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Textiles and cordage from the seventeenth century English shipwreck of the *London*

Margarita Gleba, Angela Middleton and Ina Vanden Berghe

Abstract

The *London* was an English Second Rate ship of the line built in 1656. The ship served in both the Cromwellian and Restoration navies and formed part of the fleet that brought the future King Charles II back from exile in the Netherlands. The *London* sank in the Thames estuary in 1665 whilst preparing for the second Anglo-Dutch war. The site was re-discovered in 2005 and was designated in 2008 under the Protection of Wrecks Act 1973. A program of archaeological excavation, geophysical survey, and finds assessments was undertaken on the site of the *London* in 2014–2015. Among the hundreds of finds are textile fragments, numerous elements of rigging, and other fibrous materials, which constitute an important collection of closely dated artefacts from a context with a well documented history. The paper presents the results of the conservation and systematic structural and fibre analysis carried out on this material. The finds are contextualized within the broader 17th century developments in textile consumption.

Keywords: shipwreck, 17th century, textiles, ropes, conservation, fibre analysis, dyes

15.1. Introduction

The *London* was an English Second Rate ship of the line built in 1656. It sank in the Thames estuary in 1665 following an explosion whilst preparing for the second Anglo-Dutch war. The site was re-discovered in 2005, and designated in 2008 under the Protection of Wrecks Act 1973. A program of archaeological excavations, geophysical survey, and finds analysis was undertaken at the site of the *London* in 2014–2015.

This contribution first summarizes the conservation and analyses of some of the artefacts from the *London* (Walsh *in press*). Conservation as well as structural analysis was performed on eight objects, including six textiles and two candle wicks, and fibre analysis was performed on 53 samples from 33 objects, including various pieces of rope, thread used for linstock repair, stitching threads from leather shoes, shoelaces, and a gun wad. The following discussion highlights how the *London* finds fit into the broader context of 17th century trends in fibrous materials, including their production technologies and patterns of consumption.

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15.2. Conservation

15.2.1. Condition

Preservation at the site of the *London* was generally good to very good, especially when the artefacts were covered by sediment, which created anaerobic conditions and provided physical protection. The textiles showed good to poor preservation, with entanglement or fraying on the edges being the main indication of decay.

The most common decay pattern for rope was fragmentation, where the rope was broken off at either end, or where the rope was separating into individual strands. On occasion strands were untwisting and separating into yarns (Figures 1A and 3A). Due to their soft and pliable nature, some ropes were squashed and deformed; some were contaminated with iron, as indicated by orange staining, while some rope fragments had been tarred, as indicated by smell. The tarring was not excessive and did not obscure any details.

Figure 1. Rope 3139 before (A) and after (B) conservation. (Photograph: A. Middleton)

15.2.2. Methods

On recovery, the artefacts were desalinated using repeated rinses in distilled water. Where fibrous materials formed part of an artefact, e.g. laces on a leather shoe or rope repair on a wooden linstock, they were conserved together with the artefact, following established treatment protocols for wood and leather, i.e. Polyethylene glycol (PEG) impregnation followed by vacuum freeze drying. The candles with wicks were air-dried.

The rope was treated on its own, after carrying out trials to establish a suitable conservation treatment (Middleton 2018). Trial treatments on fragmented strands involved: no impregnation, solvent drying (Acetone or Industrial Methylated Spirits), air-drying, 10%, 20%, and 30% impregnation with PEG 400, 1500, and 4000, followed by vacuum freeze drying. The most successful treatment initially appeared to be 10% PEG1500 followed by vacuum freeze drying; however, when this treatment was applied to a larger fragment, the rope fibres appeared wet and stuck together. To prevent this from happening subsequently, rope artefacts were therefore vacuum freeze dried without any prior impregnation, after pre-freezing in a domestic chest freezer at -30°C for one week. The vacuum freeze drying was undertaken in a LyoDry Midi Freeze Dryer s/n F012 with an RV12 vacuum pump and EMF20 mist filter. As the ice sublimated, the weight loss was recorded regularly; the endpoint was determined to be when the weight loss plateaued.

Two textile fragments (3704, 3632) were impregnated with 10% PEG1500 for four weeks. After removal from the solution, they were gently dabbed dry with tissue paper before being pre-frozen in a domestic chest freezer at -30°C. Vacuum freeze drying was then undertaken as described above. Excess PEG post-drying was removed using brushes, blowers and wooden skewers; this step required minimal input, as most of the PEG had already been removed while still wet.

15.2.3. Results

Overall, good results in terms of colour, retention of dimensions, overall appearance, and cohesion of the artefacts were achieved. The two textile fragments (3704, 3632) were extremely fragile and further attempts to unfold them were stopped as disintegration was very likely (Figure 2).

Although the rope with high levels of iron contamination would have benefited from a chemical pre-treatment to reduce iron staining, overall, the rope fared well, even without impregnation prior to drying (Figures 1 and 3). Fibre shedding was noticed and careful handling was required. Fibrous materials associated with other materials (leather or wood) responded well to the wood or leather treatment. The wicks of the candles also responded well to air-drying, which is likely due to the fact they were impregnated with wax from the candles.

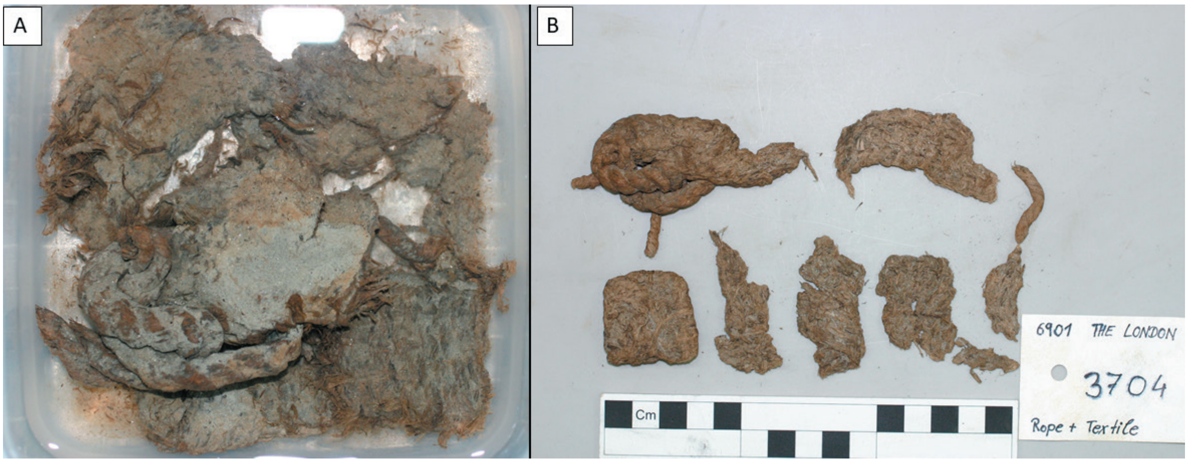

Figure 2. Textile 3704 before (A) and after (B) conservation. (Photograph: A. Middleton)

Figure 3. Rope 3210 before (A) and after (B) conservation. (Photograph: A. Middleton)

15.3. Textile, fibre, and dye analyses

15.3.1. Methods

Structural analysis following established procedures (Emery 2009) was carried out using autopic observation, hand-lens, and digital DinoLite microscope (magnifications 20x, 50x, 230x). Fibre identification was carried out using Hitachi TM3000 TableTop Scanning Electron Microscope (SEM) at the University of Cambridge, UK. Dye analysis was carried out at the Royal Institute for Archaeological Heritage (KIK-IRPA), Belgium. The identification of the organic colourants was performed using High Performance Liquid Chromatography and photo diode array detection system (HPLC-DAD) with Alliance HPLC equipment (Waters, USA), using protocol described in Vanden Berghe et al. 2009.

15.3.2. Results

Textile analysis

The textiles preserved among the finds of the *London* include three shoelaces found in association with and still passing through the holes in the uppers of the leather shoes (Figures 4–6); two textile fragments still adhering to the insoles of two shoes (Figure 7); and a textile which was found tied in an

Figure 4. Micrograph of shoelace 3390. (Image: M. Gleba)

Figure 5. Micrograph of shoelace 3751. (Image: M. Gleba)

Figure 6. Micrograph of shoelace 3731. (Image: M. Gleba)

Figure 7. Micrograph of textile found inside a shoe 3118H. (Image: M. Gleba)

Table 1. Textile data summary of textiles from the *London*.

Object no.	Weave	Size (cm)	Warp count	Weft count	Warp twist	Weft twist	Warp diameter	Weft diameter	Warp angle	Weft angle
3761	2/1 tabby or half-basket	2 x 29	26(x2)	13–14	z	z-i	0.2–0.3	0.3–0.4	medium-loose	loose
3390	Warp-dominant tabby	3 x 16	40–44	26	i	i	0.2–0.3	0.3–0.4	na	na
3731	Braid	1 x ?	na	na	S2z-i	na	Plied 0.8–0.9 (single 0.4–0.6)	na	na	na
3118H	Balanced tabby	4 x 2	8	8	z	z	0.5–0.8	0.5–0.8	medium	medium
3118O	Balanced tabby	3 x 1	7	7	z	z	0.5–0.8	0.5–0.8	medium	medium
3704	2/2 tabby or basket weave	Largest fragment 6x2	4(x2)	2(x2)	z	z	1.2–1.8	1.4–1.5	medium	medium

Key: thread counts are in threads per cm; thread twist: z=clockwise, i=no discernible twist; diameters measured in mm; warp angle: medium=10-30°, loose=below 10°. All measurements are approximate since the objects likely deformed after a long period in sea water.

Figure 8. Micrograph of textile and rope 3704. (Image: M. Gleba)

Figure 9. Micrograph of candle wick 3126. (Image: M. Gleba)

S direction overhand knot with a piece of rope (Figures 2 and 8). The structural analysis of the textiles is summarized in Table 1. Additionally, fine parallel lines can still be observed on the inside of a leather shoe, which count at 7–8 lines/cm. These may be imprints of a textile, possibly a knitted sock, since knitting produces a structure consisting of parallel lines.

The two rolled wax candles still contain wicks impregnated with wax (Figure 9). In one of the fragments (3126), the wick is protruding at least 1 cm and is composed of at least four (possibly more) z-twisted threads.

Functional stitching in shoes and a fragment of leather bucket was done using coarse, possibly S-plied thread, which in most cases survives as tufts of fibre in the holes only (Figure 10), not permitting complete structural analysis.

The 33 rope fragments are all of z-laid (hawser) type, but varying in diameter (Figures 1–2). Two fragments preserve serving and worming but no parcelling. Most ropes are 3-strand, but at least two of the thinner fragments are 5-strand. Only one cable was recovered. Complete structural rope analysis has been carried out by Des Pawson (Walsh *in press*). Also recovered were several samples of a gunwad (Figure 11) and oakum, a preparation of tarred fibre, painstakingly unravelled from ropes and cordage, and used for caulking or packing the joints of timbers in wooden vessels.

Figure 10. Micrograph of stitching thread in shoe 3118H. (Image: M. Gleba)

Figure 11. Gunwad 3479. (Photograph: M. Gleba)

Fibre analysis

All three shoelaces are made of silk. The fibres are continuous, fine, and smooth filaments (Figures 12), with a drop-shaped or rounded triangular cross section. The diameters of the fibres are consistent in all samples, ranging between ca. 8–17 microns, with averages of 12–14 microns. Rast-Eicher (2016: 283) provides a silk diameter range of 10–12 micrometres.

The two textiles from the shoes and the textile associated with the rope are made from poorly processed plant bast fibre. Hurds are present in all these fragments and visible to the naked eye, with epidermal tissue preserving stomata clearly visible when observed in the SEM. Similarity with rope samples suggests the fibre may be hemp (*Cannabis sativa*), but further multi-analytical investigation is needed to confirm this identification. The fibres in the candle wicks appear to be of plant bast origin, but these were not sufficiently well preserved for species identification.

The material used as the stitching medium for the leather shoes and a leather bucket consists of coarsely processed plant bast fibres. Microscopically, the fibres are round bundles, and are still covered in connective tissue, which obscures their surface and diagnostic characteristics. They were likely not well heckled, although they appear to be better separated than material used for ropes and other related objects. Fibre diameters range between 14.2 and 33.8 microns. Nodes are discernible in all samples, although due to the flattening of the fibres they are not very pronounced.

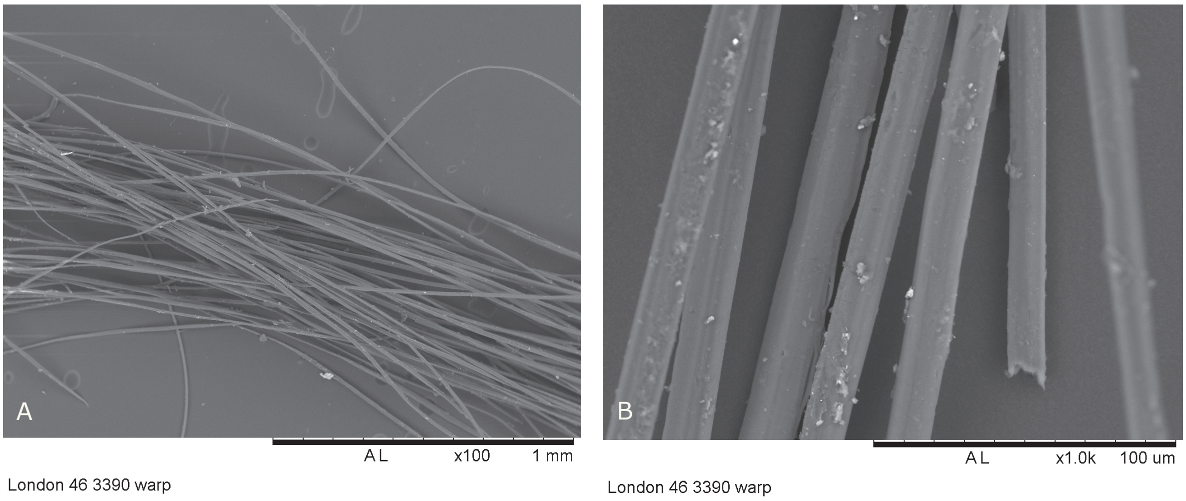

Figure 12. SEM micrograph of silk fibres in shoelace 3390 at x100 (A) and x 1000 (B) magnification. (Image: M. Gleba)

Occasional z-splitting of the fibres is possibly indicative of the z-microfibrillar orientation, which is typical for hemp. As opposed to z-oriented hemp, flax and various other plant bast fibres are s-orineted (Bergfjord and Holst 2010: 1193; Haugan and Holst 2013; Lukesova 2017; Suomela et al. 2018). Note that no studies have been carried out to date in order to prove that the splitting observed in the SEM occurs in the direction of the natural microfibrillar orientation of the fibres, so this characteristic must remain tentative and on the level of observation only.

The same characteristics were observed for the samples from a powder cartridge bottle cap and linstock repair thread. In the latter case 'cottonized hemp' was observed: when hemp fibres separate, they are often flat and especially when degraded start twisting and looking like cotton.

Samples from eighteen rope fragments were analyzed. The material used for rope construction consists of very coarsely processed plant bast fibres, with non-fibrous material ('hurds') present throughout. Microscopically, the fibres are not well separated and appear in ribbon-like or round bundles, which obscures their surface and diagnostic characteristics (Figures 13A and 13B). In the cases of ropes preserved in association with iron objects, the diagnostic features are also obscured by iron concretions on the fibre surface. The fibres were likely not or only coarsely heckled. The fibres are mostly collapsed, making cross sections not very informative, but the nodes or dislocations are discernible in most samples. The non-fibrous material consists of both epidermal and parenchymal plant tissues, including helical tracheids and pitted vessels in several cases. The few fibres which permitted diameter measurement range from 10–40 micrometres. All samples examined in the SEM appear to be made of the same material, bast fibre of hemp.

Oakum from a basket and the gunwad have characteristics similar to the rope material and appear to be very coarsely processed hemp. The abundant presence of cannabis pollen in oakum from Sample 6 further supports hemp identification (Grant 2016). The Herzog test of the gunwad sample carried out by Jenni Suomela confirmed z-microfibrillar orientation.

Dye analysis

Dye analysis identified the presence of tannins in the samples from the three shoelaces. Indigotin was detected in one of the two yarns from the braided shoelace, indicative of dyeing with either woad (*Isatis tinctoria*) or indigo (*Indigofera* or *Poligonum sp.*). The presence of gallic acid, a tannin, in both samples of the braided shoelace suggests that it may have been added intentionally, possibly to achieve a black colour in combination with the indigoid dye. The presence of ellagic acid and its derivatives

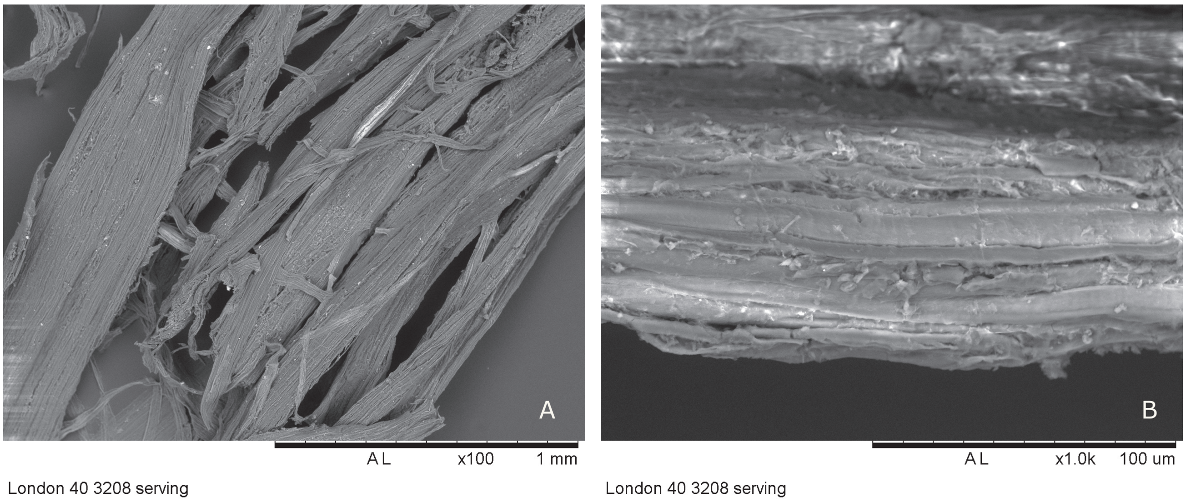

Figure 13A and 13B. SEM micrograph of likely hemp fibres in rope serving 3206 at x100 (A) and x 1000 (B) magnification. (Image: M. Gleba) in all shoelace samples could indicate that the tannins were either used as dye to obtain brown shades or are present as the result of contamination from shoe leather or wood from the ship's hull (both leather and wood being tannin-rich materials).

15.4. Discussion

The three surviving shoelaces are all made of silk, a luxury fibre historically associated with the upper classes. The seventeenth century was one of the most excessive in costume history and has been termed the century of ribbons, bows, and lace (Ordoñez and Welters 1998). Both men's and women's clothing of this period were extravagant, and every accessory from gloves to bonnets and shoes was decorated with ribbons in many forms. Silk, the raw material used to make these ribbons, became "an essential luxury" (Rothstein 1990: 3).

Silk ribbons in tabby weave first appear in English archaeological deposits in the 10th–11th centuries AD, but then do not reappear again until the late 14th century AD (Crowfoot et al. 2006: 141). The technical differences indicate that while the earlier finds were imported, the latter ones were likely produced locally from imported raw material. These ribbons are similar to the *London* examples in that they are all warp-faced and have thread counts between 28/12 and 50/18 threads/cm, but differ in their width (not exceeding 13 mm) and the fact that the thread is plied rather than single (Crowfoot et al. 2006: 141 Table 14). Silk ribbons and laces were also recovered from the *Mary Rose* (1545). They are warp-dominant tabbies with only slightly twisted yarn, and thread counts of over 40–50 threads/cm in the warp and over 25 in the weft (Forster et al. 2005: 30–31). Plaited silk braids have been found in the 13th and 14th century AD deposits of London (Crowfoot et al. 2006: 140–141). The silk laces from the *London*, thus, appear to be typical accessories of the wealthy classes, in use at least since the late 14th century AD.

The two textiles found adhering to the insoles of the leather shoes are made of plant bast fibre that was not very well processed. They could be fragments of either lining for the shoe uppers or insock, which was a textile lining placed on top of the insole. However, such items tend to be made of wool, as for example the items recovered from the *Mary Rose* (Forster et al. 2005: 88). The material and the rather coarse quality of the cloth in both *London* textiles recovered from the shoes leaves open a possibility that these may be bits of sacking or even sail that might have got lodged inside the shoes. The few extant sail fragments from other 16th–18th century shipwrecks have a comparable quality (Table 2).

Table 2. Comparative data for sail cloth from other shipwrecks.

Site	Date	Weave	Thread count	Twist	Material	Reference
Mary Rose	1545	tabby	10–12/8–10	z/z	hemp/sisal?	Gleba unpublished analysis
Vasa	1628	tabby	10–12/7	z/z	hemp	Westheden Olausson 1998: 309
		tabby	11–13/9–11	z/z	flax	
Jeanne-Élisabeth	1755	tabby	12/6	z/z	hemp	Bartoš and Sanders 2011: 70
Swash		tabby	10–12/10–12	z/z	hemp	Gleba unpublished analysis
Queen Anne's Revenge	1718	tabby	10/10	z/z	hemp or flax	Focht 2008
		2/1 half-basket weave	14x2/7–9	z/z	hemp or flax	

The construction of the textile fragment associated with rope is not sufficiently well preserved to understand its function. Its association with a rope at first glance suggests that it may be part of a sail, but the cloth is generally coarser than all other extant sail cloth fragments and is woven in basket weave. Another possibility is that it constituted some type of chafing gear or serving.

The possible textile impression on the leather shoe could be from a knitted sock. Textile impressions have also been noted on two shoes from the *Mary Rose* (Forster et al. 2005: 87).

Candles are exceedingly rare archaeological finds. The oldest reported extant beeswax candles north of the Alps were found at the Alamannic cemetery of Oberflacht, Seitingen-Oberflacht, Kreis Tuttlingen, Germany, and are dated to the 6th or beginning of the 7th century AD (Paulsen 1992). They appear to have multiple strand wicks, like the ones from the *London*. The candles from the *London* appear to have been made by rolling wax sheets around a wick. The successive layers of the sheets are clearly visible in the candle profiles. The standard material for wicks was flax. Candles made of beeswax were a luxury commodity during the 17th century, the norm being tallow candles or rushlights made by dipping a wick made of the stripped and dried pith of a rush (*Juncus effusus*) or reed into hot waste animal fat (Everleigh 2003). Beeswax was significantly more expensive than tallow, because the raw material was less abundant and beeswax candles were extremely labour-intensive to produce. They also produced the cleanest light without smell and lasted the longest. Given their high cost, it is likely that the two beeswax candles on board the *London* belonged to an officer.

The remains of the sewing thread in the leather shoes and the leather bucket are all made of plant bast fibre. Plant fibres became the norm for shoe making from the Medieval period onwards (Walton-Rogers 2003: 2361). Shoes from the late 14th century city of London had plied waxed flax threads (Grew and de Neergaard 2001: 48). Plant bast fibres in the sewing threads on leatherwork from 16–22 Coppergate and Bedern Foundry in York, spanning the period from the 12th to the 18th century AD, were identified as either flax (*Linum usitatissimum*) or hemp (*Cannabis sativa*). According to Penelope Walton-Rogers, in all cases, "the fibres are in intact bundles, which means they have not been fully processed by heckling" (Walton Rogers 2003: 3259). Where discernible, the thread is z-twisted and S-plied (Walton Rogers 2003: 3260). Small lengths of stitching thread preserved in the shoes from the *Mary Rose* were not analyzed, but it is suggested they may have been made of waxed linen (Forster et al. 2005: 88). The lack of processing resulted in a strong and relatively stiff thread, which was needed for the leatherwork, while waxing contributed to the waterproofing of the openings, eased stitching and reduced breakdown/chaffing of thread during stitching. Up to this day, hand-made shoes are stitched with pitched or waxed hemp thread.

All cordage on board the *London* appears to be made of plant bast fibre, almost certainly hemp, although a mixture of other bast fibres cannot be absolutely excluded on the grounds that only very small samples were analyzed from each object and many samples are too degraded for a definite identification. Mixing of various plant bast fibres with very similar characteristics (hemp, flax, nettle) in ropes and oakum would have been the standard practice during this period (Pers. comm. Des Pawson and Damien Sanders).

This was also the case with oakum. Oakum found in a basket from the *London* contained large quantities of hemp pollen, suggesting that it is made of hemp (Grant 2016). According to Grant (2016), a high abundance of hemp pollen on-board wreck sites is well documented, being associated with the use of its fibres for making rope, cordage and sailcloth. For example, hemp pollen was also abundant in the samples from the *Mary Rose*, but so was nettle pollen (Scaife 2005).

The fibres in all of the ropes and the oakum from the *London* still adhere in bundles, with much of the epidermal and connective plant tissues and hurds still present. This suggests that the fibres were not well or not completely processed and heckling was either not carried out or carried out only partially.

The use of hemp for the cordage onboard the *London* is not surprising. There was a shift towards hemp cordage in northern Europe at the turn of the 14th century AD (Sanders 2010: 18). The 14th-century medieval cog in Tallinn, Estonia, contained predominantly hemp ropes, with a smaller number made of lime bast (Rammo 2017). The *Mary Rose* (1545) also carried hemp cordage (Scaife 2005: 626), as did the Swedish *Vasa* which capsized on her maiden voyage in 1628 (forthcoming in *Vasa II* publication), and the French *La Belle* that ran aground in the Gulf of Mexico in 1686 (McCaskill 2009). The ropes from the 17th century Swash Channel Wreck have been tentatively identified as hemp as well (Pers. comm. Des Pawson and Damien Sanders). *Queen Anne's Revenge*, which ran aground in Beaufort Inlet, North Carolina, in 1718, had cannon wads and other ropes primarily made of hemp (Chen and Lusardi 2001). Samuel Pepys' diaries (1660–1669) also refer to hemp as the principal material for the cordage.

15.5. Conclusions

The present analysis represents one of the very few systematic scientific investigations of fibrous material recovered from a shipwreck. While ropes are frequently found on shipwreck sites, little or no scientific fibre analyses are usually carried out. Other fibrous objects (shoelaces, shoe linings, candle wicks) have few analyzed and published comparanda and add important information regarding the realities of daily life on the *London* and more generally in 17th century England and Europe. Retrieval of silk shoelaces still connected with shoes, which would have been items of relative luxury, highlights the absence of other textiles, in particular any items made of wool. As silk is the most fragile of the fibrous materials when waterlogged, it is unlikely that the absence of wool is due to preservation conditions. Indeed, numerous wool clothing items were recovered from the *Mary Rose*, which is a very similar environment. More likely this is due to the specificity of the areas of the ship that have been excavated to date, which is the area around a gun carriage. While plant bast fibres would have been used around the ship for cordage, sails, stitching/repair medium etc., wool (and silk) would have been primarily used for people's clothing. We would expect them to survive either in association with the human remains, or if they were protected within a container (e.g. a chest), as in the case of the *Mary Rose*. The few human remains retrieved from the *London* to date are very disarticulated and dispersed, and no garments were recovered in association with them. The shoelaces have survived because they were connected with multiple shoes that were all tightly packed in one area, resulting in a lot of compression and physical protection. Future excavation of the other areas of the ship may be expected to produce more textile items.

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Ina Vanden Berghe has an MSc in Chemistry with a focus on textiles from the University of Gent. In 1998 she began work at KIK-IRPA and became head of the Textile Research Unit in 2007. She is a specialist in the fields of natural and synthetic organic dyes and fibres (amino acid based) using chromatographic, spectroscopic and microscopic techniques, as well as in the study of metal threads. She has a particular interest in archaeological textiles and their degradation problems related to various environmental conditions.

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