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the testing of cleaning and drying processes for historical wet rags

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The Texel textile find revisited: the testing of cleaning and drying processes for historical wet rags

Abstract

In 2016, a unique archaeological find of seventeenth-century silk clothing in the form of countless pieces of silk from a shipwreck off Texel, in the Netherlands became world news. In 2017 it was discovered that part of the find had remained damp, and this presented a unique opportunity to conduct research into controlled rinsing and drying methods for this type of material. The aim of the resulting research project was to find a treatment—in as short a time as possible—which would not only save these fragmentary and very degraded silk textiles, but also establish which treatment method would be most suitable to deal with any similar find. Four rinsing agents, rinsing methods and drying techniques were tested on samples of the original material. Of the methods tested, rinsing with a fine and controlled stream of water produced the best cleaning results, but due to its mechanical action it also caused the greatest loss of material. The drying experiments produced no significant differences in fibre condition at a micro-level, with any changes unnoticeable due to the heterogeneous character of the material and the very damaged surface of the fibres. However, freeze-dried samples remained significantly more flexible than those which had been air-dried and were also less distorted and crumpled. Although the research did not provide any definitive 'best' combination of treatments, it did offer insight into the risks and advantages of the chosen methods to enable a better-informed treatment choice. As such, final treatment of the damp silks involved their separation, smoothing and careful rinsing on both sides using a controlled stream of water. The entire collection was then freeze-dried and as a result around 60 fragments were successfully conserved.

Keywords

archaeological textile; maritime silk; aqueous rinsing; freeze-drying; cleaning; shipwreck BZN17 Texel

Introduction

The Rede van Texel, located off the Dutch island of Texel, was an important anchorage for shipping during the seventeenth and eighteenth centuries. It was there that ships waited for a favourable wind to set sail, but this did not always go well, and it is known that many ships were lost as a result of storms. As the seabed is constantly in motion at this location, layers of sand metres-thick can move because of currents and tides, and so now and again 'new' shipwrecks can appear on the sea floor.

It was in this way that in 2009 the seventeenth-century shipwreck *BZN17* appeared out of the sand. The ship is still to be identified but it was a Dutch ship, and its armour suggests that it arrived from or set sail to the Mediterranean. In 2014 a large number of textile fragments were found amidst the wreckage and salvaged by local divers. How the fragments were brought

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to the surface and how they were treated is unfortunately not recorded. While they did their best to dry the fragments, it is known that a significant amount of material was lost.[1]

A maritime find of textiles such as this is unique, not just because historic textiles do not generally survive in seawater, but principally because maritime textile finds often consist of tiny fragments and are seldom of silk.[2] Altogether, more than 100 pieces of varying sizes were found in *BZN17*, of which the majority appeared to be silk, many decorated with silver and gold thread. Among the objects and fragments were entire pieces of both clothing and interior textiles. Although the condition of the individual fragments varied enormously, as a whole, the collection seemed to be in surprisingly good condition for textiles that had been on the sea bottom for roughly 350 years.[3] When such material does survive, it is generally in a very weak state, as was the case with this find.[4] Examination by a scanning electron microscope (SEM) revealed that the entire collection had, to a greater or lesser extent, been damaged by an attack from some sort of bacteria. This damage took the form of dents and grooves in the surface of the fibres.

Little is known about the consequences of long-term damp storage conditions for the chemical and physical structure of textile fibres.[5] This lack of knowledge makes it difficult to predict how such material will react to new storage conditions or to any subsequent conservation treatments. As such, the Texel find offered a great research opportunity to try and answer these and other questions. It became apparent that, by good fortune, in addition to those textile fragments already dried by the divers, there was still a large bundle of wet textiles stored in a plastic bag and held together by a long piece of braid. Although it was impossible to discern the original form and function of the individual pieces of textile in this bundle, it was clear that there were a number of large pieces among them. Although the silk was very weak, dirty and crumpled (Fig. 1), there was much to be gained if the fragments could be saved. It was immediately apparent that the silk was far too weak for any cleaning process involving mechanical action and that this obviously limited the choice of treatments to a great extent.[6]

From the extant literature it can be deduced that the drying process is a critical point in the treatment of any waterlogged archaeological material,[7] but given the amount of dirt and sand that remained between the fragments, it first had to be established if and how they could be rinsed before considering how to dry them.

Setting up the study

The precise conditions in which the silk had survived on the seabed were unknown, nor were the degradation processes which had taken place during that time fully understood, but it is possible that some sort of equilibrium had prevailed.[8] This balance had been disturbed after salvage of the textiles and it was impossible to predict how the fragile fibres would react to any new dry storage conditions, and after drying the material could react very differently to textiles which had not been wet for such a long time. One assumption was that molecular, structural changes had taken place in the fibres,[9] and that further weakening could have been effected by chemical and physical degradation.[10] Any treatment could therefore have a bearing on the condition of the material such that it is not possible to say which treatment might be the 'best'.

Doing nothing was one option, but it would mean that the textile would have to be kept wet, which would require that it be kept cold or frozen to decrease the risk of moulds and fungi and this in turn might cause yet more damage; it might also prove impossible to prevent the development of mould.[11] In addition, if kept wet the fragments would remain inaccessible

1 Arent D. Vos, *Wereldvondsten uit een Hollands Schip, Basisrapportage BZN17/Palmhoutwrak* (Provincie Noord Holland: Haarlem, 2019), 22–3; Hanneke Kramer, 'Diving into Details: Reconstructing the Research and the Practices of the Textile Collection Found at Shipwreck Burgzand North 17' (master thesis, University of Amsterdam, 2017), Scripties online UvA, https://scripties.uba.uva.nl/search?id=635791 (accessed 9 November 2021).

2 Kathryn A. Jakes and John C. Mitchell, 'The Recovery and Drying of Textiles from a Deep Ocean Historic Shipwreck', *Journal of the American Institute for Conservation* 31, no. 3 (1992): 343; R. Srinivasan and Kathryn A. Jakes, 'Examination of Silk Fibers from a Deep Ocean Site: SEM, EDS & DSC', *Materials Issues in Art and Archaeology* 5 (1997): 375.

3 Marijke de Bruijne and Sjoukje Telleman, 'Textielschat uit zee', *Kostuum Nederlandse kostuumvereniging* (2016): 8–19.

4 V. Jenssen, 'Conservation of Wet Organic Artefacts Excluding Wood', in *Conservation of Marine Archeological Objects*, ed. Colin Pearson (London: Butterworth Heinemann, 1987), 81.

5 Kathryn S. Tarleton and Margaret T. Ordoñez, 'Stabilization Methods for Textiles from Wet Sites', *Journal of Field Archaeology* 22, no. 1 (1995): 81; Mary-Lou E. Florian, 'Deterioration of Organic Materials Other than Wood', in Pearson, *Conservation of Marine Archaeological Objects*, 47.

6 SEM-EDX examination established that the structure and surface of the silk fibres was very damaged, possibly due in part to the way in which the textile had been stored after finding.

7 Daphne Reijs, 'De oudheid bewaard voor de toekomst, een onderzoek naar de conservering van archeologisch textiel' (master thesis, University of Amsterdam, 2009), 69.

8 Lynda Hyllyer, 'The Cleaning of Archaeological Textiles', in *Archaeological Textiles, Occasional Papers Number 10*, ed. Sonia A. O'Connor and Mary M. Brooks (London: The United Kingdom Institute for Conservation, 1990), 18.

9 Runying Chen and Kathryn A. Jakes, 'Cellulolytic Biodegradation of Cotton Fibers from a Deep-Ocean Environment', *Journal of the American Institute for Conservation* 40, no. 2 (2001): 101–2.

Fig. 1 Sample 15, a wet textile silk with metal thread.

and any opportunity for research or exhibition would be lost. It was considered that conservation would be better than doing nothing as treatment could make the textile more accessible and easier to inspect and handle.

The condition of the fragments was unique because of the very particular conditions in which they had survived. As it could not be assumed that tests on artificially aged material would deliver representative results for this specific study, the decision was made to conduct experiments on original material before tackling the textiles kept in the plastic bag. This meant that the number of tests would be limited and samples were taken from a piece of silk satin with silver wire recovered from the shipwreck. These still damp samples were, as far as possible, similar in size, condition and material.

10 See, for example, Elizabeth E. Peacock, 'Drying Archaeological Textiles', in *Report from the 4th NESAT Symposium 1–5 May 1990 in Copenhagen*, ed. Lise Bender Jørgensen and Elisabeth Munksgaard (Copenhagen: Getty Conservation Institute, 1992), 198–9.

11 Peacock, 'Drying Archaeological Textiles', 200–1; Louise Mumford, 'The Conservation of the Llangorse Textile', in *Proceedings of the 8th ICOM Group on Wet Organic Archaeological Materials Conference. Stockholm 2001*, ed. Per Hoffmann, James A. Spriggs and Tara Grant (Bemerhaven: ICOM Committee for Conservation Working Group of Organic Archaeological Materials, 2002), 5.

Method

There are three significant components that play a role in the cleaning of archaeological textiles: the medium used to rinse them; the way in which they are rinsed; and the method of drying. The study was set up so that variables in each of these components could be compared to each other, after which the best options could be combined into an optimal treatment method.

1 Rinsing medium

The rinsing mediums tested by the authors were: soft tap water (7.8°dH),[12] as the most universally available substance; deionised water, a purer but potentially also more aggressive medium; seawater, in which the fragments had survived for so long; and a mixture of ethanol and water (70:30%), which can mitigate against further mould damage.[13]

Tap water, deionised water and seawater have different properties which can influence both the condition of the fibres and the effectiveness of the rinsing (Table 1). Another factor which should be considered is that the character of both tap water and seawater can differ from region to region.

12 '°dH' is the Dutch/German unit for measuring water hardness from the amount of calcium and magnesium in the water, see https://www.waternet.nl/service-en-contact/drinkwater/waterhardheid/ (accessed 22 November 2021).

13 Mary-Lou E. Florian, *Fungal Fact* (London: Archetype Publications Ltd, 2002).

2 Rinsing method

Rinsing methods requiring the minimum of handling were sought to reduce mechanical action as far as possible. Detergents and wetting agents were not tested because these would require further rinsing to remove residues. Neither were brushes or sponges used during the treatment and optimal support for the textile fragments was ensured at all times.

Even though mechanical action does not form part of the cleaning process, a certain amount of movement will always be required to remove dirt and sand as they can themselves present a mechanical threat to the textile if not removed. It is to be expected that all the methods would result in some degree of loss.

These factors led to the choice of the following rinsing methods:

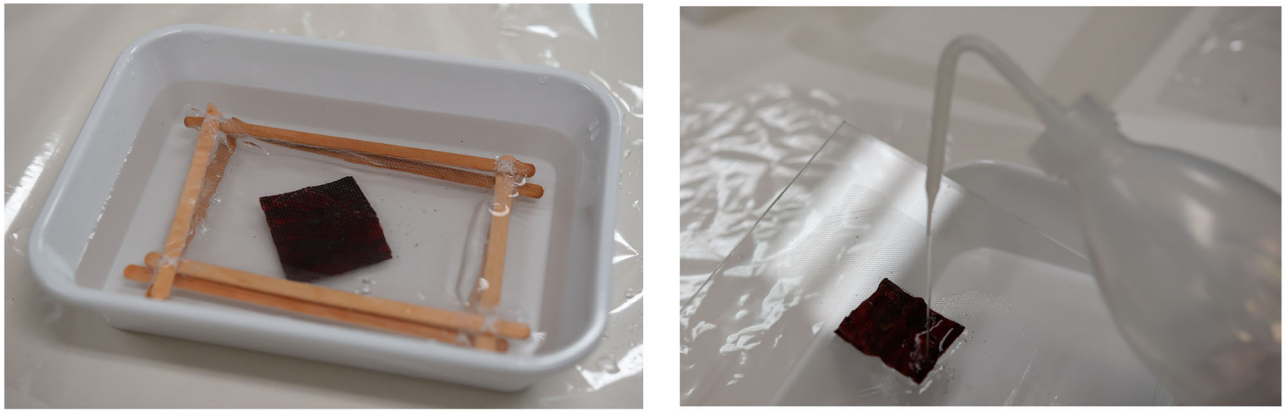
(a) No rinsing (for reference).
(b) Submerging the textile in a bath of water several centimetres deep. To achieve this, the fragments were placed on a piece of tulle stretched on a frame before being submerged. A certain amount of mechanical action was caused by the movement of the frame (Fig. 2a).
(c) Rinsing with a fine, gentle stream of water applied by means of a flexible plastic squeezable bottle. For this treatment the textile was supported on a rigid glass plate, held at an angle to allow the water to run off (Fig. 2b).
(d) Applying a stream of water from a sponge above the sample, which had been placed on a glass plate at a slight angle. The sample was laid on Hollytex, a water absorbent material, so that water could flow over and behind the fabric (Fig. 2c).[14]

14 Hollytex™, non-woven polyester material; a shape-retaining material through which water passes easily.

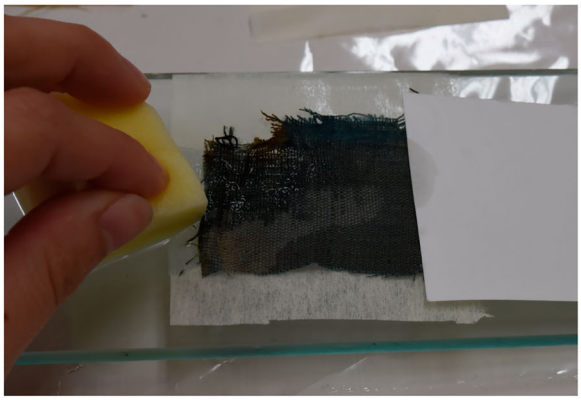
In addition to photography and SEM-analysis, the rinsing water from each test was collected and filtered for assessment. Observations of particular importance for comparison of the methods were: minimising

Table 1 Specifications of the test mediums used for rinsing.

	Tap water	Demineralised water	Seawater	Ethanol (70%) demineralised water (30%)
pH	7.7	6.7	7.7	7
Conductivity	0.56 mS/cm	0.001 mS/cm	50 mS/cm	



(a) (b)



(c)

Fig. 2 (a) Submerging a sample in a shallow bath; (b) application of a controlled stream of water from a bottle (rinsing bath); (c) application of water from a sponge held above a sample (flowing water).

residual dirt and the spreading of dirt; minimising metal and fibre loss; minimising disruption to the structure of the fabric.

3 Drying experiments

Four drying methods were tested; three of these were different forms of air-drying, whereby the speed of evaporation was manipulated. The fourth method was freeze-drying. Drying with the help of solvents was rejected as an option because it would have involved too many handling operations which might have caused mechanical damage to the textiles.[15]

(a) Air-drying at room temperature (21°C) with a humidity of 51%.[16]
(b) Accelerating the speed of air-drying with the application of absorbent material (filter paper).
(c) Slowing the air-drying process by increasing humidity in the area of the object to 80–85%, thereby causing the textile to lose moisture more slowly.
(d) Freeze-drying: freezing for c. 12 hours in a freezing cell at −25°C and then drying in a separate vacuum chamber at room temperature for 24 hours at a pressure of 2mbar.[17]

Air-drying is the simplest method available, and the one applied most frequently, with the speed of drying influenced by controlling humidity, temperature and ventilation. However, drying is always a risky process

15 Jakes and Mitchell, 'The Recovery and Drying of Textiles', 346.

16 The climatic conditions at the time of the experiment.

17 Freeze-drying was performed at Hoogduin Preservation B.V., Hoogduin, the Netherlands, using an Edwards Super Modulyo freeze-dryer.

with such weak material with negative effects including shrinkage, stiffness, brittleness and the collapse of fibres.[18] By accelerating—experiment (b)—and slowing down—experiment (c)—the drying process, it was possible to investigate whether such negative effects could be influenced.

In freeze-drying, the textile is frozen before drying takes place by sublimation.[19] The freezing process is critical, and a point at which the speed of freezing and temperature are both important as the manner of freezing determines the size of the ice crystals formed, which in turn can pose a potential threat to the structure of the fibres. The faster the freezing, the smaller the ice crystals, meaning less damage is likely to occur.[20] The subsequent drying process is characterised by low temperatures and low air pressure. Although the drying process can take place at atmospheric pressure (1013mbar), reduced pressure is often used in practice to speed up the process (vacuum freeze-drying).[21] One advantage of drying by sublimation is that surface tension is reduced, whereby there is less chance of the risks associated with air-drying.[22] As mentioned, the main risk factors associated with freeze-drying are damage from ice crystals or too strong a vacuum, but there is also a risk of removing too much moisture from an object.

Problems to look out for during drying are shrinkage, stiffness, damage to fibres, distortion and puckering of the fabric.

Because it was quickly established that tap water was the best rinsing medium (see results), all the rinsing and drying methods were tested with this medium. This resulted in the testing regime shown in Table 2.

18 Peacock, 'Drying Archaeological Textiles', 200–2.

19 Direct transformation from solid (ice) to gas (vapour) without passing through the intermediate liquid state (water).

20 Jakes and Mitchell, 'The Recovery and Drying of Textiles', 346.

21 Edwards Modulyo freeze-dryers were used.

22 Peacock, 'Drying Archaeological Textiles', 200–2.

Analysis

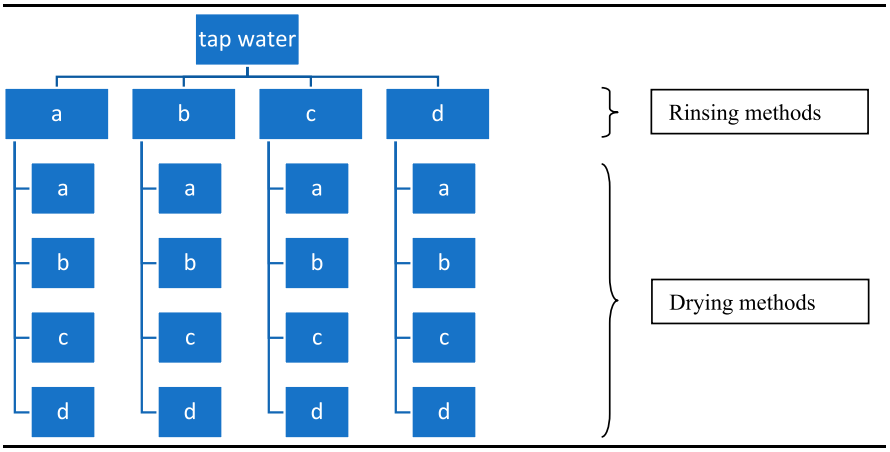
All the 16 samples were visually evaluated before and after treatment using digital photography and stereo and digital microscopy.[23] SEM was used to analyse the condition of the fibres.[24]

In evaluating the rinsing medium, particular attention was paid to the conductivity between the fibres and the medium, the collapse of fibres, and the formation of any salts or calcium crystals. The chemical composition of any crystals observed was analysed using SEM-energy-dispersive X-ray spectroscopy (SEM-EDX). The textile samples were compared to each other to evaluate differences in condition. It was problematic given that these analyses could only be conducted after the completed treatment because the vacuum of the SEM chamber would have caused drying of the textile.

23 HIROX-microscope Model KH-8700, normal lens AD-2016H.

24 Model JSM-5910LV from JEOL, with Silicon Drift Energie Dispersive X-ray detector from Thermo Scientific, acceleration voltage 20keV, 30Pa.

Table 2 Schematic representation of tests performed.



In the course of the study, findings were recorded in radar diagrams to provide a visual comparison between the positive and negative consequences of various treatments. By placing the diagrams containing useful observations next to each other, it was possible to determine an optimal combination of treatments. In order to compare the results, working from the inside to the outside of the diagram, a ranking between 1 and 5 was given for each criterion.

Results

Relatively little difference was observed in the properties of the various textile samples as a result of the different treatment methods. Clear similarities were observed when it came to the condition of the fibres and the structure of the fabric, with minimal differences apparent in mould reduction, distortion and shrinkage. However, for a number of important points differences could be reliably demonstrated. The biggest differences were seen in the effectiveness of each rinsing method in terms of the removal of visible dirt and the loss of material due to the rinsing. Important differences also became apparent with regard to the stiffness of the samples according to the drying method used.

A significant problem with the analysis of the samples was that the fibres of silk are very heterogenous in character. The SEM images showed that the fragility of the fabric was largely due to damage by unidentified bacteria visible as dents and notches in the surface of the fibres. This damage had almost certainly occurred before treatment and was visible in all the samples. The analyses also indicated that this bacterial attack had not occurred uniformly throughout the fabric. There were areas in each sample where the fabric surface looked smooth and supple, while a few centimetres away the fibres had clearly been under attack. (Fig. 3). The more bacterial degradation could be seen, the more brittle and broken the fabric was.

The same heterogeneous character was visible in the extent to which the silver thread had become degraded. Unlike the fibres, this damage was visible to the naked eye (Fig. 4). The fact that the condition of the material varied so much within each sample inevitably affected the evaluation of the test results.

1 Evaluation of rinsing mediums

SEM-EDX analysis led to the conclusion that tap water was the most suitable medium for rinsing. Although the media used did not show any significant differences with regard to the effectiveness of cleaning, it seemed that tap water caused the least damage. Deionised water proved to be more aggressive, causing more breakage in the textile fibres. Because deionised

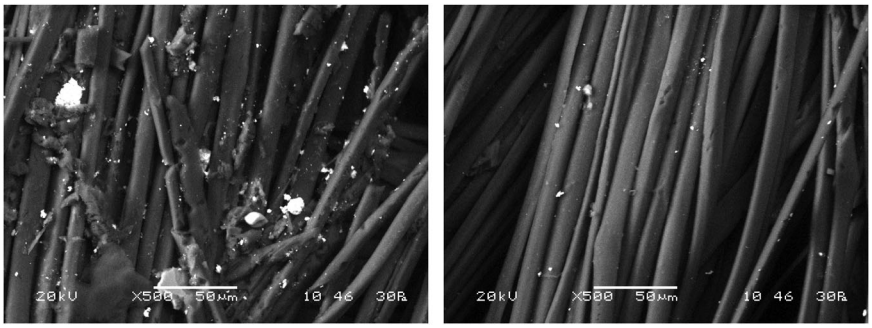


Fig. 3 Two SEM-images from sample 22 of silk, magnification 500×. (a) On the left, damage from severe bacterial attack; (b) on the right, relatively undamaged fibres. The products of silver corrosion are visible in the form of light flecks.

Fig. 4 (a) Sample 13 (40×40mm), corroded silver threads (black), largely unravelled; (b) sample 14, corroded silver threads (black), mostly intact together with the silk thread that forms their core (brown).

water contains no minerals, there is also a danger that osmosis will be greater than with tap water because in order to reach a balance, more minerals are drawn out of the fibres into the water, thereby increasing the risk of fibre collapse. The mixture of ethanol and water resulted in flatter and more brittle fibres and rinsing with seawater caused the formation of new salt crystals. It was also concluded that using seawater resulted in the formation of a new corrosion product, namely silver chloride. A further concern was the possible effect of calcium in the tap water, but as there were no visible signs of calcium deposits after rinsing, the choice was made to conduct the remainder of the rinsing tests using tap water.

2 Evaluation of rinsing methods

The main differences observed between the treatments concerned the effectiveness of the cleaning and the degree of material loss. Any differences in changes to fabric structure and reduction of mould were found to be minimal. Because no significant differences were observed when it came to changes in colour and the condition of fibres, these criteria were not included in the radar diagrams. The results from the various rinsing methods are presented in Fig. 5.

The main purpose of rinsing the textile was the removal of dirt, whereby further damage could be limited. It was concluded that the soiling present consisted of sand (from the sea) together with loose and broken fibres and corrosion products (from the textile) which, for the most part, lay loosely on the surface or between the fibres of the fabric. None of the cleaning methods resulted in the samples becoming completely clean, with the samples which had not been rinsed being the dirtiest. However, a lot of dirt also remained after cleaning with both the flowing water and the submerging bath. Because of the limited mechanical action involved in both these methods, a good deal of the dirt was not removed, but merely spread. The samples rinsed using the squeezable bottle were by far the cleanest (Fig. 6). Grains of sand were for the most part gone, though the products of metal corrosion—strictly speaking not part of the original

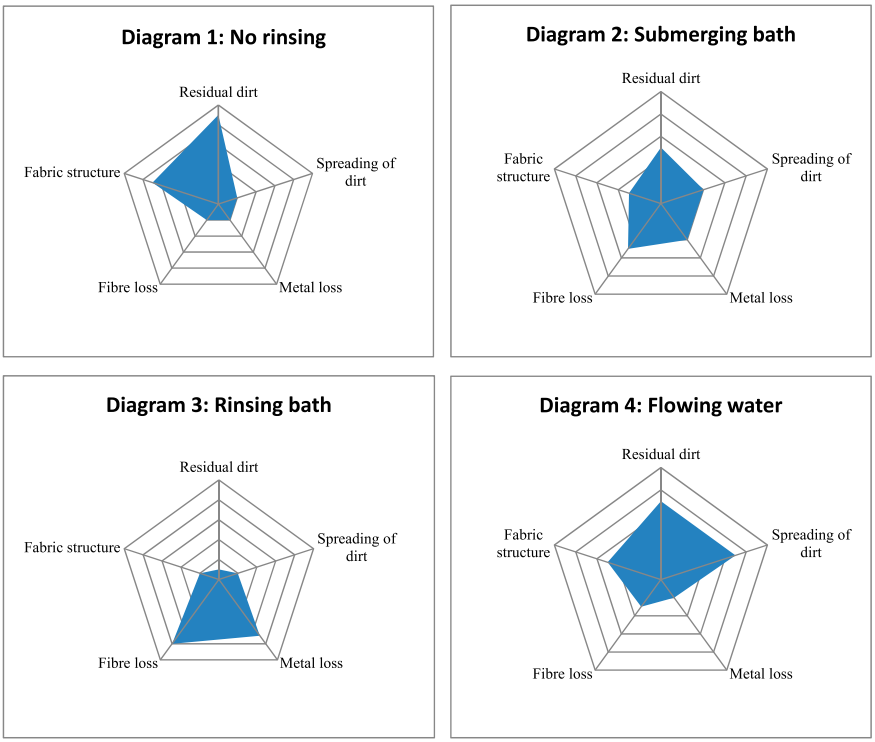
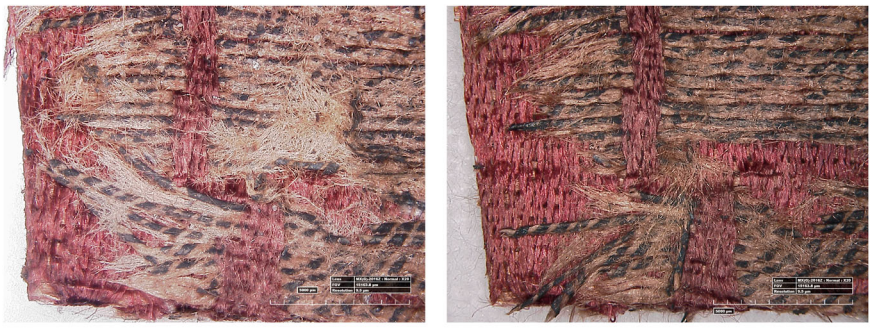


Fig. 5 Diagrams 1–4. Showing the negative parameters of the rinsing treatments. The larger the blue area, the more damaging the method proved to be for the samples.

material—remained. It also became clear that this method offered the most control unlike the other rinsing methods, as it is possible to control precisely where and with how much force the water is applied.

The aesthetic appearance of all the rinsed samples was improved by the reduction in the presence of mould and dirty, loose and raised fibres. In general, the structure of the fabric was not much altered, with the number of dents and grooves in the surface of the fibres not being significantly changed in the test samples; the damage could still be seen in both the rinsed and unrinsed samples. This seemed to confirm that the water itself had caused no damage.

As expected, there was a downside to the treatment; the effectiveness of the cleaning was, amongst other things, linked to any associated mechan-



(a) (b)

Fig. 6 (a) HIROX-image, sample 14 rinsed with a stream of water, before treatment; (b) right, after treatment; the loss of fibres can be compared. Magnification 20×.

ical action. Alongside the desired cleaning result, rinsing in a controlled stream of water also caused the greatest loss of metal and fibres (see Fig. 5). Despite this negative side-effect, it was nevertheless the only method in which rinsing proved to be effective and also the method which offered the most control over the rinsing process.

3 Evaluation of drying methods

The results of the drying experiments are shown in Fig. 7. There are fewer comparative differences apparent than in the rinsing experiments. The greatest difference was in stiffness. There were only minimal differences in shrinkage and distortion and no significant differences in the condition of the fibres.[25]

The samples which had been freeze-dried were clearly much more flexible than those which had been air-dried; whereas the maximum angle of bending in the air-dried samples was only 16°, that of the freeze-dried samples was 72°. The differences between the various air-dried samples were minimal, with the samples in which drying had been slowed down proving to be the most flexible of the three.

The amount of shrinkage observed was limited, with all the samples suffering shrinkage of between 0% and 2.5%. The standard air-dried samples exhibited shrinkage of 0–2.5%; the accelerated air-dried samples 0–2.3%; and the delayed air-dried samples 0–2.4%. The freeze-dried samples, with a shrinkage of 0–1.8%, were somewhat less affected.

None of the samples became flat and the folds and crumpling evident before treatment did not disappear. If a textile has remained for long enough in one position, the folds and distortions caused frequently become permanent. The freeze-dried samples were relatively speaking the flattest, together with those subjected to accelerated air-drying.

25 Shrinkage was checked by measuring each sample before and after treatment. Stiffness was measured by letting 50% and 75% of the samples hang over an edge and measuring the angle at which the fabric bends (after drying). Both processes were imaged.

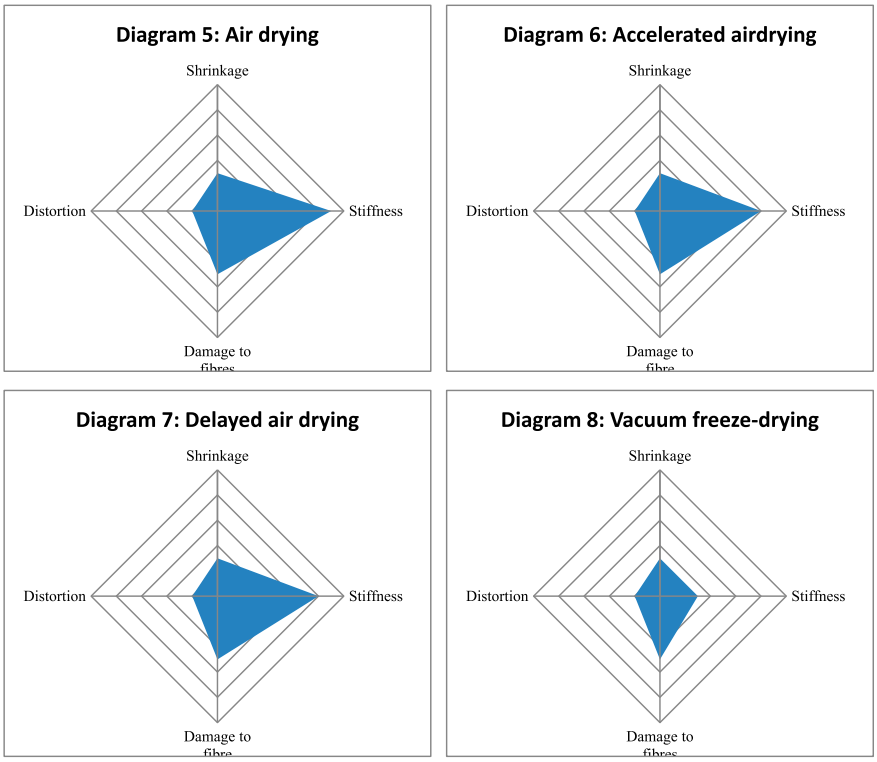


Fig. 7 Diagrams 5–8, the negative parameters of the drying methods are shown. The larger the blue area, the more damaging the method proved to be for the samples.

No salt deposits appeared on any of the samples, and neither were any significant differences in the condition of the fibres detected. As explained earlier, it must be remembered that the condition of the textile being studied was fairly heterogeneous which makes an exact evaluation of the results complicated. What can be said is that there appeared to be no significant increase in damage caused by any of the methods tested in the drying process.

Discussion

As expected, the method which involved the most mechanical action produced the cleanest samples, although even this method failed to remove all the dirt. Rinsing with a controlled stream of water was the only method that appeared to have any cleaning effect. However, the mechanical action intrinsic to this method also resulted in the most damage to the weakened silk, which could be seen in the form of lost fibres. This damage was not particularly noticeable by eye, and most of the materials washed away were already loose fibres. Furthermore, the structure of the fabric was easier to read once this loose material was removed. This does not, however, alter the fact that more loss of material was caused by this method. Greater control of the process was the second observable advantage of rinsing using a stream of water as it is possible to control the strength of the stream as well as where and for how long it is applied.

Whether this method is preferable to the other methods is also an ethical question, given the damage. Testing allows for the consequences of the methods detailed to be understood beforehand, so that the advantages and disadvantages can be carefully weighed up before choosing a preferred treatment.

It is striking that, in terms of the structure of the fibres and fabric surface, no significant differences were observed between the different drying experiments. This is worth noting, particularly because the literature is clear on the point that drying is a critical stage in any treatment and can, more than rinsing, be the cause of further damage depending on the method used.[26] The fact that little difference was observed between the methods used here may be due in large part to the heterogeneous character of the textiles and their heavily degraded fibres. As such, these factors made it difficult to establish whether there had been major changes to the structure of the fibres in the course of the treatments, which made the choice of an optimal drying treatment difficult. Differences in the degree of distortion and shrinkage also appeared to be minimal. More interesting was the flexibility of the freeze-dried and this appeared to be the best choice based on this criterion.

26 Peacock, 'Drying Archaeological Textiles', 200–1.

Freeze-drying can be a lengthy process and requires specialist equipment. The limited availability of the equipment is possibly one reason why, until recently, freeze-drying has remained a technique little-used in the treatment of archaeological textiles. Another factor is that a freeze-drying process can be conducted in different ways: drying can take place at room temperature provided there is enough of a vacuum, or at atmospheric pressure provided the temperature is low enough, or by using both low temperatures and a vacuum. In addition, the temperature and duration of freezing, as well as the strength of the vacuum, can be varied. However, only one freeze-drying method was tested for this study, and was based on equipment availability. This means that although the results are insufficient to provide definitive conclusions or determine differences between these variables, what can be said is that the results of freeze-drying were favourable compared to the other drying methods tested.

Further research into the freeze-drying of similar textiles is therefore also an important recommendation for future studies.

Treatment

Because delaying treatment of the remainder of the collection was not an option, it was decided—on the basis of the test results and prevailing knowledge at the time—to rinse all 60 of the textile fragments which were still damp using the water-stream method and then freeze-dry them. The advantage of removing the sand and salt was weighed up against the disadvantage of the material loss using this method, and it was decided that the advantages outweighed the disadvantages.

It should be noted that there is a big difference between 'damp' and 'wet' textiles.[27] The degraded silk appeared to be very weak when wet, such that it took very little mechanical action for it to simply fall apart. It appeared to be significantly less weak when it was merely damp, so it was in a damp state that the fragments were unfolded insofar as possible and laid out flat before rinsing began. For this purpose, the fragments were placed on a rigid surface made of foamboard covered with melinex. For maximum control of the textile, a layer of tulle was inserted between the board and the fragments which meant that they could be moved around relatively easily, and then carefully removed from the board without having to 'peel' them off. The textiles were carefully unfolded by hand as far as possible which in practice meant that not every fold could be opened out. No weights were used. Each object was individually evaluated to establish whether the fabric was in a sufficiently good condition to be further unfolded, and to what extent more information would be gained by doing so.

One by one, the fragments were then rinsed with tap water using the squeezable bottle (Fig. 8). The board on which the fragments were spread out was held at an approximate angle of 30°, which increased the run-off of water and dirt. The tulle could be partially lifted to further allow the run-off while the textile was supported. By sandwiching the fragments between two boards covered in tulle, it was possible to turn the fragments over so that both sides could be rinsed. Once the textile was wet, mechanical action was limited as far as possible to keep damage to a minimum, and for this reason brushes and sponges were not used. However, some

27 Peacock, 'Drying Archaeological Textiles', 198.

Fig. 8 The rinsing of archaeological silk (fragment 15), with, on the left, Renate van Oosterhout, and on the right Sjoukje Telleman. Image by Ton Lupak.

damage in the form of material loss, was unavoidable and expected due to the extreme fragility of the fibres. In the event, the amount of loss was relatively small. It also proved impossible to remove all the dirt, partly because the washing away was impeded by the layers and bumps in the fragments.

Because treatment could not be postponed any longer, it was eventually decided that the fragments would be vacuum-freeze-dried using the equipment available. It should be noted that this treatment differed somewhat from the method tested, mostly due to the limited size of the freeze-dryer used in testing. To fit the large objects another freeze-dryer from a different company, had to be chosen.[28] Because that company uses other protocols, testing was performed to make sure the results were similar. The textile was frozen at a temperature of c. −40°C, as quickly as possible to prevent the formation of large ice crystals. Drying took place in the same chamber at a pressure of c. 1mbar. Because the freeze-dryer chamber was about 1.7m deep with a diameter of 0.43m, it meant that, among other things, it was too narrow for several of the fragments, so these had to be freeze-dried partially folded, which can be considered a disadvantage of this particular treatment. Finally, the temperature was raised each day by 2°C and the drying process took c. 20 days.

28 Freeze-drying was performed at Restauratieatelier Restaura, Heerlen, the Netherlands, using an Edwards Modulyo freeze-dryer.

Concluding remarks

The study did not produce a clear optimal combination of rinsing and drying methods for this type of textile, and it appears that all methods have significant drawbacks as well as advantages. In this case it meant that pragmatic choices had to be made so that the fragments could be treated. Having said this it should be noted that other methods were not tested and should not be ruled out as they might be suitable in other situations. It is always important to weigh up the possible outcomes from a range of treatment options, taking into account the desired effects as well as any potential negative consequences before making a final decision.

The most significant result obtained from the study was the difference in flexibility between the freeze-dried samples and the various air-dried samples. Given that flexibility and suppleness are essential properties of textiles, this was an important advantage. Stiffness of the fibres can also lead to breakage and loss. This meant that vacuum freeze-drying emerged as the 'best' treatment option. Freeze-drying is actually a specialist process with many variables for which there is little published research with regard to treating archaeological textiles. One promising option is non-vacuum freeze-drying, whereby the process takes place under atmospheric pressure, and further research into its use is recommended.

The eventual treatment consisted of three parts: flattening, rinsing and freeze-drying. The purpose of opening out and flattening the fragments was to make them more readable, and to gain more insight into their original forms and functions by re-establishing their shape. No attempt was made to fully flatten the fragments as this would almost certainly have caused more damage. This part of the process was successful and the bundle of wet textiles was separated into individual items which could thereafter be stored flat.

The aim of the rinsing treatment was the removal of surface dirt, sand and any loose corrosion products. This proved to be a realistic aim as while it was not possible to remove all the dirt, most of the potentially damaging particulate matter was removed using a controlled stream of tap water.

The reason for drying the textile was to make it easier to store and handle, creating the possibility for research and exhibition and by using a freeze-drying method this last aim was also achieved.

The treatment enabled the transformation of an incoherent bundle of textiles into a collection of readable and accessible textile fragments,

capable of interpretation and study. The 60 fragments were traceable to some eight different objects or pieces of fabric, with only a few fragments of some fabrics with many more for others. It was not possible to ascribe a function to all of the textiles, but the bundle appeared to contain several pieces from suits or costumes. Further analysis and historical research will hopefully clarify this. The conserved textiles now form an important addition to the collection of previously studied fragments from the textile find discovered in wreck BZN17.

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Samenvatting
"De Texelse textielvondst opnieuw bekeken: het testen van reinigings- en droogprocessen voor historische natte vodden"
Een unieke archeologische vondst van zeventiende-eeuwse zijden kledingstukken en talloze fragmenten uit een scheepswrak bij Texel, Nederland, was in 2016 wereldnieuws. In 2017 bleek een deel van de vondst nog vochtig bewaard te zijn gebleven. Dit bood een uitgelezen kans om onderzoek te doen naar gecontroleerde spoel- en droogmethodes van dergelijk materiaal. Het onderzoek was erop gericht om op korte termijn een behandeling te vinden om ook dit textiel—fragmentarisch en sterk gedegradeerde zijde—te redden, maar ook om te bepalen welke behandelingsmethode het meest geschikt is bij vergelijkbare vondsten. Vier spoelmiddelen, spoelmethodes en droogmethodes zijn getest op monsters van origineel materiaal uit de vondst. Het onderzoek heeft aangetoond dat spoelen met een gecontroleerde en fijne waterstraal het beste schoonmaakt van de geteste methodes. Door de mechanische actie van het spoelen zorgt deze methode echter ook voor het meeste verlies. De droogexperimenten hebben op microniveau geen significante verschillen in vezelconditie laten zien. Eventuele minimale verschillen vielen echter niet op door het heterogene karakter van het materiaal en het zeer aangetaste vezeloppervlak. Gevriesdroogde monsters zijn echter significant soepeler gebleken dan 'aan de lucht' gedroogde varianten. Tevens zijn de gevriesdroogde monsters iets minder vervormd en gekrompen. Het onderzoek heeft niet geleid tot één 'beste' combinatie van handelingen, wel tot meer inzicht om voordelen en risico's van de gekozen behandelingen tegen elkaar te kunnen afwegen. Aan de hand van de resultaten is een onderbouwde keuze gemaakt voor de behandeling van de collectie vochtige zijde. Alle fragmenten zijn zo goed mogelijk van elkaar gescheiden en gevlakt. Vervolgens zijn ze aan beide kanten gecontroleerd gespoeld met een straal kraanwater. Tot slot is de gehele collectie gevriesdroogd. Dankzij de behandeling zijn ca.60 fragmenten met succes geconserveerd.

Résumé
« La découverte textile de Texel revisitée: les essais de procédés de nettoyage et de séchage de chiffons humides anciens »
En 2016, une découverte archéologique unique de vêtements en soie du XVIIe siècle sous la forme d'innombrables morceaux de soie provenant d'un naufrage au large de Texel, aux Pays-Bas, est devenue une renommée mondiale. En 2017, il a été découvert qu'une partie de la découverte était restée humide, ce qui offrait une opportunité unique de mener des recherches sur des méthodes de rinçage et de séchage contrôlés pour ce type de matériau. L'objectif du projet de recherche qui en a résulté était de trouver un traitement—dans les plus brefs délais—qui permettrait non seulement de sauver ces textiles de soie fragmentaires et très dégradés, mais également d'établir la méthode de traitement la plus appropriée pour faire face à toute découverte similaire. Quatre agents de rinçage, méthodes de rinçage et techniques de séchage ont été testés sur des échantillons du matériau d'origine. Parmi les méthodes testées, le rinçage avec un jet d'eau fin et contrôlé a donné les meilleurs résultats de nettoyage, mais en raison de son action mécanique, il a également causé la plus grande perte de matière. Les expériences de séchage n'ont produit aucune différence significative sur l'état des fibres à l'échelle microscopique, avec des changements imperceptibles en raison du caractère hétérogène du matériau et de la surface très endommagée des fibres. Cependant, les échantillons lyophilisés sont restés significativement plus flexibles que ceux qui avaient été séchés à l'air et étaient également moins déformés et froissés. Bien que la recherche n'ait pas défini la « meilleure » combinaison de traitements, elle a permis de mieux comprendre les risques et les avantages des méthodes choisies pour permettre un choix de traitement plus conscient. Ainsi, le traitement final des soies humides impliquait leur séparation, leur aplanissement et un rinçage soigneux des deux côtés à l'aide d'un courant d'eau du robinet contrôlé. L'ensemble de la collection a ensuite été lyophilisé et une soixantaine de fragments ont ainsi été conservés avec succès.

Zusammenfassung
„Der Textilfund von Texel: Prüfung von Reinigungs- und Trocknungsverfahren für historische nasse Lumpen"
Im Jahr 2016 machte ein einzigartiger archäologischer Fund von Seidenkleidung aus dem 17. Jahrhundert in Form von unzähligen Seidenstücken aus einem Schiffswrack vor Texel in den Niederlanden weltweit Schlagzeilen. Im Jahr 2017 wurde entdeckt, dass ein Teil des Fundes feucht geblieben war, was eine einzigartige Gelegenheit bot, kontrollierte Spül- und Trocknungsmethoden für diese Art von Material zu erforschen. Ziel des daraus resultierenden Forschungsprojekts war es, in möglichst kurzer Zeit eine Behandlung zu finden, die nicht nur diese fragmentarischen und stark degradierten Seidentextilien erhält, sondern auch feststellt, welche Behandlungsmethode sich für ähnliche Funde am besten eignet. Vier Reinigungsmittel, Nassreinigungsmethoden und Trocknungstechniken wurden an Proben des Originalmaterials getestet. Von den getesteten Methoden führte das Spülen mit einem feinen und kontrollierten Wasserstrahl zu den besten Reinigungsergebnissen, verursachte aber aufgrund seiner mechanischen Wirkung auch die größten Materialverluste. Die Trocknungsexperimente ergaben auf Mikroebene keine signifikanten Unterschiede im Zustand der Fasern, wobei etwaige Veränderungen aufgrund des heterogenen Charakters des Materials und der stark beschädigten Oberfläche der Fasern nicht zu erkennen waren. Die gefriergetrockneten Proben blieben jedoch deutlich flexibler als die luftgetrockneten und waren auch weniger verformt und zerknittert. Obwohl die Untersuchung keine endgültige 'beste' Kombination von Behandlungen ergab, bot sie einen Einblick in die Risiken und Vorteile der gewählten Methoden, um eine fundiertere Wahl der Behandlung zu ermöglichen. Die abschließende Behandlung der feuchten Seiden umfasste das Trennen, Glätten und sorgfältige beidseitige Abspülen mit einem kontrollierten Strom von Leitungswasser. Die

gesamte Sammlung wurde anschließend gefriergetrocknet, so dass etwa 60 Fragmente erfolgreich konserviert werden konnten.

Resumen

"Examinando de nuevo el hallazgo de los textiles de Texel: análisis de los procesos de limpieza y secado de fragmentos textiles históricos húmedos"

En 2016, un singular hallazgo arqueológico de ropa de seda del siglo XVII compuesto de innumerables piezas de seda provenientes de un naufragio frente a Texel, en los Países Bajos, se convirtió en noticia mundial. En 2017 se descubrió que parte del hallazgo había permanecido húmedo, y esto presentó una oportunidad única para realizar investigaciones sobre métodos de lavado y secado controlados para este tipo de material. El proyecto de investigación consecuente se enfocó en encontrar un tratamiento, en el menor tiempo posible, que no solo salvaría estos tejidos de seda fragmentados y muy degradados, sino que también establecería los métodos de tratamiento más adecuados para hacer frente a cualquier hallazgo similar. Se realizaron pruebas en muestras del material original usando cuatro agentes de limpieza, métodos de aclarado y técnicas de secado. De los métodos probados, el aclarado usando un chorro de agua fino y controlado produjo los mejores resultados de limpieza, pero debido a su acción mecánica también provocó la mayor pérdida de material. Los experimentos de secado no produjeron diferencias significativas en el estado de las fibras a micro-nivel, con cambios imperceptibles debido al carácter heterogéneo del material y a la superficie muy dañada de las fibras. Sin embargo, las muestras liofilizadas permanecieron significativamente más flexibles que las que se habían secado al aire y también estaban menos deformadas y arrugadas. Aunque la investigación no proporcionó ninguna combinación definitivamente 'mejor' de tratamientos, sí ofreció información sobre los riesgos y las ventajas de los métodos elegidos para permitir una elección de tratamiento mejor informada. Como tal, el tratamiento final de las sedas húmedas implicó su separación, alisado y enjuague cuidadoso por ambos lados con un chorro controlado de agua del grifo. A continuación, se liofilizó toda la colección y, como resultado, se conservaron con éxito alrededor de 60 fragmentos.

摘要

"重新审视特瑟尔的纺织品发现：对历史性湿布料的清洁和干燥测试"

2016年，一个罕见的考古发现成为了世界新闻——在荷兰特瑟尔附近的一艘沉船中，发现了以无数碎片形式出现的17世纪丝绸服装。2017年，人们发现部分丝绸仍然潮湿，这为研究此类材料的可控漂洗和干燥方法提供了绝佳机会。由此产生的研究项目，其目的在于尽量在短时间内找到一种处理方法——不仅能够挽救这些零碎且降解严重的丝绸纺织品，还可以确定何种方法最适宜处理此类发现。作者在原材料样品上测试了四种漂洗剂、漂洗方法和干燥技术。在所测试的方法中，使用精细且可控水流的清洗，获得了最佳清洁效果，但由于其机械作用，也造成了最大材料损失。干燥实验在微观层面上没有引起明显的纤维状况差异，由于材料的异质性和严重受损的纤维表面，使得任何改变都不太显著。但是，进行了冷冻干燥的样品要比风干的样品柔软得多，且变形和皱褶的情况也更少。尽管此研究没有提供任何明确的'最佳'治疗组合，却也深入察看了所选方法的风险和优势，以便于做出更明智的选择。像此类情况，潮湿丝绸的最终处理包括了将其分离、平顺，并使用可控自来水水流仔细清洗两面。作者随后将整个系列冷冻干燥，结果成功保护了约 60 个碎片

Biographies

Sjoukje Telleman completed her training as a textile conservator at the University of Amsterdam. This research was a part of her studies. After graduation in 2017 she has worked as an independent textile conservator in the Netherlands on projects for various private clients as well as museums including the National Museum of Antiquities in Leiden, Museum Valkhof in Nijmegen and the Dutch Open Air Museum in Arnhem. The conservation treatment of the Texel textiles described here was performed in 2018.

Emmy de Groot has been involved with textile conservation training in the Netherlands since 1991 and currently teaches at the University of Amsterdam. Her initial training was the teaching of Textile Design and Manufacturing Techniques. After graduating she trained as a textile conservator while working in the largest private conservation studio in the Netherlands. At present she combines her teaching work with projects as an independent textile conservator. Among other activities in conservation she was involved as an editor and member of the advisory board for the Dutch 'Textile Commission' which supports the preservation of the textile heritage by offering a platform and network, organising symposia and events, and publishing articles on textile topics in the Netherlands.

Ineke Joosten is a senior heritage specialist with over 25 years of experience studying cultural heritage materials such as archaeological textiles and metal, paintings, stone monuments and sculpture, garnet, glass and ceramics. Her research focusses on materials degradation and archaeometric studies. She specialises in the micro analysis of cultural heritage objects using SEM-EDX and has collaborated on several European projects, such as CHARISMA, IPERION CH and IPERION HS.

René Lugtigheid is a lecturer in textile conservation and a textile art historian in the Department of Conservation and Restoration of Cultural Heritage at the University of Amsterdam. She recently completed her PhD into the reuse of silk ladies' dresses into priestly robes in Dutch clandestine churches in the eighteenth century.

Maarten R. van Bommel is professor of conservation in the Department of Conservation and Restoration of Cultural Heritage (C&R) in the Faculty of Humanities at the University of Amsterdam (UVA), as well as a professor of analytical science at the Van't Hoff Institute for Molecular Sciences (HIMS) in the Faculty of Science. In this unique position he bridges the two disciplines of analytical science and conservation. His main research is focussed on the characterisation and behaviour of organic colorants, including research into their degradation. He has been awarded several national and international funded grants, and has written over 90 publications, including articles, book chapters and books.