we do nowadays. Also, the ancients realized the health risk of throwing the leftover bones from meat into public spaces, and maybe there were some regulations to forbid that.²⁵ Many waste heaps involve some dry and solid materials (such as: papyrus, glass, metals, woods and construction materials), but the problem is that the shortage of archeological evidence that reveals the purpose of discarding the objects, and whether it was in use, in storage, in waste deposit, or wait for be reuse and recycle, as noted by Lisa C. Nevett.²⁶

Papyrus recycling in Greco-Roman Egypt

Papyrus as a writing material "*Cyperus Papyrus*" was common in ancient Egypt and during the Greco-Roman period, into Byzantine and early Islamic period. The earliest archeological evidence of a blanked papyrus roll came from the (tomb 3035) of Hemaka at Saqqara, dates back to early first dynasty *ca.* 3100 BC, while the latest papyrus document in Arabic dates back to 1087 AD. Besides using papyrus as writing material, it was used for many varied functions; from a foodstuff to a material for making baskets, sandals, mats, ropes, tables, chairs, mattresses, medicine, perfume,

²¹ Luijendijk, A. M. *On Discarding Papyri in Roman and Late Antique Egypt*, p. 729.

²² For the Greek text of (*P.Ryl.* II.162) and its translation, see: Luijendijk, A. M. *On Discarding Papyri in Roman and Late Antique Egypt*, note. 37, p. 730.

²³ Grenfell, B. P., Hunt, A. S. and Hogarth, D. G. (1900). *Fayum Towns and Their Papyri*. London: Egypt Exploration Fund, Graeco-Roman Branch, p. 263-264.

²⁴ Luijendijk, A. M. *On Discarding Papyri in Roman and Late Antique Egypt*, p. 731; For the full Greek text, see: <https://papyri.info/ddbdp/p.oxy;42;3066> (18 September 2023, 1:00 am).

²⁵ Boozer, A. L. (2021). *At Home In Roman Egypt: A Social Archeology*. Cambridge University Press, p. 109-110.

²⁶ Nevett, L. C. (2015). "Artifact Assemblages in Classical Greek Domestic Contexts: Toward a New Approach". In: Miriam Muller and others (eds.), *Household Studies in Complex Societies:(Micro) Archeological and Textual Approaches*. University of Chicago: Oriental Institute Seminars (10): 112.

clothes, and even small boats.²⁷ However, the great importance of papyrus as writing sheets, the only surviving ancient account of papyrus manufacture is by Pliny the Elder's (*Nat. Hist.* XIII.23).²⁸ Bridget Leach and John Tait comment on this Pliny's passage as a problematic description which has been widely discussed by modern scholars.²⁹ Such as, Naphtali Lewis, who concluded that probably Pliny had never witnessed the material first-hand of papyrus manufacture. Also, Bulow-Jacobsen, A. sets a genuine discussion for this passage and the unsuitable mistakes in which Pliny had fallen.³⁰ Illustrating these points is significant to clear the shortage in information about papyrus manufacture and production. Thus, there is no information about how the ancients recycled papyrus, except some archeological cases that were discovered in its final stage without any information about its process or how it had been recycled.

Erja Salmenkivi discusses the using of papyrus as writing material during Greco-Roman period; also, she argues the decline in papyrus use toward the end of this period. Further, she illustrates the production of papyri books (codex) that replace the papyrus roll [Fig. 3], and the use of parchment instead of papyrus [Fig. 4]. She uses data available on *Leuven Database of Ancient Books* (LDAB) and the website of (<https://papyri.info/>) [Fig. 5]. She concluded that papyrus was used in large quantities during the 2nd - 3rd century CE, with a decline in use during the 5th to 8th century CE, according to database of *papyri.info*. by considerations that this website does not involve Arabic documents from 7th to 8th century CE, which certainly increase substantially. Finally, papyrus was gradually by the time replaced by other writing materials, such as, firstly by parchment and later by paper.³¹

²⁷ Leach, B. and Tait, J. (2000). 'Papyrus', in P. T. Nicholson and I. Shaw (eds), *Ancient Egyptian Materials and Technology*. Cambridge, p. 227.

²⁸ For the complete text of Pliny's passage, see: Pliny the Elder. (1892). *The Natural History of Pliny*, Vol. III. Translate with copious notes and illustrations by: John Bostock and H. T. Riley. (London: George Bell & sons), Book XIII, chapter 23, p. 187-189.

²⁹ Leach, B. and Tait, J. *Papyrus*, p. 231.

³⁰ Bulow-Jacobsen, A. (2009). Writing Materials in the Ancient World, in: Roger S. Bagnall (ed.). *The Oxford Handbook of Papyrology*. Oxford University Press, p. 5-8.

³¹ Salmenkivi, E. (2020). "Reuse and Recycling of Papyrus". In: Duckworth, Chloë N., & Andrew Wilson (eds.), *Recycling and Reuse in the Roman Economy*. Oxford Studies on the Roman Economy. Oxford University Press, p. 90-93.

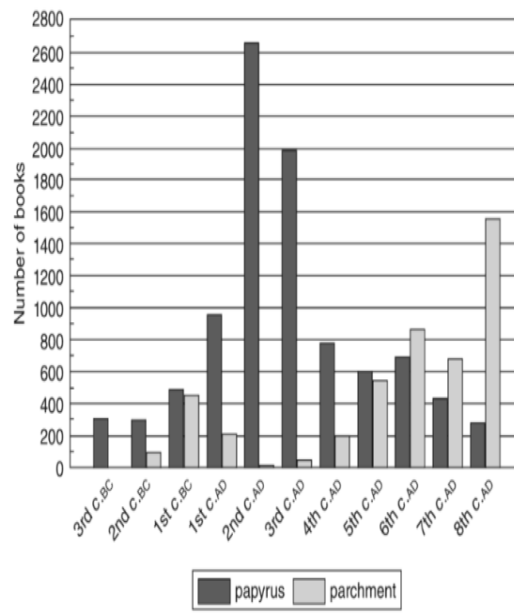
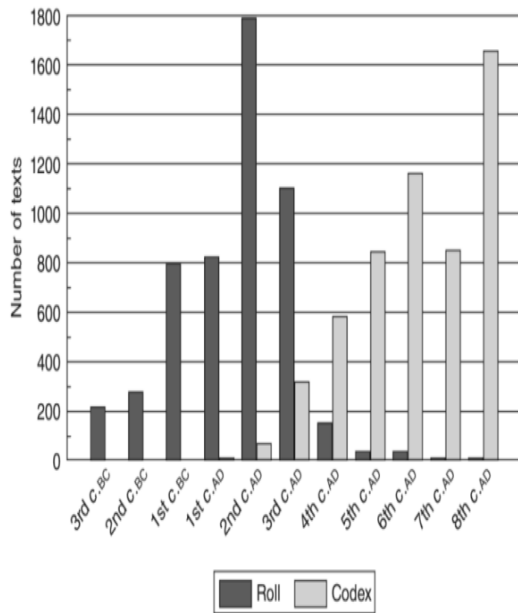


Fig. 3. Number of literary fragments written on rolls and on codices from 3rd century BC to 8th century CE included in (LDAB). (Salmenkivi, E. *Reuse and Recycling of Papyrus*, fig. 4.2)

Fig. 4. Number of literary fragments included in (LDAB) written on papyrus or parchment. (Salmenkivi, E. *Reuse and Recycling of Papyrus*, fig. 4.3)

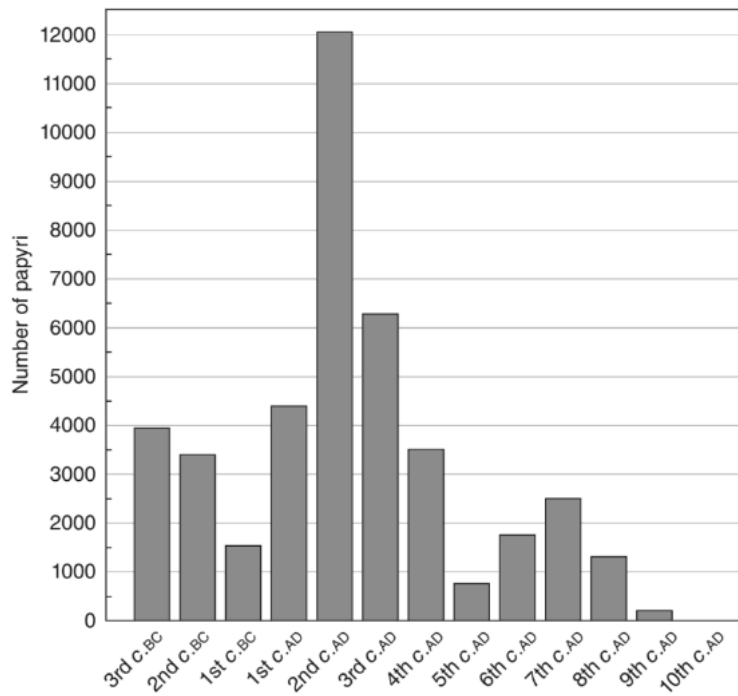


Fig. 5. Numbers of published (mostly Greek) papyrus texts that can be dated within a century included in the website of (*papyri.info*). (Salmenkivi, E. *Reuse and Recycling of Papyrus*, fig. 4.4)

Reusing papyri sheets are common practice during Greco-Roman period, while about (9%) of literary papyri documents were reused as scrap papyri. They would either

sponge off the text on sheets, write on the *verso*, or cut the blanked parts and paste them to make a new sheet. Surprisingly, Laura Santander discusses the reusing of two fragments of the Michigan Collection, in which the original texts of Homer's *Iliad* were erased and replaced by other texts. The first papyrus fragment (*P. Mich.* 2931) had lines from Book 2 of the *Iliad*, which were later sponged off and replaced with a tax receipt (*annona* of wine). The second one (*P. Mich.* 1576) contains some lines from Book 1 of the *Iliad*, while the *verso* was reused for a private letter.³²

On recycling papyri, archeologically, discarded papyri were reused as a raw material in a special way that close to modern recycling methods, particularly, in making of what so-called "*Cartonnage Mummy Masks*" and other parts of covering mummies like "*foot cases*".³³ Cartonnage was known in ancient Egypt, as an alternative wood coffin material, from at least the early first intermediate period to the late period. Cartonnage Mummy Masks flourished in the Ptolemaic and Roman Egypt wider than before. In the beginning, Cartonnage was made out of layers of gummed linen and plaster, while during Ptolemaic period scrap papyri (discarded papyri documents) were commonly used instead of linen.³⁴ It is widely accepted by scholars that it was only under Ptolemy II "Philadelphus" that the practice of using recycled papyri for cartonnage mummy casing was introduced.³⁵ Mummy cartonnage casing made out of papyrus included texts (mostly Greek) dated almost from mid-third century BC (reign of Ptolemy II) to the first century CE. Although Greek documents from cartonnages do not carry any evidence to be dated to the time of (Ptolemy I)³⁶, this does not necessarily imply that Egyptians were unaware of papyri recycling prior to the reign of Ptolemy II.

Among the archeological sites that have cartonnage casing made from recycled papyri are the following:

1. The crocodile cemeteries at Tebtunis (modern, Umm al-Baragāt) in Fayoum [Fig. 6 and 7], in which many of mummified crocodiles were cased by cartonnages out of recycled papyri. The most noted remark in these papyrus cartonnage is that most of them are related to "Menches", the administrative village scribe of

³² Santander, L. (2016). Recycling Homer in Greco-Roman Egypt: The Appreciation and Consumption of Homeric Papyri. In: Carson Woodbury and Laura Santander (eds. In chief), *Discentes 1* (1): 24-36.

³³ Salmenkivi, E. *Reuse and Recycling of Papyrus*, p. 96.

³⁴ Taylor, J. H. (1992). The Development of Cartonnage Cases. In: *Mummy and Magic: The Funerary Arts of Ancient Egypt*. Boston Museum of fine arts, 166-167; Derbala, A. (2022). Unpublished Cartonnage Mummy-Mask from El-Ashmounin Museum Magazine. *Bulletin of the Center of Papyrological Studies (BCPS)* 39: 105-120.

³⁵ Thompson, D. J. (2008). Economic Reforms in the Mid-Reign of Ptolemy Philadelphus. In: Paul McKechnie and Philippe Guillaume (eds.), *Mnemosyne, Supplements, History and Archaeology of Classical Antiquity* 300:27-36; Thompson, D. J. (1999). New and Old in the Ptolemaic Fayyum. In *Proceedings of the British Academy* 96: 123-138; Cauville, S. (1995). 'Un inventaire de temple: les papyrus Berlin 10.472A et 14.400', *Zeitschrift für Ägyptischer Sprache und Altertumskunde (ZÄS)* 122: 38-61.

³⁶ Salmenkivi, E. *Reuse and Recycling of Papyrus*, p. 96; Thompson, D. J. *New and Old in the Ptolemaic Fayyum*, p. 125.

Kerkeosiris.³⁷ Thus, Arthur Verhoogt divided the recycled papyri get from cartonnages mummies casing of crocodile into two groups; (The Menches Archive) and others. He hardly illustrates the reasons for how and where the texts were held during and after use, the importance of when and where recycling took place; how papyri came to be available for use in cartonnage mummy casing remains a complete mystery.³⁸

2. A large quantity of broken papyrus-cartonnage and Ptolemaic mummies with papyrus-cartonnage were discovered in the Ptolemaic Necropolis of al-Hība/Hībeh (ancient, Ankyronpolis, Ἀγκυρῶν πόλις), on the east bank of the Nile between Benisuef and Shekh Fadl (Cynopolis); of the ancient Herakleopolite nome [Fig. 6 and 7]. Grenfell and Hunt who discovered this site and worked during 1902 excavation session, refer to the discovered mummies with papyrus-cartonnage casing.³⁹ They clarify also that Papyri that came from mummy-cartonnage give little help towards the identification of where they were found, or where they were manufactured, since mummies were often carried a long distance to be buried in a particular place. Very few of the pieces of cartonnage found in the Hibeh cemetery are likely to have been manufactured at Hibeh itself, and from internal evidence it is clear that many of the mummies came from villages on the west bank in the Oxyrhynchite nome.⁴⁰ Further, Grenfell and Hunt set that the proportion of Greek to demotic texts in the Hibeh cartonnage is distinctly smaller than in that discovered by Flinders Petrie at (Gurob and Hawâra), and apparently smaller than in that found by Jouguet and Lefebvre at (Magdola). Although larger than the Tebtunis cartonnage, the demotic papyri outnumber the Greek by two to one.⁴¹
3. The Ptolemaic Necropolis of Abū Sīr al-Malaq (ancient Busiris, Βούσιρις) of Herakleopolite nome in Middle Egypt (nowadays in Benisuef) [Fig. 6 and 7], reveal hundreds of papyri documents recycled into cartonnages. Most of those papyri texts were written in Herakleopolite nome, and date back to the Late Ptolemaic period (first century BC). Erja Salmenkivi notes that cartonnage makers gathered their raw material of papyri from sources in close proximity, except

³⁷ For more about Kerkeosiris during the Ptolemaic period, see: Crawford, D. J. (1971). *Kerkeosiris: An Egyptian Village in the Ptolemaic period*. Cambridge University Press.

³⁸ Verhoogt, A. (1998). *Menches, Komogrammateus of Kerkeosiris: the doings and dealings of a village scribe in the late Ptolemaic period (120-110 BC.)*. Leiden; New York; Koln: Brill, chapter III (wastepaper archive), pp. 22-49; Eyre, C. (2013). *The Use of Documents in Pharaonic Egypt*. Oxford Studies in Ancient Documents, Oxford University Press, Note. 474, p. 341.

³⁹ The much damaged character of the cartonnage containing these literary fragments indicates that the mummies to which they belonged had been broken up anciently, probably in Roman times, while the comparatively well-preserved pieces of cartonnage bought with them no doubt came for the most part from the chamber which remained intact until 1902. On the remarkable items in papyrus cartonnage of al-Hība and a comparison between them and of Fayoum papyrus-cartonnages, see: Grenfell, B. P. and Hunt, A. S. (1906). *The Hibeh Papyri*, Part I. London: Egypt Exploration Fund, Graeco-Roman Branch, pp. 1-5.

⁴⁰ Grenfell, B. P. and Hunt, A. S. *The Hibeh Papyri*, p. 8.

⁴¹ Grenfell, B. P. and Hunt, A. S. *The Hibeh Papyri*, p. 10; for more about the literary papyri from al-Hība, see: Falivene, M. R. (1997). 'The literary papyri from al-Hība: a new approach', in B. Kramer, W. Luppe, and H. Machler (eds), *Akten des 21. internationalen Papyrologenkongresses Berlin, 13-19.8.1995, Archiv für Papyrusforschung Beiheft 3*, Band I. Stuttgart and Leipzig, 273-80.

some of the Abū Sīr al-Malaq cartonnages which yielded texts written in Alexandria.⁴² Among the Alexandrian papyri that were extracted from Abū Sīr al-Malaq papyrus-cartonnages, is the famous so-called (Cleopatra Papyrus = *P.Bingen. 45 = P.Berol. inv. 25239*)⁴³ that has a subscription by the own hand of Cleopatra VII. Besides, the Alexandrian papyri that were recycled in this Herakleopolite site, there are other documents came from another site called (χώρα), and many other documents date to Augustine period. All of them recycled together in the same cartonnage in some cases discovered in Abū Sīr al-Malaq.⁴⁴ Obviously, all this may refer that there was a system for collecting the scrap papyrus from all over Egypt, and there were waste papyrus merchants and dealers who may have been responsible for collecting waste papyrus, preparing and transporting to such recycling workshops of papyrus in middle Egypt.

4. New excavations in 2018 at the tombs of Tuna el-Gebel, Minya through a joint expedition of the University of Minya and Ministry of Antiquities, northeast of the animal galleries, discovered four cartonnage mummy masks date to the late Ptolemaic and early Roman period. Cartonnage masks (I-II) were manufactured on recycled papyrus [fig. 8], while mask (III) was on a linen base, and the head of mask (IV) was moulded exclusively in plaster. Ahmed Derbala and Asja Müller assume that masks (I-II) were manufactured firstly, and then the others were made. They add that it's possible that various workshops or craftspeople worked on different ways at the same time, with some utilized recycled papyri as the basis of the cartonnage and others used repurposed linen instead.⁴⁵

⁴² Salmenkivi, E. *Reuse and Recycling of Papyrus*, p. 97. Erja Salmenkivi submits a genuine discussion about more than twenty fragments that dismantled from Abusir al-Malaq, and were excavated by Rubensohn of the German expedition in 1904, and exhausted in Berlin. All these texts came from one piece of cartoonage, while most of them were written in Alexandria. Texts no. (1-16) belonged to the royal scribe of Herakleopolite nome and of "Archive of Peteimouthes", and texts no. (17-20) related to officials of Harchebis of first quarter of 1st century BC. For more see: Salmenkivi, E. (2002). *Cartonnage Papyri in Context: New Ptolemaic Documents from Abū Sīr Al-Malaq*. Commentationes humanarum litterarum 119. Helsinki: Societas Scientiarum Fennica.

⁴³ For more about the so-called "Cleopatra Papyrus", see: Van Minnen, P. (2000). "An Official Act of Cleopatra (With a Subscription in Her Own Hand)," *Ancient Society* (30): 29–34; Van Minnen, P. (2001). "Further Thoughts on the Cleopatra Papyrus," *Archiv für Papyrusforschung* (47): 74–80; Van Minnen, P. (2003). "A Royal Ordinance of Cleopatra and Related Documents," in *Cleopatra Reassessed*, (ed.): Susan Walker and Sally-Ann Ashton (London: British Museum), pp. 35–44; Van Minnen, P. (2018). "P.Bingen 45 Revisited," *Bulletin of the American Society of Papyrologists* (55): 292–293.

⁴⁴ For further discussion and comparison between texts dismantled from Abū Sīr al-Malaq cartonnages, see: Amendola, D. (2022). *The Demades Papyrus (P.Berol. inv. 13045)*. Berlin and Boston: Walter de Gruyter GmbH, pp. 7-16.

⁴⁵ For further information and comparison, see: Derbala, A. and Müller, A. (2023). "Cartonnage to Plaster: Mummy Masks of the Ptolemaic and Early Roman Periods from Tuna el-Gebel". *Archäologischer Anzeiger*. Deutsches Archäologisches Institut, 238–266.

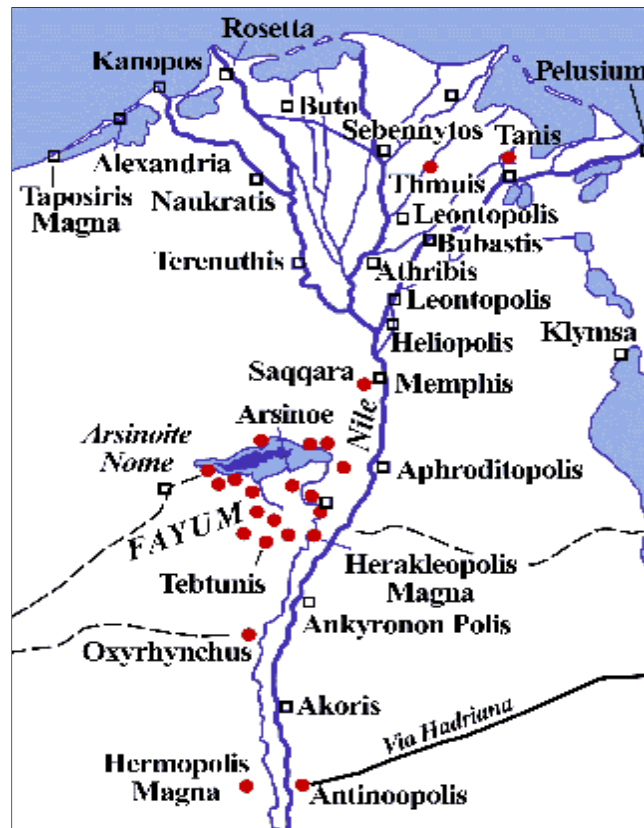


Fig. 6. Lower and Middle Egypt, with sites of Greco-Roman papyrus finds (red circles). (Grenfell et al. 1900; <https://www.athenapub.com/AR/egypt1.htm>)



Fig. 7. Villages of the Fayum region during Greco-Roman Period. (Grenfell et al. 1900; <https://www.athenapub.com/AR/egypt1.htm> (14 December 2023, 9:30 pm).



Fig. 8. (A) Tuna el-Gebel. Masks I-II, (B) Tuna el-Gebel. Mask II *in situ*. (Derbala, A. and Müller, A. "Cartonnage to Plaster", fig. 4-5).

On the comment on all these archeological sites mentioned above that have papyrus-cartonnages manufactured on waste papyri by recycling, there are some clear notes. Most of these sites are located in middle Egypt, which may signify that most of recycling papyrus workshops and craftsmen were centralized in middle Egypt or at least up to now as we know from archeological evidence. The diversity in waste papyri sources from cities and villages all over Egypt illustrates the existence of an efficient waste management system for collecting scrap papyrus through a trading system by waste papyrus merchants and collectors, in order to transport the raw material of papyrus to the workshops and craftspeople in middle Egypt. Archeologically, the needs for recycling papyrus into cartonnages began from the reign of King Ptolemy II up to the Augustine period, and was especially practiced during the Late Ptolemaic period, which coincides with the economic crisis happened during that period and began from the economic reforms by Ptolemy II "Philadelphus".⁴⁶ Most of these archeological artifacts of papyrus-cartonnages were dismantled in order to read papyrus texts; in a way scholars believed that the importance of texts is greater than cartonnage itself.⁴⁷ Thus, in modern scope of research, scholars have invented some high technologies to read papyrus texts without damaging the cartonnages or dismantling them, by an advanced range of different imaging modalities. The techniques include optical (multispectral imaging with reflection and transillumination, and optical coherence tomography), X-ray (X-ray fluorescence imaging, X-ray fluorescence spectroscopy, X-ray micro computed tomography and phase contrast X-ray) and terahertz-based approaches.⁴⁸ Still work in progress, because in some cases, no one of these techniques is enough to read the complete layers included in one papyrus cartonnage manufactured on a recycled papyrus.

⁴⁶ For more about economic reforms of Ptolemy II, see: Thompson, D. J. *Economic Reforms in the Mid-Reign of Ptolemy Philadelphus*, 27-36.

⁴⁷ Amendola, D. *The Demades Papyrus (P.Berol. inv. 13045)*.

⁴⁸ This techniques work in imaging by high sensitive to iron-based inks with excellent penetration, while terahertz imaging use for carbon-based inks with good penetration but with less sensitivity to iron-based inks. For more see: Gibson, A., Piquette, K.E., Bergmann, U. *et al.* (2018). An assessment of multimodal imaging of subsurface text in mummy cartonnage using surrogate papyrus phantoms. *Heritage Science* 6 (7): 1-13.

Glass recycling in Greco-Roman Egypt

Archeologically, Glass recycling was widely practiced during Roman period. However, glass recycling is correctly described as the return of previously formed glass items to a 'pool' of glass meant for shaping into new forms. Roman glass making depended mainly on the recycled glass shards and 'raw' material of glass, which were mixed together to make a new glass forms. Chloë N. Duckworth states that actually, at certain production centers, recycled and 'raw' glass ingredients may have been mixed together, and glass cullet may have been added to main batches to aid in the fusing of the raw elements. This is useful, because the already manufactured glass would melt firstly forming a liquid pool that would spread the heat more evenly, and melting the 'raw' glass ingredients at a lower temperature or in a shorter time than it should be. Thus, Chloë N. Duckworth assumes that it was a Roman standard of glass manufacturing practices to add some cullet or 'raw' material of glass to the recycling glass batches.⁴⁹

Glass recycling was plentifully implied in many literary sources, which may refer to the increase of glass production and possibly also "broken glass" which was widely recycled. Those date to the second half of 1st century CE onwards, as follows:

Table 1. Literary sources on Roman glass recycling and broken glass recycling.⁵⁰

<i>Sources</i>	<i>Passages</i>
Petronius, <i>Satyricon</i>. 10.1. <i>Emperor Nero (54-68 CE)</i>	“Was I to go on listening to his views, all broken glass and interpretations of dreams?”
Martial, <i>Epigrams</i>. I.41.3–5 Martial, <i>Epigrams</i>. X.3.3–4 <i>(ca. 41-104 CE)</i>	“Just like a hawker from Trastevere, who barter pale sulphur for broken glass”. “The exchange of broken glass for sulphured sticks [<i>sulphrato... ramento</i>] is alluded to as a regular thing”.
Stattius, <i>Silvae</i>. 1.6.70–74 <i>(ca. 45-96 CE)</i>	“Here are plebeians from the theatre and those who exchange pale sulphur for broken glass”.
Pliny, <i>Nat. Hist.</i> 36.199. <i>(ca. 70 CE)</i>	“Pieces of broken glass can, when heated to a moderate temperature, be stuck together, but that is all. They can never again be completely melted except into globules separate from each other, as happens in the making of glass pebbles that are sometimes nicknamed eyeballs”.
Juvenal, <i>Satires</i>. 5.48. <i>(end of the first and the early second centuries CE)</i>	Juvenal’s writing describes an unfortunate client having a meal with his wealthy patron. The client is featured drinking out of a cheap goblet that is so badly broken it “calls for sulfur” (<i>poscentem sulphura</i>).
Cassius Dio, <i>Roman History</i>, 60.17.6	“For this reason, though the privilege was at first sold only for large sums, it later became so cheapened by the facility with

⁴⁹ There is no archeological evidence of mixing two "raw" materials of glass of different composition together. For more see: Duckworth, C. N. (2020). “Seeking the Invisible: New Approaches to Roman Glass Recycling”, in: Duckworth, Chloë N., and Andrew Wilson (eds.), *Recycling and Reuse in the Roman Economy*. Oxford Studies on the Roman Economy. Oxford University Press, 301-357.

⁵⁰ This table developed by researchers depended on information in: Leon, H. J. (1941). “Sulphur for Broken Glass (Martial 1.41.3-5)”. *Transactions and Proceedings of the American Philological Association*, 72, 233–236; Jones, A. G. (2015). *Motivation, Mechanics and Magnitude: A Study of Glass Recycling in the Roman Empire*. (MA thesis): Faculty of North Carolina State University, 22-34; Duckworth, C. N. *Seeking the Invisible*, 307-308.

(ca. 155-235 CE)	which it could be obtained that it came to be a common saying, that a man could become a citizen by giving the right person some bits of broken glass”
Bishop Gregory of Tours, <i>Glory of the Martyrs</i>, 58. (Write during the six century CE)	“put the glass in a furnace and heated it for three days, but he accomplished nothing. [Although] he was overwhelmed by his crime and [although] he realized that a divine judgment had been passed on him, he was not upset and persisted in his evil deeds. He took from the furnace, glass that had been changed into some sort of small strands and sold it to merchants who had arrived”. ⁵¹

Ashley Gordon Jones states that the literature on glass recycling is rather limited and problematic. No detailed descriptions of glass recycling process have survived, and most of them have negative indications. Glass recycling was a casual activity carried out by lower-class people in society. From the above cases, glass recycling was not the primary emphasis of the story. Instead, it appears to have been referenced simply in passing: to offend someone, to create imagery, or perhaps to convey a moral lesson. It is an inaccurate manner, in which ancient authors depict the glass collecting procedure, however, they attest to the existence of glass recycling in Roman times.⁵²

It is useful to know that literary evidences imply the existence of a broken glass market, and those were purposely collected during Roman era. The literature included the existence of street peddlers "hawkers" who collect broken glass, in order to sell it for the recycling workshops and craftsmen for re-melting and forming new objects. But, no literary evidence included exactly what value the Romans placed on broken glass. Probably, the values of glass have been varied based on its type and the place where it was recycled. Naturally colored spectacles would have been preferred over vividly colored alternatives. It is also plausible that the value of shattered glass would have been higher in locations with limited access to the raw materials needed for glassmaking. Indeed, although the literary sources have many problems (but, we should not serve to undermine their importance on discussion of Roman glass recycling), the archeological evidences give a much different account rather than what literary reveals. It obviously appears that glass recycling practices could be a formal and large-scale activity.

The famous Edict of Maximum Prices (*Edictum de pretiis*)⁵³, issued by Emperor Diocletian in 301 CE, aimed to contain excessive inflation by setting maximum prices that might be charged for a vast array of raw materials, finished commodities, and services accessible across the empire. In this edict, Diocletian determines the price of glass as raw material and manufactured, as follows:

⁵¹ Gregory of Tours. (2004). *Glory of the Martyrs*, translated with an introduction by Raymond Van Dam. Liverpool University Press, p. 57.

⁵² Jones, A. G. *Motivation, Mechanics and Magnitude*, p. 32-34

⁵³ For more about the edict and its translation, see: Kent, A. G. (Nov. 1920). The Edict of Diocletian Fixing Maximum Prices. *University of Pennsylvania Law Review and American Law Register* 69 (1): 35-47; Kropff, A. (2016). *An English translation of the Edict on Maximum Prices, also known as the Price Edict of Diocletian. (Edictum de pretiis rerum venalium)*. Version 2.1. retrieved from: <https://www.academia.edu/23644199>

Table. 2. Glass prices in Price Edict of Diocletian in 301 CE.⁵⁴

16.1.	For Glass	
1a.	Alexandrian glass, one pound	24 denarii
2.	Judaean greenish glass, one pound	13 denarii
3.	Alexandrian plain glass cups and vessels, one pound	30 denarii
4.	Judaean plain glass cups and vessels, one pound	20 denarii
5.	Window glass, best, one pound	8 denarii
6.	Window glass, second [quality], one pound	6 denarii

It is notable from this table, that one pound (Roman pound = 327,45 grams)⁵⁵ of “Alexandrian glass” (raw glass from Egypt) would have cost 24 denarii, whereas one pound of simple vessels made out of this type of glass would cost 30 denarii, leaving a profit of 6 denarii.⁵⁶ Also, it is notable that window glass was far less expensive than new chunk glass, and given the labour and energy inputs required to transform raw glass into sheets, this is best explained if the window glass referred to is cullet, waste glass from broken windows sold for recycling. Furthermore, Alexandrian glass was better than Judaean glass. So, did the terms ‘Alexandrian’ and ‘Judean’ be trade names, or refer to glass made mainly in Alexandria and Judea? According to archaeological and chemical evidence, the names reflect both origin and type of glass, with the Alexandrian glass interpreted as antimony decolored, soda-rich Egyptian glass that was more perfectly colourless than the ‘greenish’, presumably manganese de-colored Judaean glass. Ian C. Freestone mentions that the relatively high soda content in Alexandrian glass, suggests that this glass type was made close to the Egyptian natron sources.⁵⁷ Thus, where was glass produced and recycled in Egypt during Roman period?

Egyptian Roman glass (HIMT group) is classified as primary glass production center, beside the Levant groups (Levantine 1, Levantine 2), which supplied the secondary glassmaking workshops around the empire. While, there are no primary glass production centers found in the west. Generally, there are three types of Roman glass; (Roman Mn, Roman Sb, and Roman Mn-Sb). The first (Roman Mn) refers to glass of Egypt and Levant, while the second (Roman Sb) refers to the others. The third (Roman Mn-Sb) refers to the glass manufactured of the two recycled types.⁵⁸

⁵⁴ Barag, D. (2005). Alexandrian and Judaean Glass in the Price Edict of Diocletian. *Journal of Glass Studies*, (47): 184–186. <http://www.jstor.org/stable/24191095>

⁵⁵ Kropff, A. *An English translation of the Edict on Maximum Prices*, p. 5.

⁵⁶ Ashley Gordon Jones refers that this was by no means a large profit considering that the minimum daily wage of an unskilled laborer was 25 denarii, plus meals worth *ca.* 5-10 denarii. See: Jones, A. G. *Motivation, Mechanics and Magnitude*, p. 31.

⁵⁷ Freestone, I. C. (2015). The Recycling and Reuse of Roman Glass: Analytical Approaches. *Journal of Glass Studies* 57, Corning: The Corning Museum of Glass, 29–40.

⁵⁸ Barfod, G. H., *et al.* (2020). ‘Alexandrian’ glass confirmed by hafnium isotopes. *Scientific Reports*, (10): 11322. <https://doi.org/10.1038/s41598-020-68089-w> ; Schibille, N., Sterrett-Krause, A., and Freestone, I. C. (2017). Glass groups, glass supply and recycling in late Roman Carthage. *Archaeol Anthropol Sci* (9): 1223–1241.

Archeologically, primary production Roman glass of Egypt (HIMT) contained high soda (Natron).⁵⁹ Strabo indicates in his Geography that there are “two nitre-beds” above Memphis (Strabo, *Geography* 17.1.23), while Pliny the Elder states in his Natural History that “The soda-beds of Egypt” were around Naucratis and Memphis (Pliny, *Nat. Hist.* 31.46). Devulder, V., Degryse, P. suggest that these passages may refer to the Wadi Natrun as one deposit, and al-Barnuj as another.⁶⁰ Marie-Dominique Nenna identifies five primary glass workshop sites from field surveys in (Mareotid and Wadi Natrun), a depression with salt and natron lakes between Alexandria and Cairo. Two were in the Mareotid in: (Taposiris Magna and Marea-Philoxenité); and three were in Wadi Natrun in: (Zakik, Bir Hooker and Beni Salama).⁶¹ [Fig. 9]



Fig.9. Map of Lower Egypt, including primary glass production centers during Roman period. (Nenna, M. D. *Primary glass workshops in Graeco-Roman Egypt*, fig. 1.1)

The presence of surface finds of tiny raw glass fragments, larger blue-green glassy chunks of poor quality, bricks covered with a thick vitreous material with a fractured surface indicating that glass had been broken off, and others bearing an irregular blue-green vitreous layer enabled the identification of these sites. These traits point to the

⁵⁹ Natron, also referred to as *natrun*, is actually a mixture of different minerals formed in the evaporation of alkaline lakes. These deposits contain minerals such as natron ($\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$), trona ($\text{Na}_2\text{CO}_3 \cdot \text{NaHCO}_3 \cdot 2\text{H}_2\text{O}$), burkeite ($\text{Na}_6\text{CO}_3 \cdot 2\text{SO}_4$) and halite (NaCl), amongst others, in varying proportions. See: Devulder, V., and Degryse, P. (2014). ‘The Sources of Natron’. in: Patrick Degryse (ed.), *Glass Making in the Greco-Roman World: Results of the ARCHGLASS Project*. Leuven University Press, 87-96.

⁶⁰Devulder, V., and Degryse, P. *The Sources of Natron*, p. 87-88.

⁶¹ Nenna, M. D. (2015). Primary glass workshops in Graeco-Roman Egypt: Preliminary report on the excavations of the site of Beni Salama, Wadi Natrun (2003, 2005–9). In: Justine Bayley, Ian Freestone, and Caroline Jackson (eds.), *Glass of the Roman world*. Oxford & Philadelphia: Oxbow Books, 1-22.

presence of main tank furnaces in these locations, where a glass slab was formed and broken up into chunks for transporting.⁶²

A new Archaeometric study has shown that a new type of glass appeared in the 4th century in the glass industries of the Roman Empire, which had previously been supplied mostly with Levantine glass. This new glass was produced in northern Sinai from at least the mid-fourth century until the mid-seventh century, when the primary workshops in Sinai ceased production and were replaced by other primary glass workshops in Egypt, which primarily supplied the eastern Mediterranean region. Throughout these three centuries, the primary glass manufacturers in Sinai supplied raw glass in a variety of tints and colours ranging from yellowish to black to all regions of the ancient world (including Europe and the Mediterranean).⁶³

All these sites worked as primary glass production centers in Roman Egypt from the first century, onwards. However, this does not mean that Egypt had not produced glass during Hellenistic and Ptolemaic period. Archeological excavations reveal the existence of glass-working and making-models in many Hellenistic and Ptolemaic temples in Egypt. Despite that may have been used for religious practices and for internal consumption and not for free trade, still considered an important reference to local glass production and waste-glass recycling during that period. Examples of these are found in the temple of Gemayemi, close to Tanis; the temple of Soknebtynis at Tebtynis, Fayoum; the hypostyle hall of the temple at Ayn Manawir, Kharga Oasis; in 2000–2009 excavation, the temple of Skonopaios, Fayyum. Finally, Cristina Boschetti mentions that new finds from the Denderah temple workshop have contributed for shaping a model for glass production in Ptolemaic and early Roman Egypt.⁶⁴

Conclusion:

Recycling as we know nowadays did not exist in Greco-Roman Egypt, but rather practiced in ways close to modern perspectives. Potentially, ancients practiced recycling in economic necessity for shortage in raw materials, rather than sustainable development concepts. Ancient Egyptians practiced recycling, but on a small scale without any national income for the country, while during Greco-Roman period, recycling activities were developed into national exports for supplying secondary production workshops of glass around the entire Roman world. There are many

⁶² For more about the characteristics of these sites and their time limitation of use during Roamn period, and new excavation on the site of Beni Salama, see: Nenna, M. D. *Primary glass workshops in Graeco-Roman Egypt*, pp. 1-22.

⁶³ Nenna encourages more assessment on the degree and importance of recycling in the secondary glass workshops, and more detailed archaeological studies of the artifacts. In order to determine the chronological phases of this trade, and the range of activities of the secondary glass workshops, accurately. Also, to follow the progress in the distribution of HIMT raw glass and finished objects from Egypt, and its recycling in secondary workshops. For more see: Nenna, M. D. (2014). Egyptian Glass abroad: HIMT glass and its markets. In: Daniel Keller, Jennifer Price and caroline Jackson (eds.), *Neighbours and successors of Rome: traditions of glass production and use in Europe and the Middle east in the later 1st millennium AD*, Oxford & Philadelphia: Oxbow Books, 177-193.

⁶⁴ Boschetti, C. (2018). Working glass in Ptolemaic Egypt, a new evidence from Denderah. *Journal of Archaeological Science: Reports* (22): 550–558.

categories of material/archaeological evidence of recycling during Greco-Roman Egypt.

Recycling depended on waste and scrap materials for supplying the recycling workshops and craftsmen. Although, Greco-Roman Egypt had a waste management system known from archeological and textual evidences, it was not an efficient system or perhaps irregular through the informal distribution of waste inside and outside the cities and villages of Greco-Roman Egypt. Further, despite the existence of street peddlers and hawkers who collect the scrap materials (such as papyrus and glass) to sell them to the recycling workshops and craftsmen, there is no evidence that it was a formal activity or supported by the state.

Archeological evidence of recycling papyrus into cartonnage mummy masks and books (codices) covers, reveal that may recycling papyrus activities centralize in the cities and villages of middle Egypt nomos (Tebtunis, Ankyronpolis, Busiris of Herakleopolite nome and Tuna el-Gebel). The diversity in waste papyri sources from all over Egypt, refers to the roll of peddlers and hawkers who collect the scrap papyri for supplying recycling workshops of middle Egypt. Although, archeologically, the evidences of recycling papyrus date between the times of Ptolemy II to the Augustine period, it does not mean that Egyptians had not recycled papyri before or after that period. Modern scholars and recent studies seek to innovate methods to read recycled papyri in cartonnages without dismantling or damaging them.

Mainly, Glass making during Roman period was based on burning of some recycled glass objects in furnaces during manufacturing. The most famous "Alexandrian Glass" of the primary production workshops in Egypt, played a vital role in supplying the secondary glass production workshops around Europe and Mediterranean cities during Roman period. These primary glass production workshops in Egypt were located in the areas of Alexandria and Wadi el-Natron in (al-Barnuj) next to ancient Naucratis; (Taposiris Magna, Marea-Philoxenité) in Mareotid; and (Zakik, Bir Hooker and Beni Salama) in Wadi el-Natron. New studies shed to other primary glass production workshops in Sinai, which supplied all the Roman period from the 4th to 7th centuries CE. However, we do not have records for the revenues gained from these national exports of glass during Roman Egypt; this can leave the space for future studies to explore this scope of research in future.

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إعادة التدوير وإدارة النفايات في مصر اليونانية الرومانية

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الملخص

رغم أن إعادة التدوير تعد نهج حديث لتحقيق التنمية المستدامة، إلا أنها ربما كانت تمارس في مصر اليونانية الرومانية. يسعى هذا البحث لتوضيح أصول وتطور مفاهيم إعادة التدوير وتتبع أهميتها الاجتماعية والاقتصادية في مصر البطلمية والرومانية، ومناقشة طرق إدارة النفايات المتبعة خلال هذه الفترة. لذا، فإن أهداف البحث هي: التعرف على ممارسات إعادة التدوير في مصر اليونانية الرومانية؛ تصنيف الفئات المختلفة للأدلة المادية/الأثرية لإعادة التدوير؛ توضيح طرق إدارة النفايات المطبقة؛ إظهار دوافع وتقنيات إعادة تدوير ورق البردي والزجاج (كدراستي حالة)؛ توثيق ممارسات إعادة تدوير ورق البردي والزجاج من خلال الأدلة الأثرية والنصية؛ مناقشة الأساليب الجديدة المتبعة في إعادة تدوير ورق البردي والزجاج من خلال الاكتشافات الجديدة. تعد أحد التحديات التي تواجه البحث: أنه قد يكون من الصعب التمييز بين إعادة التدوير وإعادة الاستخدام في بعض الحالات. بالإضافة، تصل بعض المواد إلينا في شكلها النهائي دون أي معلومات تتعلق بعملية التصنيع أو ما إذا تم إعادة تدويرها أم لا. سيتبع البحث منهجية علمية من مستويين؛ تحليل المصادر التاريخية

الأولية والثانوية؛ تفسير الأدلة الأثرية والنصية من خلال الأطر النظرية. وقد توصل البحث لممارسة إعادة تدوير أوراق البردي والزجاج على نطاق واسع خلال فترة البحث؛ مع امتداد إعادة تدوير الزجاج طوال تلك الفترة؛ وربما كان له دخل قومي للدولة في مصر اليونانية الرومانية.

الكلمات الدالة:

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