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Wet Organic Archaeological Materials

WOAM NEWSLETTER

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Welcome to the 63rd WOAM Newsletter which is slightly longer than usual and forms a special edition in order to share with you the question and answer sessions from the ICOM-CC Wet Organic Archaeological Materials Working Group Conference in Mainz 2023. We know that these sessions are important for the dialogue in our group. As the publication for this conference was prepared as a pre-print, and given out to participants at the time of the conference, it was not possible to include the live Q and A sessions, so we are pleased to share them with you here.

The abstract for each paper/poster has been included as a reminder of the subject under discussion and the questions and answers are then included, as transcribed from the recordings of the sessions.

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Session I: Conservation treatments and case studies

Analytical methods can help with the melamine conservation process: A case study on a logboat from the Ljubljanica River

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In 2015, a large ancient logboat dating to the end of the 2nd century BC (measuring 14.3-14.5 m in length, up to 1.38 m in with and 0.78 m in height) made from oak (*Quercus* spp.) was raised from the river Ljubljanica, near Vrhnika, 20 km southwest of Ljubljana, Slovenia. At the time of discovery, it was broken into three larger pieces and several smaller ones. Several historical repairs could be observed, mainly iron clamps and resin soaked woollen textiles, telling about its value for ancient owners. It was decided for several reasons that the consolidation would be carried out with melamine resin. It was the first time that such a large object was conserved by melamine resin in Slovenia, therefore several questions and problems were raised before and during the work. To address some of them, we used different analytical methods, mainly FTIR spectroscopy. FTIR was applied to monitor the resin solution in order to prevent damage of the object due to resin deposits on the surfaces of the objects. We found out that certain bands in FTIR spectra can serve as markers, that can help to monitor the melamine resin solution and give information about progressing polymerisation even before a turbidity test (pouring melamine resin into water) is positive. Furthermore, FTIR was applied on core samples to monitor depth of penetration of melamine resin, to decide when the impregnation process can be terminated. Additional analyses include weighing of drying pieces and measuring wood humidity to monitor drying process of the objects. All these analyses help us to monitor as well as better understand the conservation process and make decisions in favour of conserved objects.

Q/A:
Laure Meunier: I wanted to know if you left the reparation textile in place during the conservation process?
Katja Kavkler: Some smaller pieces were left in place but there was a large piece which was falling off so it was conserved separately. I didn't talk about it. I just froze it and didn't conserve it because it's very well preserved.
Katharina Schmidt-Ott: Melamine resin is irreversible. Did you maybe take a few samples aside for later investigations?
Katja Kavkler: Of course, we took some samples aside. C^{14} was done on the untreated samples, so yes, of course.
Markus Wittköpper: If you would find another log boat this size. Would you decide on the same conservation method or would you change to another one?
Katja Kavkler: I know this method the best. So yes, I think I will decide to use melamine resin. I have one a bit smaller now you don't know about. I intend to do the same.

Extraction and short-term stabilisation of a 13th century AD grave

Laure Meunier[1] and Laurent Cortella[1]
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The discovery of a 13th century grave by French archaeologists at the end of their excavation campaign led to the development of a new post-extraction stabilisation method. This grave contained multiple organic materials which were generally in a wet condition but not waterlogged, and it was therefore not possible to consider conserving them immersed in water. Due to the archaeological significance of this particular grave, archaeologists decided to perform a block excavation. This block had to be maintained in the relative humidity conditions of the excavated site for a few months until laboratory excavation was possible. This took place in April 2021 and involved separating the different materials to allow suitable treatments to be administered and perform comprehensive studies of the rare materials. The new method presented here allows fine excavation to be delayed so it can be properly prepared without being rushed. This technique cannot be envisaged as a long-term storage option, but will simply alleviate time constraints for a few months and prevent having to deal with biocides or mold. This type of excavation is rare, and constitutes a complex salvage recovery. Improvements made now ensure safe working conditions and maximum recovery of artefacts and data.

Q/A:
Johanna Rivera: You mentioned using gamma radiation for the burial. Are you concerned that gamma could affect DNA analysis or future analysis of DNA?

Laure Meunier: I was not responsible for the DNA analysis. My part was to separate the different materials, not only the organics. The archaeological team took some samples to make DNA analyses. There was some kind mystery in this grave: the Bishop was supposed to be dead near 60 years old and the anthropologists say that it was very odd because his spine was in very good condition and it was so odd for this period, because they were all riding horses and so on. There is a big mystery around this grave. I think they were searching for DNA to see if they could find some genetic disease that can be tracked.

Angeliki Zisi: It is interesting that you dismantled the grave, so you took out all the layers one by one? And why did you do that? Are you happy with that? Or would you rather have it as one object with all the different types of materials?

Laure Meunier: We were asked to separate the different materials because the archaeologists decided to make an anthropological study, so they had to have access to the bones. And to have this they had to remove the clothes because they were covering the bones. The archaeologists called us to manage the process and to take the maximum information. This would allow us to conserve each material in the right way because they were so different and they needed very different treatments. To conserve them, we had to separate them. We thought of leaving the burial complete and making some kind of scan and screening. While dismantling, you can see things that cannot be seen in the scan. When you wait and leave the materials together you can't recover this information because of alterations. So this kind of grave and the information is rare. It has been found in the past and is not so well studied. It was a very good occasion to do so and we discovered very interesting things, for example that certainly the corpse was not dressed. The clothes have been put over him to make it look as he was wearing them. So it was interesting because if you had left everything in place, you would not have been able to see that.

Ida Hovmand: Do you know how the leather was treated?

Laure Meunier: Celine Bonnot-Diconne made a PEG impregnation and she removed the iron with a ultrasonic pencil. She found very fantastic details.

Ida Hovmand: We would like to hear about that some other time.

Ida Hovmand: Did you see any preferential preservation of the materials in relation to the burial conditions of the grave? Were some of them affected by the proximity to the body?

Laure Meunier: Yes, first the archaeologists said to me that the body was just laid on a lead sheet. When I arrived I saw the lead was completely corroded and full of holes. So instead of just taking the lead sheet with the corps up I decided to take 10 centimeters of soil below the sheet to ensure everything was kept in place. The textiles were in less good condition on the corps. Maybe because the skull was crushed, it allowed organic material to degrade the textile. As I said the clothes were just put on the corpse and when I removed the first part from the legs there was nothing there but the bones. Where are the clothes? We understand that it was just placed on the body and this was really a huge discovery. And everything was very well preserved because of the sandy soil and the sarcophagus made of stone allowed a really slow drying and no water to stay inside. So it was a very perfect, slow drying system and it allowed us to conserve all the things very well.

Nicole Doub: Post analysis. Is there any intent to rebury the materials or the bones?

Laure Meunier: No, because when archaeologists opened the sarcophagus they had to decide what to do if they left the body in the grave. Degradation would take place. There was very little funding in France for archaeology, so it would have degraded more before they got funding and began to study the burial. We could choose if we analyse it now or if we just left it here and wait. The archaeologists, since the very beginning, decided to study it because it was so huge and rare to have so many different materials. We just intervened in this operation, but we didn't choose anything. So we had to adapt to some decision already taken.

Ingrid Stelzner: How did you conserve the textiles?

Laure Meunier: I asked the Lyon Textile Museum and they told me just to let them dry softly because they were in a good condition. And some of them could have been unfolded by putting them in water so they didn't have to support their own weight. I managed to put a plate on just one piece, but not all of them, because I am not a textile conservator and so I just prepared the best I could for further steps with the specialized conservator. As advise, I passed them quickly without touching under tap water to remove the main soil. Then the conservator from the Textile Museum came and we cleaned a little together by putting a netting on the textile so you can protect the surface and put a very, very soft vacuum. It was all and just packaging.

The conservation treatment of the 5th Pirogue of 'La Marmotta' Neolithic archaeological site in Anguillara Sabazia (Rome) and a comparison among different consolidant alternatives to PEG

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In this work we want to illustrate the recovery operations carried out on the fifth monoxyl pirogue found in 2005 in Lake Bracciano and left in Anguillara Sabazia (about 30 km from Rome) according to a plan to establish a local museum dedicated to 'La Marmotta', the oldest pile dwelling Neolithic site in Western Europe. Unfortunately, for funding reasons, the pirogue remained in the tank for fifteen years, and only in 2020, thanks to the interest of Filippo Maria Gambari, former Director of Museo delle Civiltà (of which the 'L. Pigorini' museum has been part since 2016), funds were found and conservation could begin.
The treatment started in 2021 and is currently being carried out. Considering the urgent necessity of intervention, it is being performed according to the traditional methods of deferrisation with ethylenediaminetetraacetic acid disodium salt (Na_2-EDTA) chelator and consolidation with polyethylene glycol (PEG) 1500 and 4000 at room temperature. The pirogue will then be freeze-dried. At the same time, an experimentation to evaluate other consolidants useful for treating waterlogged wood in place of PEG was started, in consideration of its hygroscopicity, the difficulty of homogeneous penetration into the wood, as well as the chemical reactions with other substances that can cause further degradation.
Experimentation is in progress. It takes into account sugar-based consolidants: trehalose, lactitol, xylitol. To these is added lignosulfonate. The products have been tested on fragments of wooden poles from the 'La Marmotta' site stored in tanks at the Museo delle Civiltà. The samples were analysed by SEM-EDS before and after the treatment, evaluating penetration and post-treatment dimensional variations, keeping samples treated with PEG as a reference for the comparison.

Q/A:
Shanna Daniel: How you're gonna reattach and what you'll be using for the smaller objects to reattach to each other.
Serena Francone: The conservation treatment is carried out with interventional external conservator Illaria Bianca Perticucci. But I'm quite sure that she will use a polyvinyl acetate adhesive. Yes, but only for the smallest fragments.
Magdalena Zborowska: I thought that you used lignosulfonates. Could you tell me the results of this conservation, because you finally used PEG due to for example the color of the solution. Is this the only one reason?
Serena Francone: It was done because our former director didn't like PEG very much. We had to use PEG because it was very urgent and we couldn't wait any longer. We tried to use lignosulfonate. After testing with nano lignin we found that lignosulfonate is quite cheap and also has some advantages. For example, as it has a sodium inside, you can detect the penetration of this substance inside the wooden structure. But it also has some drawbacks as you know. At the moment we don't have a lot of results because we had some problems with SEM analysis and especially with NMR imaging. So unfortunately, I don't have more results.
Magdalena Zborowska: Because you also put sulphur inside? This is a problem maybe also?
Serena Francone: We have to deepen this aspect, of course.
Zara Walsh-Korb: I was wondering how you selected the alternative consolidants for your study. And what were the criteria you used for your selection?
Serena Francone: We decided with reference to literature research. So, we followed the article that you will find in the bibliography in the proceedings. Of course, we had to decide a limited number of consolidations, so we choose to use the sugars: trehalose, lactitol that usually are used together, but we decided to test them singularly to look at the differences in the behavior inside the wooden structure and then the lignosulfonate.
Morgan Creed: When the Pirogue was first in the display tank, what was the solution it was immersed in?
Serena Francone: Before it was only in water. It was waiting for the intervention, because the municipality had to pay for the restoration and then bureaucracy and administrative problems led to this situation. So for 14 years the pirogue was in the tank with only demineralised water. There was not a constant change of the water. There was an intervention in 2012, when the pirogue was cleaned and the water was cleaned because there were a lot of microorganisms in the water. It was not treated. In 2019 we put in a pump to maintain circulation of water without anything else. In 2012, I think they put in biocide.
Michael Sietz: Why was PEG 1500 used?
Serena Francone: We started with PEG 1500 and then 4000. In 2020 we had delivery problems to buy PEG 1500 and 2000. So, we used what we already had.

Conservation treatment of organic objects using amorphous glass of trehalose

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We are continuing our research on the conservation treatment of excavated wooden objects using sugars. Currently, we have established an impregnation treatment method using trehalose, and are conducting research on the application of this method not only to general wooden objects but also to various other materials. Our research on the conservation treatment using sugars spans over 35 years, during which time we have treated various excavated objects. In recent years, we have been conducting research on the application of trehalose impregnation treatment to fragile objects excavated from archaeological sites in Japan and abroad. Aqueous solutions of trehalose can be solidified in crystalline and amorphous states by controlling the conditions. We use both crystalline and amorphous depending on the state of the objects, and we generate them intentionally. Since amorphous glass is highly transparent, it does not require surface treatment, depending on its condition. Depending on the materials and condition of the excavated objects, we can choose whether to weight them toward crystalline or amorphous (Ito et al. 2022). This method of deflecting and solidifying trehalose into amorphous glass can easily conserve and treat objects that are otherwise difficult to conserve and treat. In this article, we report on a conservation treatment method for deflecting and solidifying trehalose into amorphous glass, including ropes excavated from the Mietsu Naval Dock (a World Heritage site) and shavings of wooden tablets from the Dazaifu site. These are objects that have conventionally been considered difficult to conserve. This time, we were able to quickly and safely treat them by using both crystalline and amorphous trehalose.

Q/A:

Katharina Schmidt-Ott: Is the trehalose treatment reversible?

Kouji Ito: Yes.

Katharina Schmidt-Ott: So it is no matter which state, if it is amorphous or syrup glassy or you can always take it out again?

Kouji Ito: To use sugars as a consolidant it is important to keep it as a glass state. If it is rubber, it will be soft and change. This should be avoided. And as it's sugar, it's reversible. If you want to get rid of those sugars, you need to keep it in a rubber state. You need to soak it in hot water, then it will melt and dissolve again. Then you can get rid of those sugars. It takes less time to get rid of those sugars than it takes for conservation. Trehalose is a very natural product, it doesn't come from petroleum sources. If you get rid of the trehalose, you can do analysis for carbon 14 more accurately. We have already done some experiments on it and even with sugars we can do carbon 14 analysis on those conserved objects.

Vicky Richards: How do you remove the trehalose?

Kouji Ito: Surplus trehalose can be removed with a steam from the surface. It can be softened with steam and use tissues paper or paper toweling to soak up the excess.

Katharina Schmidt-Ott: In the discussion earlier, you said that trehalose is reversible. How do you do that? Do you have to immerse the object again?

Kouji Ito. When you want to get rid of trehalose completely, you can put it in hot water, then it will dissolve again. Then you will get rid of the trehalose from the object. If you want to remove the trehalose completely, it is better to do it before you do the final surface treatment.

Angela Middleton: I want to know what your environmental conditions have to be like for trehalose treated objects and especially how susceptible it is to fluctuating humidity?

Kouji Ito: You want to know how stable trehalose is for the humidity? In the crystalline state it is very stable. Above 95-97% RH and 25 ℃ it will get wet. It is otherwise stable.

Morgan Creed: Does the trehalose make the surface of the object appear shiny? If so, are you pleased with this finish?

Kouji Ito: After the final treatment, it will not be shiny. You can see the natural colour of the wood.

Christine Henke: I once used trehalose together with lactitol in a treatment and the objects came out heavy in weight, but with quite a natural appearance. It was not shiny.

Dagmara Bojar: How about biohazards when exposed in exhibitions?

Kouji Ito: No fungus, no bacteria on treated objects. If insects get in, then they (the objects) can get eaten like other objects.

Lars Brock Andersen: You were aiming for a glass state. You said you could make it happen more or less crystalline towards the glass state. How do you do that? Is that by making it solidify very fast? How do you control the process, so you get a glass state instead of a crystalline state?
Koiji Ito: To prevent crystallisation, we make it dry very fast, to concentrate fast.
Katharina Schmidt-Ott: Do you monitor the process? Is there any way to see if it is a crystalline state? Is it experience? If we want to do it as well, how do we know?
Koji Ito: To monitor the process, we smell, handle, and feel the object. We can judge from experience. Experience is important. It is important to make amorphous solidification.
Katharina Schmidt-Ott: I think we need a training course in Japan.
Emily Williams: I just wanted to remind people that the past WOAM proceedings contain many wonderful articles about trehalose written by this team, so think about looking at those, too.

Fig. 1: Koji Ito presenting his paper (photo Ida Hovmand)

Condura Croatica – The 11th century ship, re-conservation and new discoveries

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Two ships, respectively found in 1966 and 1968 at the entrance of the port of Nin, Croatia, were identified as old vessels of the condura type from the late 11th century. The ships represent unique Croatian cultural heritage of exceptional value also known as *Condura Croatica*. They were excavated in 1974 followed by desalination, conservation, restoration and reconstruction of one of the ships. Both ships have been exhibited at the small Museum of Nin Antiquities since the end of the 20th century. Shortly after the conservation process, more precisely in 2010, signs of fast degradation of the wood were noticed. Several factors are contributing to the degradation process including sulfur and iron located inside the treated wood, polyethylene glycol as the impregnation agent and a lack of climate control in the exhibition gallery. The need for intervention to mitigate the degradation led to a re-conservation process started in 2017 which is still ongoing. The re-conservation process includes removing factors causing the fast degradation of the wood as much as possible. Surface polyethylene glycol and degraded and acidic wood were only one part of the aforementioned factors. A priority was the establishment of climate control conditions in the gallery which can slow down the process of wood degradation. This paper will present the re-conservation work carried out so far on the reconstructed ship.

Q/A:

Vicki Richards: How are you monitoring the acid degradation process in the retreated timbers?

Anita Jelić: We measure pH of the wood. And that's basically what we do. Every time we are there, we monitor this.

Katharina Schmidt-Ott: How is the climate around the objects? Is it more stable now? You talk about dehumidifiers, but is it over the year?

Anita Jelić: Yes, it's better, but I'm not sure if the dehumidifier is turned on all the time. It's a very small museum and they are lowering the costs. For this dehumidifier they need more electricity. So I'm not actually sure. And the problem is that this museum is open only during the summer season. During the winter time, it's closed. You can enter and see the museum, but it's actually closed. So I'm not really sure what is happening with this dehumidifier in that room. I hope it's turned on all the time.

Katharina Schmidt-Ott: The big problem?

Anita Jelić: It's a big problem, yes. We are not there every day.

Vicky Richards: How do you monitor the pH? Do you use pH papers? Or Electrodes?

Anita Jelić: We used pH papers. And we measure on the surface.

Ida Hovmand: I think I noticed that there was some adhesive on one of the photographs. What kind of adhesive did you use to adhere the fragments ?

Anita Jelić: We used Araldite SH for wood. I Think something like that. We decided to use it because we only combined together pieces we broke or were broken during excavations, so we didn't interfere with the other surface of the wood.

Conservation of two Neolithic wickerwork wells: A case study

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In the course of archaeological investigations related to the NOWAL natural gas pipeline, remains of six prehistoric wells were discovered in Stemshorn, Germany, in 2017. The wells dated between 1400-3500 calCE. It was decided to preserve two of the Neolithic wickerwork constructions which dated between about 2522 and 2500 calCE. Both wells consisting of wooden pegs driven vertically into the sand, around which twigs were intertwined. The two wells were uncovered and block lifted. Due to the complex structures and the high degree of degradation of the materials, the wells were conserved as a whole, *en bloc*. After surface cleaning, the constructions were stabilised with multi-part custom made fiberglass and epoxy moulds to give them sufficient physical support during impregnation. The wells were then conserved with an aqueous solution out of high molecular weight polyethylene glycol (PEG) at room temperature. The concentration of the conservation solution was slowly increased. The wells were then slowly and

controlled air-dried. Each dried well was transferred on a stainless-steel plate. After removal of the multi-part custom made fiberglass and epoxy moulds the wells had to be stabilised since the condition was very fragile overall. In order to stabilise the wickerwork, a mixture of sand and PEG 2000 was dissolved in ethanol and used for consolidation of the loose sand in between. This allowed the well walls to be secured to such an extent that they were sufficiently stable in themselves. In addition, branches and the bark also had to be secured. After stabilisation, the wells were transferred to the the Landesmuseum of Hannover where they will be exhibited. In all, the conservation project could be finished in a period of two years. The most critical part of the conservation process was the removal of the moulds after drying, as the object showed a certain instability after drying.

Q/A:

Katja Kavkler: I saw that you also conserved part of the sediment. Did you ever think of removing all and letting just the wooden parts be, or was it too fragile? What were your considerations for all this?

Ingrid Stelzner: At first when we thought about this. When we had to apply for this contract, we thought about it differently: we thought we could remove everything and make a nice construction, and then when we saw this object, it was a different story. Because it was very, very fragile and the walls were leaning inwards, we couldn't see another way of removing more sand. We thought it might be a good idea to consolidate the sediment and the twigs; we will see in a few years. Because the same consolidant, PEG 2000, we have everywhere. We hope that everything will behave the same way, if there are fluctuations in the humidity. We couldn't see any way to remove more of the sediment.

Christina Hanker: It looked like there was some dark material in between the branches and it looked like birch tar. Or was it only the soil?

Ingrid Stelzner: Yes, the sediment in between the branches was dark but the excavation was carried out by another company and we didn't excavate it. So I can't say anything about the condition on the site. But also when we were conserving and we saw this dark sediment in between and I cannot say what it is. I don't think there was any analysis made.

Angeliki Zisi: Did you cover the impregnation tank? How was the setup? Was the concentration higher at the top than the bottom?

Ingrid Stelzner: We covered the tank with PE foil. There are limits to how high you can concentrate on the solution. I think at 20 degrees Celcius you can concentrate until about 60%. We stirred the solution but it didn't dissolve anymore. Probably also I took the measurements from the upper part of the solution. The concentration I measured might not represent the concentration in the whole bath.

Angeliki Zisi: In retrospect would you make any adjustments to have a better result during impregnation and the whole process.

Ingrid Stelzner: I can see where I could improve. The results might have been better with the freeze-drying of the branches because we had shrinkage and you could see it. Otherwise we were concerned because it was so fragile and we needed to get a high amount of consolidant inside. Anyway, we didn't have a facility to freeze-dry it. It was too big and there were also the boards underneath, because of the stabilisation, you couldn't remove it in the wet condition. So, we waited to remove the boards until after the conservation and transfer of the wells onto the stainless-steel mounting. The other thing, which we didn't expect, was that only the outer layers of the sediment were consolidated after the drying. The sediment underneath was a little bit fragile and porous and didn't give enough stability. Two things that could be improved, but on the other hand the structure is preserved in itself, and it's now stable.

Katharina Schmidt-Ott: Was the sediment itself sufficiently consolidated with the PEG?

Ingrid Stelzner: The upper layers yes but inside there were some areas and it also depended I think on the sediment, that was not everywhere the same. Some were coarser and not stabilized so well, that's why we stabilized it afterwards again with a mixture of ethanol/PEG.

Lars Brok Andersen: It was this problem of consolidating the inner part of the sediment. I think you have probably had it consolidated, but when you evaporate the water from the surface, there would be a movement of the PEG which is dissolved to the surface. So you have probably had a very fine, even concentration in the sediment at the point of impregnation. But as it evaporates, it will just move to the surface and you will get this lack of impregnation in the sediment because the sediment won't hold the PEG very well. I think it's only natural and you can expect that.

Markus Wittköpper: Did you perforate your epoxy capsule for better penetration or did it penetrate covered with epoxy resin?

Ingrid Stelzner: No, we didn't perforate the capsule, because underneath it wasn't water tight, so we didn't need to.

Conservation of an 18th century chain pump, a composite object, from the protected shipwreck Northumberland

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In 2008 a rare chain pump was successfully recovered from the designated wreck of the *Northumberland*. The ship sank with the loss of all hands during the Great Storm of 26th/ 27th November 1703 on the Goodwin Sands, off the Kent coast, UK. This is a highly dynamic site where the wreck is periodically covered and uncovered by the shifting sands. Exposed material is vulnerable and at risk from biological decay and natural attrition caused by strong tides and mobile sands over the site. The pump was exposed and at risk of loss and therefore recovered. It was lifted in two large sections and subsequently delivered to the archaeological conservation laboratories of Historic England at Fort Cumberland, Portsmouth, UK.
The pump itself contains wood, wrought iron, leather and leaded bronze. Similar pumps are preserved as small fragments or described in the literature, but the Northumberland pump provided an opportunity to study a well preserved and largely intact section of a chain pump.
Composite objects often present the conservator with challenges as not all conservation methods are compatible with all materials present on one object. This presentation will discuss the process, methods and techniques used to analyse and describe the construction of the pump and will then describe the conservation techniques used.

Q/A:
Gillian Portous: You mentioned that the wrought iron chain was not there anymore. Were there any concerns about how that might interact between the two items?
Angela Middleton: The short answer is no.
Gillian Portous: A follow up question. How long did you chelate it for?
Angela Middleton: I think two days, followed by numerous rinses.
Katharina Schmidt-Ott: Did you stabilise the iron separately?
Angela Middleton: Yes, I have. I mentioned the very fragmented iron cladding around the base of the chamber. The fragments are still there, but in a really mineralised state, so I applied a Paraloid to keep the individual fragments in place.
Markus Wittköpper: What would have happened, if you had not added an inhibitor to the PEG solution?
Angela Middleton: I spoke to some colleagues at the Museum of London and they said to me, if there is not a lot of iron on their wooden object, they just put it through PEG without any inhibitors and it normally comes out fine. So I don't know what would have happened. Maybe - nothing, maybe- the same result. Maybe I was just overcautious.

Session II: Evaluations and assessments

Optimisation of the Alcohol-Ether-Resin method for wood and composite objects

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The Alcohol-Ether-Resin method is well established in the laboratories of the Swiss National Museum to conserve waterlogged wood and composite artefacts. The results of conservation for archaeological wet wood finds with the Alcohol-Ether-Resin method generally are very good, yet a replacement of the old established resin mixture, with a more stable acrylic resin, consisting of Paraloid B72 and PEG 400 in diethyl ether, was investigated. A change to an acrylic mixture was found to be particularly desirable in order to obtain better reproducibility of the resin.
Visual inspections of archaeological wooden objects, conserved with this method about 40 years ago showed that several of them were fragile showing fissures or fractures. Due to the composition of the established resin, consisting mainly of natural resins and oils, it is a possibility that this had become brittle over time. Also, some of these objects had been exhibited for numerous years and ageing due to light cannot be ruled out for the period up to 1995.
A set of experiments was prepared to evaluate the performance of the new resin, both on wood and blocks consisting of sediment and cultural layers.
Parallel artificial light ageing was performed on different resins applied on glass slides. After artificial light ageing, Fourier Transform Infrared (FTIR) analysis showed that the old resin mixture was altered, whereas in the acrylic resin the polyethylene glycol (PEG) addition showed changes. FTIR analysis of the old resin extracted from fragments of fragile objects only showed very little change.

The results especially of a mixture of Paraloid B72 and PEG 400 dissolved in diethyl ether are very promising for preserving different types of wood. Yet in this stage of research, the Paraloid-PEG 400 mixture must be considered not recommendable to be used on block lifts containing objects and sediment. Further tests with variations of the acrylic resin for the conservation of composite objects and block lifts are therefore ongoing at the Swiss National Museum.

Q/A:

Lars Andersen: I see that you haven't been talking about the hygroscopicity of introducing the 7.5% of low molecular PEG and the possible problems with the PEG moving around over time. Have you addressed these questions because in the old mixture you had only 0.4% PEG400?

Katharina Schmidt-Ott: That's right and thank you for this input. Not yet. We're not changing the composition of the resin, yet. That it's still work in progress and it's an important point to address as well. We haven't been doing that, but we have the fortunate situation of having a lot of these samples. So, we can now subject them to different relative humidities to see how they perform, we do know that the old resident is. It's really quite an interesting mixture over a long range because in the old time the climate has not always been as stable as it is nowadays in our museum and storage facilities, and also some objects are stored in other places if they were treated for other institutions. But this is an important point.

Ankeliki Zizi: When you dehydrate wood from water to ethanol to ether, how do you come up with the of duration of 12 months and how do you monitor if this is a successful replacement?

Katharina Schmidt-Ott: The object is waterlogged and usually we start with about 75% ethanol, 25% water mixture. So we just have the moist object, we place it in the container. Then we pump in the ethanol mixture with an air pressure driven pump. We let it soak for about two weeks, sometimes a bit longer, and then we measure with an aerometer. At that time, the density of the solution is usually reduced because there has been an exchange of the water with the ethanol. Then we pump that out. We get to the next step, which is going to be a higher ethanol concentration, so let's say 85% and then again two weeks later we measure, we take it out, it's all noted. And so we can see the sequence of the exchange of the water out of the object because everything that changes; the density of the solution comes from the object. You could theoretically also start with a higher ethanol concentration, but it's expensive. So, we try to reuse our solvents as much as we can and then we only have the last two baths with the pure ethanol. The same applies to the ether. But here we have a dye that is only soluble in ethanol. So, with the colour of the solution and a colour chart we made with known concentrations, we can see the concentration of that solution and the pure ether is colourless. Only the ethanol will dissolve that dye and if you just have a small object it's fast, but like with a fish trap which is a huge block, it takes a while. And then we have longer than a year of treatment. We need to replace the water with the ether and because they are not mixable, we need this ethanol stage in between.

Michael Sietz: Do you measure the ASE (anti shrink efficiency) values of the wood samples?

Katharina Schmidt-Ott: Well, we do not have a system. Sometimes we measure the sizes and we measure the state of the degradation of the wood. Umax. But on these samples, we went more for the overall size and shape changes in this series. But, as I said, some of these woods are going to be further processed with the Cutaway Project. A lot of them have already been processed with the KUR Project some ten years ago. This method has been tested a bit more over the years and it seems to be performing still in the range, but then with this sequence we didn't.

Molly McGrath: Looking at doing ethanol extraction in diethyl ether. Are you seeing a lot of small molecule extraction in addition to first water and then ethanol? Are you seeing a lot of things coming out of your extractions in addition to water?

Katharina Schmidt-Ott: No, it's really quite clean. Also, the good thing is that you have no problems with biocide, fungi, because of the ethanol. We see no big extractions or colour changes. Sometimes you might see some from the woods or if you have sediment. Sometimes maybe a bit yellowing.

Melamine-formaldehyde versus freeze-drying: A comparative evaluation of treatments

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The revival of the melamine-formaldehyde treatment over the last decades has raised arguments for and against its use. Disadvantages such as toxicity and irreversibility are often combating the good dimensional stability and the adequate preservation of wood macroscopic features. This study aimed to evaluate melamine-formaldehyde (MF) in comparison to freeze-drying (FD), a widely used successful method in waterlogged wood conservation.

Waterlogged samples of Greek fir (*Abies cephalonica*, L.), presenting two diverse preservation states, were used. Scanning electron microscopy (SEM), energy dispersive analysis (EDS), resistance to penetration, and physical

properties assessment were implemented to document the condition of the samples. MF treatment involved impregnation in an aqueous mixture of Kauramin 800, triethylene glycol, urea and triethanolamine, whereas for FD, samples were impregnated in aqueous solutions of polyethylene glycol, (PEG), (MW: 400 and 4000) prior to drying. The conservation efficacy of the methods was evaluated based on i) % anti-shrink efficiency (ASE), ii) wood ultrastructural alterations observed with SEM and iii) chemistry examined with Fourier Transform Infrared (FTIR) spectroscopy.
Results obtained showed that both methods were equally effective in stabilising dimensionally the waterlogged material, presenting ASE values near 100%.
However, under SEM the MF chemically modified cell walls were seen flaking and cracking, probably due to the resin or the removal of some wood constituents. FTIR analysis indicated lignin depletion possibly due to alkaline hydrolysis. Further research is needed to understand the chemical interactions between MF treatment and waterlogged wood.

Q/A: no questions.

Factors influencing the choice between single and two-step methods of impregnating waterlogged wood with PEG prior to freeze-drying (Part I: Survey)

James Harvie[1]
[1]Durham University, Durham, UK

The use of polyethylene glycol (PEG) to partially impregnate waterlogged wooden objects prior to freeze-drying is one of the most common methods used by conservators. It is accepted as the industry standard in most western countries thanks to its favourable results, relative reliability, and years of research, among its list of positives. Though it should be noted that there are drawbacks to the use of PEG, for example, it is a petroleum product and a corrosion accelerator. There is, however, often debate among conservators who use PEG as to the exact concentrations, molecular weight and number of steps in which the PEG is applied to the object.
This paper aims to establish the current perspectives on the use of polyethylene glycol prior to freeze-drying when treating waterlogged wood. In order to do so, a survey was disseminated amongst current conservators in order to gain an understanding of the current comprehension of both treatment types as well as what is understood of their advantages and disadvantages. This paper outlines the results of the survey and establishes the key considerations made by conservators when picking between single and two-step treatment methods. The factors highlighted were as follows: dimensional change after treatment, penetrative abilities of PEG solutions in regard both into the cell wall and the depths of the wood, properties during freeze-drying, potential activity after treatment, and practical considerations.
Overall, this paper provides an overview of the primary factors separating the use of single-step and two-step methods of PEG, as well as the current trends in the practice of using PEG prior to freeze-drying to treat waterlogged wood. It is the first of two papers with the purpose of establishing the factors that influence conservators in the choice between single-step and two-step methods of PEG impregnation prior to freeze-drying.
Q/A: no questions.

Fig. 2: James Harvie giving his paper (photo Ida Hovmand)

Factors influencing the choice between single and two-step methods of impregnating waterlogged wood with PEG prior to freeze-drying (Part II: Theory)

James Harvie[1]
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Using responses to a survey disseminated amongst practising conservators as a guideline, this paper looks into the key considerations made when choosing between a single-step or a two-step treatment with polyethylene glycol (PEG) prior to freeze-drying when treating waterlogged wood. The primary difference between the two is that a single-step method uses only a high molecular weight PEG solution that is gradually increased in concentration during treatment baths, while a two-step method uses increasing concentrations of low and then high molecular weight PEGs, resulting in a mixed molecular weight solution. This paper synthesises past and current research. In the majority of cases a single-step method is the preferential treatment type due to the extra potential risks associated with the use of low molecular weight PEG in two-step methods.
A two step-method is, however, better suited for the treatment of particularly thick and well-preserved wood, or when shrinkage is the primary threat to the condition of the object. As such a conservator should still consider the use of a two-step treatment in some scenarios.

Q/A:

Johanna Rivera: It's interesting you talked about the availability of PEG 2000 in the States. We actually were discussing yesterday. We're very upset with our own supplier of PEG 2000 in Texas. It can only be shipped in January because of the heat and now he's missing in action, so we're trying to track him down. And we're trying to see if we can get perhaps another supplier in Wisconsin, I believe so. And that's the only place we can get by PEG 2000. So, it's really difficult for us in the States. I talk for a couple of labs I guess, we end up loving the Danish method. But it's really hard for us to get it.

James Harvie: It's interesting knowing things like this that you don't necessarily consider when you're just reading papers about, which may or may not be better. You can't get what you can't get.

Johanna Rivera: In the USA it can be state by state regulations that decide whether you can use certain chemicals. So, you really need to be sure.

Susan Braovac: Just wanted to add to that we also have had trouble sourcing PEG 2000 and in Oslo and one of the solutions was to buy a whole 8 to 10-ton load. And when we asked about more, it took several months and then I got a reply saying we have a small batch left. You can get it if you want it. So, it seems to be a common problem. I don't know why.

Lars Brock Andersen: I have a comment on the penetrative ability of low and high molecular PEGs. I was happy to see that you also have recognised or found that the high molecular PEG also is able to penetrate. In general, we have a kind of simple understanding of what PEGs are. Because the PEG molecule is very long, but any PEG molecule has the same width. And they're winding up in the solution; they're like strings or they can be globular. It's always a very, very dynamic process. So, it's the ability of a string going into a hole, for instance. But of course, it is very much slower, but it's not unable to penetrate into these. Even if it's a PEG 10,000 or something like that, it has the same width in the solution. It is able to pop into a hole.

I was talking to a man who is working with nanotechnology, and they are using these high molecular PEGs to make very, very, very small holes because they're using this ability to use the active end of these extremely long molecules. So, what we maybe see it's not the ability of PEG to penetrate into the structure but it's the rate of penetration into the structure. So, it's able to penetrate, but at a very slow rate.

James Harvie: That's an interesting way of thinking about it and quite succinct and better than I definitely could have done myself.

Susan Braovac: When we order PEGs, there's a molecular weight distribution, right? And I wonder if there perhaps is also separation when you impregnate? If you have the low molecular weight coming in first and reaching further in than the higher parts of the molecular weight distribution curve. Has anybody seen differences there? Does it affect the treatment result?

James Harvies: I have not come across anything and that.

Lars Andersen: The lower ones are faster.

Jana Gelbrich: Your comparisons, are they based on the same wood species, mainly oak? Or are there different species? Maybe you should look at wood species properties. I would say that the treatability differs between species. Especially oak with a low degree of degradation is difficult to treat: it's not easy for PEG in general to penetrate or for water itself. So maybe the species and their degree of degradation have to be looked at as well.

James Harvie: Is this in regards penetrative ability of the PEG? Looking at the different studies by various groups of people, I think that is something that I came across was people were getting very different results, I think that was probably due to wood species and I do think that's something that should be considered and oak there's obviously the difficulty of like 2 levels of degradation. I think that was the initial reason that Hoffman developed the two-step treatment I believe was for this specific problem with oak and I think it kind of snowballed maybe beyond that and I don't want to step on anyone's toes saying that. I think the wood species does play a definite role and that is something that should be considered when thinking about which treatment choice you're selecting. Thanks for the question.

Evaluation of conservation methods for archaeological wet wood with structured light 3D scanning and µ-CT

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The conservation of wooden cultural heritage from wet sites is challenging. Depending on its degree of degradation, waterlogged archaeological wood will collapse, shrink and distort upon drying. Besides damage in the surface, the structure itself is damaged leading to destabilisation or a completely damaged object. Conservation measures are a prerequisite for the preservation of the find material. The various conservation methods available can prevent this damage, but in some cases only up to a certain degree. The evaluation of the conservation methods is usually limited to the surface of the object. Invasive methods, such as the examination of core holes under the microscope, provide information about the structure of the sample, but only a small area of the sample can be examined with preparative effort. In this study, we aimed to analyse both the three-dimensional changes and the inner structure of the conserved wooden samples. Therefore, we used structured-light 3D-Scans before and after conservation and micro-computed tomography (µCT) after conservation. The samples were conserved with some of the most common conservation methods: besides the alcohol-ether-resin method, the conservation methods by impregnation with melamin-formaldeyde (Kauramin 800), lactitol/trehalose, saccharose and silicone oil were investigated. In addition, different polyethylene glycol (PEG) treatments with subsequent freeze-drying were also investigated: one-stage with PEG 2000, two-stage with PEG 400 and PEG 4000 and three-stage with PEG 400, PEG 1500 and PEG 4000. On the basis of the data we analysed and classified the damage patterns in the conserved samples according to a catalogue. These were shrinkage, collapse and cracks. The best results were obtained by the conservation methods using PEG and freeze-drying, alcohol-ether-resin method as well as Kauramin 800. This evaluation showed the respective disadvantages of the individual conservation methods. These damages provide indications for the further development of the methods.

Q/A:
Kristofer Gamsted: I am especially impressed by the use of the X-ray Micro CT to look inside the material, and I noticed you used the software VG STUDIOMAX. In our lab we have a similar software, it's called Visual Fire, and there is one option called digital volume correlation. So, with one 3D picture before and after it's possible to cross-correlate them and see shrinkage, not only the entire volume, but locally also to see if it's bigger and close to a knot or a certain defect. Is that something you have considered doing in the future? I know that you don't have the before images.
Ingrid Stelzner: Yes, we have had the opportunity with a smaller test series and we also tried this, because the VG studio Maxx software also provides this module. We also tried to analyse the cracks automatically. There are several approaches we tested. Perhaps my colleague who is specialised in this and also giving a presentation can go further into this discussion.
Kristofer Gamsted: I think it could be useful information to see where the strain or the shrinkage is the highest inside, so we can target this area with special treatment.
Michael Sietz: Is it not a problem to use CT-scan for evaluation only after the conservation treatment?
Ingrid Stelzner: We use not only CT-scan for the evaluation of the conservation. The Kur projects, these samples originate from, was also documented with colour and other means. But I only focus on the examination of the stabilisation which I think is very important from a conservation point of view, because we want to stabilise the object to avoid shrinkage and collapse. For sure other criteria to evaluate conservation agents.

Assessing conservation agents in archaeological wood by neutron imaging

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Archaeological wooden artefacts are commonly found in waterlogged conditions exhibiting a degraded and fragile wood structure. Depending on the degree of degradation, they might collapse and/or shrink during drying processes after excavation, leading to a total loss of the cultural heritage information encoded in the wood structure. Conservation treatments are thus required to prevent damage and to bring the samples into a chemically and physically stable condition. However, the distribution of conservation agents might impact the conservation quality, impairing the analysis of the sample. Relevant information of the internal anatomical wood structure and its interaction with impregnated conservation agents can be obtained in a non-destructive manner using imaging-based techniques, such as X-ray and Neutron computed tomography. In this work, neutron computed tomography (N-CT) has been used to study the penetration behaviour of different conservation agents using alcohol-ether resin (AlEt), saccharose (Sac), silicone oil (Sil) and polyethylene glycol with different treatments, PEG (1), PEG(2) and PEG(3), in archaeological wood samples exhibiting different anatomical structures. Fifty-one samples from a reference collection established between 2008 and 2011 covering a wide variety of methods and wood genera were measured with thermal neutrons. Thirteen of them were fully investigated to assess the penetration depth and distribution of the conservation agents inside the samples. The results show that neutrons feature high contrast for Sil, PEG and Sac conservation agents, which display different penetration paths depending on the anatomical wood structure. The AlEt treatment, on the other hand, is barely detected from the measured imaging data.

Q/A:

Lars Brok Andersen: I think it was very interesting to see. It's a marvelous method. The three different PEG methods: Well, the one-step method (PEG 2000) was very nicely spread. You can see that it's very evenly spread. Because during the process of freeze-drying it's totally vitrified, so the PEG doesn't move. But for instance, the three step PEG (400, 1500 and 4000), where you have the low molecular weight PEG it is moving during the process or after the process. So, you get it into the denser parts of the structure. So you can kind of have a view into the process where you have the stability of a well-done freeze-drying and the instability when you have the low molecular weight PEG.

Jorge Martinez-Garcia: In those cases, it seems that the samples were fully impregnated. What is interesting is that all these vessels, a typical feature of oak, seem to be empty and we don't understand in principle why the consolidant prefers to fill the inside of the lumen and not the vessels. Probably one potential explanation is that the vessels are filled with another substance which is transparent from neutrons, or they have some protuberance inside that are transparent to neutrons such as tyloses which can block the flow of the consolidant. That could be one of the potential reasons.

Kristofer Gamsted: Do you think the following would be possible? Or maybe it's just a fantasy. Based on your 3D images before or after your time lapse, to compliment it with the finite element model like a multi-physics model that would include diffusion, impregnation and then sort of the plastic viscoelastic model of the material. How it shrinks, stresses develop, and use this to identify parameters and maybe even make predictions to see collapse or time for impregnation. Do you think that would be possible?

Jorge Martinez-Garcia: I think it's perfectly possible, but depending on your data and the quality of your measurements. Imaging of the 3D digital data is always possible to do, but it is important that you have good contrast, good segmentation between what we define as consolidant and what we define as wood. Ideally before and after the conservation. Meanwhile we have well defined good contrast and resolution. The algorithm to track this kind of problem is already done. Some algorithms perform better than others. Point one: we have to have good data with good contrast. And second, to look for the most appropriate algorithm. We need to be sure about what it is calculating what not.

Kristofer Gamsted: It´s good to hear that you're optimistic.

Evaluating archaeological wood treatments. Part I: Parameters and tools

Angeliki Zisi[1], Calin Steindal[1] and Susan Braovac[1]
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Conservators often face the challenge of deciding upon the right treatment for unique wooden objects for which the outcome can be difficult to pre-evaluate. Limited access to original material for experimentation before settling on a treatment makes it nearly impossible for a conservator to be confident with their choice. Here, we present a series of experiments designed to allow comparison of the performance of five different non-aqueous treatments as candidates for strengthening the weak wooden structure of the alum-treated objects from the Oseberg finds in Norway. The experiments are divided into *in vitro* and *in vivo* stages. Each of these two divisions comprises a series of experimental stages following a sequential order and rationale to build up knowledge gradually. Three different forms of wood substrate are used for consolidation experiments: fine wood powder from sound wood, sound wood and archaeological wood. Data variability is decreased by gradual introduction of the structural anisotropy and level of degradation of the wood, which allows for clearer results and easier interpretation of each experiment. This helps particularly when several treatments are being compared. We believe that the present work will provide practical guidance and tools to inspire conservators when it comes to treatment decision-making as well as building personal experience and critical thinking.

Q/A: no questions.

Evaluating archaeological wood treatments. Part II: A comparative study

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[1]Museum of Cultural History, University of Oslo, Norway

The aim of this paper is to classify the significance of a set of treatment evaluation procedures and parameters in forming educated decisions on how to treat or retreat archaeological wooden objects. We did this as part of our research with the Saving Oseberg project on finding an appropriate re-treating scheme for the alum-treated Oseberg wooden collection. Five non-aqueous consolidants/treatments underwent a comparative study. We assessed the consolidants in their pure form as well as in fresh wood powder and in archaeological wood treated with these consolidants. Simple and more advanced evaluation procedures were followed, producing both quantitative and qualitative results. Conclusions were drawn based on statistical tests run on the collected data, as well as on general observations from each treatment. The focus of this paper is not to give a thorough presentation of the treatments or of the results, but rather a summary from each evaluation procedure, assessing its usefulness in helping us recommend a re-treatment plan for the collection.

Q/A:

Nadja Melko: I really appreciate the sensory (haptic) analysis of the materials. It gives us so much knowledge regarding material logic. Thank you very much.

Malin Salstedt: Great work and update on your project. Thank you. Do you have an overview of the collection and how large a part of the collection demands non-aqueous treatments?

Angeliki Zisi: First of all, for the question and indeed we, after what followed this part of our research is going now back to the collection and doing a survey, so we that we knew how non-aqueous and aqueous treatments work. We went with my colleague Susan through the collection one by one all our objects that are alum treated from the Oseberg collection and we have in mind the results and starting assigning treatments. This is actually what Susan is going to present on Thursday. We have a number about, how many objects are in this category will be non-aqueous, how many aqueous etcetera. So it's coming.

Kristiane Straetkvern: Thank you very much for this wonderful study. I was thinking about the long term properties of these materials. What are your thoughts and ideas in that part of your considerations.

Angeliki Zisi: And so indeed, now as we as we present in the beginning, this was the phase, second phase of our project and we are now working on the proposal. I mean we already submitted it for funding for phase three and part of this phase three would be a research element studying exactly the long term stability of these kind consolidants that we presented here. Especially in conjunction with the nanoparticles, which is the way we decided that we are going to be deacidifing, because in case of non-aqueous of objects that cannot go in waterto neutralize the pH in that manner, we have to find another way and another way we found was using nanoparticles which is has been presented in the previous WOAMs and so we already then have these extra chemicals in there. So, part of our phase three would be to study the interaction of nanoparticles and consolidants in the long run.

Long-term properties of treated waterlogged archaeological wood – A comparative study of three treatments

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Preventive conservation has emerged as an important approach for the long-term preservation of sensitive cultural heritage, notably for artefacts in small and medium-sized museums. The European project SensMat[1] aims at developing and implementing effective, low cost, ecologically innovative and user-friendly sensors, models and decision-making tools, in order to enable prediction and prevention of degradation of artefacts as a function of environmental conditions. One aim of SensMat is to model the reactions to environmental conditions of treated archaeological wood in order to develop sensor systems based on this. In order to generate a base for modelling treated archaeological wood, several characteristic parameters of different treated samples were examined in collaboration with MPA of Leibniz-IWT Bremen.
In 2010, archaeological wood samples from discarded artefacts were conserved with Kauramin, lactitol and polyethylene glycol (PEG) 3350 in Bremen in order to investigate the common wet wood preservation methods with regard to their behaviour after preservation without climate control. In 2022, mechanical parameters such as ultrasound velocity and elastic modulus were determined by ultrasound measurements and the behaviour to water adsorption and desorption due to changing relative humidity (RH) was investigated. Computed tomography (CT) was also used as a non-destructive test method to give an idea of consolidant distribution.
Water sorption behaviour is strongly related to wood species, where beech (*Fagus sylvatica*) shows the highest water uptake and Oak (*Quercus* spp.) the lowest one. Water sorption is also related to the consolidants used; lactitol and PEG show relatively similar water sorption behaviour, which is clearly higher than that of Kauramin treated woods. Water uptake really starts at 60% RH, below that, weight percent gain due to adsorption of water is below 5% in all investigated variants. The hysteresis effect, typical for wood, is highest for PEG and Lactitol treated wood.
The ultrasonic (US) velocity results seem to be more related to wood species than to the consolidant used, also E-modulus results cannot be clearly interpreted so far. The project is not finished yet, further data interpretation and analyses using Raman and FTIR spectroscopy and mechanical tests are planned and will hopefully help to clarify interpretation and modelling.

Q/A:

Jeannette Luceiko: I have a comment. We talk about Kauramin and PEG. We compare these treatments, and we do not take into account that we have a physical treatment and the chemistry. It is not an opinion. We have a physical process in PEG, in lactitol, in the sugar that we applying and in case of Kauramin we have a reaction. We have reagents. We need to consider that we have different processes. And we cannot simply compare. In case of PEG we have absorption and desorption. In case of Kauramin, we have a reaction, we have a reagent and at the end, we have the products which are different, with different properties at the end.

Jana Gelbrich: Of course. We wanted to investigate the new properties of the products. We have the products, we have the Kauramin treated wood. Even if it's a new material and we have the PEG treated wood for example, and we want to investigate what we have. What our results are.

Jeannette Luceiko: When we consider Kauramin absorption and desorption without the reaction. It's OK. But the Kauramin is the polymerization in-situ. So, we cannot compare this simple way, I think. We need to consider different processes.

Angeliki Zisi: My questions will be about ultrasound. Well, first of all because I did my PhD on the use of ultrasound in estimating the state of preservation of waterlogged wood so indeed seeing if there is a relationship between velocity and density of waterlogged wood as it degrades. And also, because in the Saving Oseberg project, we included in our parameters evaluating mechanical properties, dynamically using ultrasound and see what the modulus of elasticity of treated wood is compared to untreated? Through our investigation, we saw that actually we couldn't get any meaningful results because indeed ultrasound will travel faster in denser materials than in less dense materials. But it's not only about density, it is also about material property. It could be that after conservation with silanol for example it was a very dense piece of wood. But because of the elastic properties of the silanol, the sound would actually attenuate a lot inside the wood. So, where we would expect high velocities, we actually receive slower velocities traveling through that treated piece of wood. There is a problem in how we use ultrasound in testing treated wood with the different consolidants. We also decided not to present it here because it's still ongoing work. So that was probably a comment. You showed us your numbers about velocities. How many replicates did you have?

And the differences you saw between velocities from axial and radial and tangential directions, these differences you saw, where they are statistically significant enough to tell us that indeed there are three separate velocities?
Jana Gelbrich: That was the first measurement. So, concerning the replicates as I mentioned, we have three samples per wood species and treatment. They were measured once, maybe you can make different positions as well. So, as I showed, it was just measured once in axial direction and three times in radial and tangential direction. There were a few pandemic related problems to get in touch with the Institute which made this investigation and we tried to communicate but it's not the same sitting next to them and explaining. So I hope that will be better now and we will continue.

Archaeological waterlogged wood from two Lusatian culture settlements

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The conservation and protection of fragile and non-renewable archaeological finds, especially in situ conservation, emerged as extremely relevant to the UNESCO Convention. Biskupin site (Poland), representative of the Lusatian culture settlement, is one of those sites where, since the first archaeological excavations in 1933 the decision was made to leave the archaeological wooden finds directly in the environment in which they were found. Since then, various monitoring programs have been conducted to investigate the environmental conditions and their effect on the wooden remains.
In this work, two archaeological sites dated back to Lusatian culture and both similar as regards the environment and the archaeological wooden remains will be studied: the first is the site of Biskupin and the other, less known, the settlement of Izdebno. The physicochemical parameters of the deposition environment and the physicochemical properties of wooden remains will be compared. The work is part of the JPI StAr project (Development of Storage and Assessment methods suited for organic Archaeological artefacts) which aims not only to broaden knowledge on the processes occurring in wooden remains and in the surrounding environment but also to explain the temporal relationships between changes in the chemical and physical properties of wood and changes in the conditions of their deposition.
The study of chemical composition and determination of physic-chemical changes occurred in archaeological wood was carried out with a multi-analytical approach which included: the determination of the maximum water content (MWC), wet chemical analysis and application of instrumental techniques based on chromatography, mass spectrometry and pyrolysis (GC/MS, Py-GC/MS and EGA-MS). The techniques based on analytical pyrolysis allowed us to observe the depletion and depolymerization of polysaccharides and the side chain shortening of their pyrolysis products, as well as the oxidation and demethylation processes that occurred in the lignin fraction. GC/MS analysis allowed us to characterize the extractives and the results compared between the various wooden artefacts studied.

Q/A:
Nanna Bjeeregaard Pedersen: Did you look into the decay pattern of your samples, like what type of decay you had on the two sites?
Jeanette Lucejko: The morphological decay pattern is not my part. I present only the part of the physical and chemical evaluation. We also performed a microscopic analysis for the identification of wood species.
Nanna Bjeeregaard Pedersen: But not how the wood was decayed?
Jeanette Lucejko: No.
Dawa Shen: Jeannette, what kind of gas is used for thermal degradation?
Jeanette Lucejko: Helium

Collapse – or not? Effects of drying on heavily decayed archaeological wood in soil

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The physical response of heavily decayed archaeological wood to water evaporation in soil was studied in a model experiment. Ten wood samples from a kitchen midden at Kangeq in Western Greenland and four wood samples from the Danish bog site Nydam were used in the experiment. Microscopic analysis showed the secondary cell wall was totally decayed in all samples. The samples from Kangeq were decayed by wood degrading fungi and the samples from Nydam were decayed by bacteria. Following characterisation, the samples were buried in moist soil that was allowed to slowly dry out in the laboratory by evaporation at room temperature with sensors measuring changes in soil water potential and soil moisture. The mass, radial shrinkage and cell wall collapse of the individual samples were determined after 26, 48, 56, 62 and 82 days in the soil. During this period, the water content of the soil decreased from 48 to 22% vol and the water potential dropped from 0 to -65 kPa, corresponding to a decrease in relative humidity (RH) within the soil from 100 to 99.95% RH. The archaeological wood from Nydam showed a high radial shrinkage and cell collapse, while samples from Kangeq only showed moderate radial shrinkage and no cell collapse with decreasing water content of the soil. The absence of cell collapse in the wood samples from Kangeq is surprising considering the degree of degradation of the secondary cell wall compared to the prevalent collapse theory of degraded archaeological wood.

Q/A:

Jana Gelbrich: The reason for different reactions is based on the wood species. Hardwood has other reactions than softwood. More shrinkage. More deformation tendencies. Even archaeological wood when you dry them without treatment. The softwood samples look better than the hardwoods. It is dependent on the structure. More reaction on shrinking for hardwoods.

Angeliki Zisi: I'm wondering if it's a very local reason why they didn't collapse as much as the other one. As the soil dries there could be methane gases released as well as thawing of soil. That organic material can produce gases and I'm wondering if they have an effect on the relative humidity, very locally. What are the other inputs there could be, creating a very favorable environment around the wood drying at that specific spot. Another thing is, usually when the structure is very perforated it has a bit better mechanical property. If you think of a diffuse porous and then ring porous wood, then usually in the diffuse porous you see more homogeneous changes in the structure, the structure is perforated. It makes a stronger material and I'm wondering if that also helps.

Considerations on how to relocate and extend the life of the Viking Ships from Skuldelev, Denmark

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Introduction and background**:** In 1957-62 The National Museum of Denmark excavated the remains of five Viking Age shipwrecks (dated to around 1000 AD) from the Skuldelev site in Roskilde Fjord. The find started a remarkable period in Denmark concerning research and development of methods in maritime archaeology and conservation of waterlogged wood. The Skuldelev Ships were the first to be treated with Polyethylene Glycol (PEG) in Denmark and the work from excavation to the exhibition was considered pioneer work in the field.
Exhibition and climate: Since the late 1960s, the Skuldelev Ships have been exhibited in a purpose-built museum constructed primarily of concrete and glass. Being situated on the water's edge at Roskilde Fjord, the building is threatened by climate changes resulting in recurring situations of flooding and heavy rain. The big window panes facing the fjord allow massive amounts of daylight/sunlight and UV-light exposure to the ships, preventing a good and stable indoor climate. New research indicates that discoloration and precipitation from the preserved wood mainly are caused by UV light. A condition report determines that the building requires extensive refurbishment to protect the ships sufficiently.
In conclusion, it is decided to build a new museum for the Viking Ships at a safe distance from, but still close to the Fjord and move the ships to be presented in a stable environment, not allowing UV and daylight on the archaeological wood.
Characterizing the current condition: In preparation for the relocation, an examination of the Viking Ships included a characterization of the condition of the conserved archaeological wood and the ship mounts. The ships are different in size, completeness, weight, wood species, degree of degradation, and the dimension of timbers. A general observation is that the interior structural timbers are stiff and in a relatively sound condition, whereas the planks are fragile, fragmented, and inflexible. All ships have been mounted on site in the building, applying the same principles for all ships. Thin metal railings are built in as integrated and stabilizing elements in the structures, supplied by external frames and columns sitting on the floor. The mounts are discreet, flexible, and light, not adding stiffness, and not designed to carry the ships anywhere. Owing to the complexity of each ship structure the conclusion is, that each ship requires a custom-designed plan for moving, combining partly dismantling pieces of wood, consolidating fragments, improving local support, etc.
Relocation of the Skuldelev Viking Ships: During the examination of the shipwrecks, different scenarios for moving have been identified and described. During spring 2023 several tests will be carried out to decide and design a safe relocation to the new museum.
The presentation will give a short introduction to the current situation for the ships in the exhibition, the method used for characterizing them, and the scenarios and tests being planned.

Q/A:
Angeliki Zisi: Is it going to be a new building?
Kristiane Strætkvern: Yes, they are actually going to build a new building so the ships have to be moved out of this building. It has not been established yet how that will actually be done and if they actually need to have some kind of temporary storage. But they have a site a bit further up on the ground where they will actually build a new building. So the ships need to be taken out of the building in a safe way and transported probably on rails or something like that. But in order to actually do so and find the requirements we need to find, first of all actually, how we can securely lift them.
Nicole Doub: The wonderful chart that you showed the weight distribution, was that based on qualitative analysis or was that just guesswork on your part?
Kristiane Strætkvern: I estimated the weight on the spreadsheet and based upon the basic density. Some of them are oak, some of them are pine. So, I looked at the basic density of degraded wood and added the weight of the PEG. So that's kind of the basic weight. And then of course I need to look at the different dimensions because the plank has its own thickness and the rips have different volumes. So, they're actually like layers put on top of each other.
Nicole Doub: I love that. That's a really good way to kind of proceed with that. I wish I thought of that at the time when we rotated the ??? shipwreck. We actually collaborated with a house a historic house mover and we place sensors across the hall and have them do a slight lift so we could get that, and that looked a little bit more affordable.
Kristiane Strætkvern: Well, we needed to figure out something that we could handle easily when we went through each ship.

European Standards for Cultural Heritage – Work of CEN/TC 346 – Preliminary Abstract

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The main objective of European standardisation in general is to facilitate the exchange of goods and services by removing technical barriers to trade. Specific European standardisation activities in the field of cultural heritage conservation are carried out in CEN/TC 346 and are essential to find a common, unified scientific approach to the problems of cultural heritage conservation. This presentation gives an introduing general overview about the work of the European Committee for Standardization (CEN), in particular the work of the Technical Committee (TC) for Cultural Heritage Conservation (346), which covers a wide range of cultural preservation topics. The scope of CEN/TC 346 includes the standardisation of definitions and terminologies, of planning and organisational procedures from object characterisation to object conservation measures, as well as testing and analysis procedures for object or condition recording.

The application of standards in our sector is relatively new and they will be of great importance to our field. There will be a report on the progress made so far by the Working Group on Waterlogged Wood, which has already published a standard (EN 16873 'Guidelines for management of waterlogged wood on archaeological terrestrial sites') and is currently working on another standard ('Characterization of Waterlogged Archaeological Wood as a Management Tool'). These will provide European archaeologists, conservators and archaeological conservators with clear guidelines and decision-making tools for the effective management of wood finds from waterlogged sites. It is hoped that these standards will trail-blaze a route for further standardisation across the conservation profession.

In addition to the standardisation in the field of water-stored wood, a small overview of thematically related standards will be given, e.g. there are already some standards with a strong reference to museums. Everyone can actively contribute to the development of standards, and information will be provided on how this can be done so that well-founded standards for the preservation of cultural heritage can continue to be developed.

Q/A:

Katharina Schmidt-Ott: So, you said that the public can join in if an inquiry is open for, being read or added to, how do you know that something is being worked on. Are these published?

Jana Gelbrich: Unfortunately, I can't give you any information on that. Maybe we have to get in touch with the national standardization body. I'm an involved person, so I will be informed. But even that is not so easy to understand. It's a very bureaucratic thing. But if you're interested just contact me and I will talk to the Mirror Committee and if I will get this information I can provide them further to the interested persons on the national level.

Session III: Conservation of non-wood organics

Interpretation and reconstruction of waterlogged archaeological textiles excavated from the *H.L. Hunley* Submarine: A collaborative effort between conservators, archaeologists, curators, and digital artists

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The *H.L. Hunley* submarine disappeared in 1864 in Charleston, South Carolina after successfully attacking *USS Housatonic* during the American Civil War. During the excavation of the submarine, researchers determined that shortly after the loss of the *Hunley*, the bodies of the crewmembers were gradually covered with sediment, protecting their clothing from the environment.
Sediment entered the submarine through the forward conning tower, covering the commander of the vessel, Lieutenant George Dixon, earlier than the rest, contributing to a better preservation of his clothing. Due to their fragility, the textiles were block-lifted, containing a combination of textiles, skeletal remains, and personal artifacts.
During conservation of the garments, it was discovered that Lt. Dixon was not wearing military clothing but rather high-quality civilian attire. This case puzzled the archaeological and conservation teams, who ultimately sought help from historians and curators to try to interpret and reconstruct his attire. Using the interpretative data from this research, students from the master's in Digital Production Arts from Clemson University, created a 3D reconstruction of Dixon's entire attire. This collaborative approach led the *Hunley* team to finally piece together what Dixon wore and led them to resolve some of the clues to his mysterious life.

Q/A:
Morgan Creed: May I ask for more detail about the drying method, please? I currently have some 18th century wool textiles which are very fragile, and I've been going around in circles deciding how to dry them, so yours were frozen at –30°C and then allowed to air dry?
Johanna Rivera: for the textile we originally thought of freeze-drying them, but it was just too fast for very fine textiles. So, what we did was just pad them dry. I put water around the edges so it'll be a little bit fluffier when it dries, and then I just put it directly into -30 °C degrees so we wouldn't have much ice crystals forming on the textiles. It took a long time but I feel like the slower the better. But you have to be careful. Where I live we have hurricanes and the electricity goes off, so we have to be connected to our generator to make sure that the freezer is constantly working. It took several months depending on the size of the textile.
Angela Middleton: Could I ask a follow-on question. How did you monitor the drying? How did you decide when it was finished?
Johanna Rivera: We just opened the freezer and took it out?
Angela Middleton: So, did you weigh it for example?
Johanna Rivera: No, you couldn't weight it. It was just too fragile. Some of the panels were too big? It was very hard to do. To remove it from the freezer we would cover it with plastic, because you will have condensation from the air in the lab, the temperature will be much higher. So, whenever there was no condensation, I knew that there was no water left.
Angela Middleton: And how would you assess the sort of dimensional stability of it? Did you draw an outline?
Johanna Rivera: Yes, the bigger panels, I drew the outline to monitor the shrinkage- we didn't have any.
Molly McGath: I was very curious. You mentioned there was some rubberized fabric. Do you have any other comments like what was it? Did it survive drying and did you see any other rubber?
Johanna Rivera: It was also very, very slowly dried. It was natural rubber. It was part of another research, but it was different than drying gaskets, because this one, it was super, super thin, it's still drying. It was covered in plastic. We keep it in the freezer and really, we're just slowly evaporating the water. We do have some shrinkage in the rubberized suspenders. So, basically it was the suspenders. They had the rubber covered with cotton. The cotton completely disappeared and it just left the rubber strings behind. So, it's just very difficult to dry and you know with material like this, you're going to lose something. So, it's very complicated. I would not have freeze-dried because it's rubber.
Elsa Sangouard: How do you store the fabric right now?
Johanna Rivera: We just have padded planks of acid-free cardboard and it's very padded and on top of that acid free paper, because if it's too flat, we cannot manipulate it. It will crack. So it is the only way we can move it, and if it needs to be transferred somewhere else, we just kind of slide it using the same acid-free paper. It was a little bit easier to manipulate when it was underwater than it is to manipulate now, actually.

Lars Andersen: I think that it could be interesting to discuss when the material feels that it is being dried, because when you freeze it until -30 ℃. The water that is connected to the material that will leave it turn into crystals. In freeze-drying far the biggest part of drying is the freezing process, because you move the water from the material into the crystals. When they are not on the material anymore, so of course you're drying, you're taking out the water very slowly, but maybe, just maybe, you have in fact dried your material quite fast, when freezing it at -30 ℃.
Johanna Rivera: We tried different temperatures, I tried -10 ℃ and I found that the crystal formation was worse. That's why I tried to freeze it as fast as possible so that wouldn't happen. And you know, when you're forming crystals in textiles it carves the textile.
Lars Andersen: That is the nice thing about freezing very fast, you get small crystals.

From finds to facts: Material-technological studies in textile conservation

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The appreciation of archaeological finds and the interest in their preservation is closely linked with making them available for research, for example in studies on the organisation of production. This paper examines the extent to which conclusions about the division of labour and specialisation in the textile trade can be drawn by the evaluation of textile finds as a primary source.
The focus is on a corpus of Roman textiles from Mainz, dating mainly to the 1st and 2nd century AD. For the most part, these pieces were found in the area of the Mainz settlement, where they seem to have been used as manufacturing waste together with other rubbish to fortify the moist ground. A smaller number of finds come from burial sites along arterial roads. These objects derive from elements of the clothing of the dead or soft furnishings in the graves. In total, up to 500 textile fragments were discovered in eleven excavations, which were carried out in the city area between 1857 and 1982. Since then they have only been presented scattered and incomplete.
After a short overview of the current practice during examination of textile finds, the methodological framework used for the textiles from Mainz is explained. Therein, the quality of the textile remains was characterised from two different, but complementary directions: material and technical science. By this means, it was possible to not only identify quality standards and variations but also production contexts.
The quality of the raw materials used was described by fibre fineness and categorised by two methods commonly in use in textile archaeology: the system by Michael L. Ryder and a system by Gustav Frölich resp. Herbert Doehner and Horst Reumuth modified by Antoinette Rast-Eicher. In order to assess the quality of threads and textile fabrics, the application of an analytical standard developed by Lena Hammarlund especially for woollen textiles from Roman times was tested.
Finally, the results of the analyses will be summarised briefly which will serve to highlight the importance of material-technological studies for conservation, especially with regard to the usual consolidation methods, as well as to the documentation of archaeological textile finds.

Q/A:
Laure Meunier: I was wondering about the range of the fibersize?
Sylvia Mitschke: I classified them after Ryder and Rast-Eicher and compared them. This says nothing concrete about the fiber fineness. It's just the class.
Janet Luceiko: I'm curious if you considered the analysis of dye stuff.
Sylvia Mitschke: As I said, in some special cases. So, for example, in the first picture is a very special piece where you can see that we not only have the coloured band in the fabric, but we also have warp threads. There you can see it in the picture on the right, that there are even different warp threads, black and a more reddish-brown warp thread. So here, I decided to do some analysis on it because it was this very special case. This was not my main focus, it was just to see at the beginning when I started my work. I had the impression we all have different shades of brown, but are they due to pigmented fibers or are they due to dyed fibers. I just made some tries to find out. What does dark brown mean? What does light brown mean? We found typical dyestuff for Roman time. So, there was woad. There was reseda there was crap, madder. The typical range. Nothing very special tannins for dark dye.
Jennifer Wakefield: I'm a postdoc investigating conservation of archaeological textiles. I'm going to be sending out a survey soon to try and collect information of different conservation methods and would appreciate as many responses as possible to get an idea of different methods used and what has worked and hasn't. Do you know which consolidants were used and which had some success and which were particularly destructive? I thought you said in the beginning that the documentation was poor to nonexistent.
Sylvia Mitschke: None. This is only an idea. I can see the different methods we used. Some were dried on a net or something. You can see shiny surface in the net on the fabric. But I haven't done any.

Neolithic bast textiles – Adjustment of the conservation methods

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More than 300 Neolithic bast fiber objects were found in 2017-18 in Lake Greifensee, Canton Zurich, Switzerland. They were preserved in the wet soil under anaerobic conditions.

This paper describes experiences gained by the conservators of the Swiss National Museum with the treatment of objects made from bast and a combination of bast and wood. Although conservators already had experience with this material, additional challenges arose due to the material's heterogeneous reaction to the applied methods.

Consolidation with polyethylene glycol (PEG) 400 used to be a common method for the conservation of archeological textile objects, but its use is questioned more and more because PEG 400 has a low critical freeze-drying temperature. Research showed that PEG 1500 is more suited. While having a higher critical freeze-drying temperature, PEG 1500 fills the fiber structure more homogeneously. It also has a better supporting and stabilizing effect.

Since PEG 1500 seemed to fulfil all essential requirements, a large bast sheet was treated in 8% (w/v) PEG 1500 in deionised water. However, the result was dissatisfactory. The fibers had only little cohesion and further stabilisation was necessary, and further problems occurred during this process because the fibers collapsed.

Additional testing was conducted using PEG 400. Despite the above raised questions, the results were still better. Most of the objects were therefore treated with this method. After freeze-drying, additional consolidation was necessary, but proved to be difficult due to the unpredictable way the fibers reacted to the different solvents.

For carbonised objects, composite objects with wooden elements and nine large fragments of a twine woven mat a high molecular PEG 2000 was chosen for the consolidation and good results could be achieved with this method.

Subsequent stabilisation was carried out either with Klucel G in ethanol or isopropanol, or Paraloid B72 in toluene or Plexigum PQ611 in isooctane. Packaging for transport and storage was done regarding the needs of each object: either flat on cardboard supports with polyethylene foam padding or with custom-fit three-dimensional epoxy resin (reinforced with glass fiber fabric) supports.

Further research is needed to provide better conservation of bast fibers. An option to consider is to build better supports that enable freeze-drying in a block, as this might reduce tension and fiber ruptures during the drying process. Another topic to be addressed in the future is the fact that the bast material behaved heterogeneously when being conserved and freeze-dried; presumably, this was either due to its prehistoric processing or to the degree of degradation.

Q/A:

Ingrid Stelzner: Did you also try to freeze-dry the textiles? Just freeze, dry them without impregnation?

Janet Schramm/Gaälle Liengme: No.

Shanna Daniel: I have a question regarding the recovery. What did they use to bring up the objects. They look very fragile. Did you have any collaboration with the archaeologists on that?

Janet Schramm/Gaälle Liengme: We're not too much involved in this process. You cannot handle them without anything. Sometimes they came already in small boxes. I don't know if they do this already underwater.

Drying methods for archaeological birch cork

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This paper discusses the development of a drying method for waterlogged and ice-logged archaeological artefacts made of birch cork. Four years of research on the structure and degradation of birch *(Betula* spp.*)* cork have shown that both structure and degradation differ drastically from wood. The challenges of finding an appropriate drying method are equally different. In wood the main issue is to prevent the collapse of the cells and cavities during the evaporation of water whereas in birch cork, deformation and increased brittleness are the main risks. We analysed the effects of four drying treatments, freeze-drying at -10 °C under vacuum and atmospheric pressure and air-drying at 4 °C and 20 °C on unconsolidated sample materials both archaeological, waterlogged and ice-logged, and contemporary. The parameters used to evaluate the effects of the drying methods were quantitative and qualitative.

They consisted in measuring shrinkage, macroscopic deformation and damage based on changes of shape, crack formation and increased brittleness. Further changes in the hygroscopic behaviour by determination of the sorption isotherm were also assessed. The more the artefacts are degraded, the larger the influence of the drying method. Specifically, the largest differences among the drying methods were observed in the waterlogged archaeological samples. Atmospheric freeze-drying resulted in significantly increased brittleness and hygroscopicity of these samples while vacuum freeze-drying caused deformations and delamination. Air-drying above zero degrees has the least negative impact, evaluated as an increase in the sorption properties, macroscopic brittleness and macroscopic delamination.

Q/A:

Angela Middleton: I'm just wondering how easy was it for you to get hold of sample materials because it's obviously a very rare material which is reflected in the lack of conservation advice. So, were people quite happy to share their few examples with you?

Johanna Klügl: I was lucky because waterlogged birch samples from stems were excavated for the dendrochronology. So, I could remove the bark because they have been preserved with the bark layer. I had a lot of help from our Russian colleague Natalia and she gave me this big sample from a permafrost site. But yes, it's very difficult to get samples and it's important to have archaeological material to do this testing and this was the main problem.

Fig. 3: Johanna Klügl giving her paper (photo Ida Hovmand)

A preliminary study on coal cubes found at a Roman wreck off the Island of Kasos

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In September 2020, during an underwater survey conducted by the Greek Ephorate of Underwater Antiquities and the National Research Foundation, 50 waterlogged coal cubes, measuring 20×20×20 cm, were discovered at a Roman shipwreck off the island of Kasos.
This preliminary study aimed to investigate basic physico-chemical and morphological properties of the constituent material of the cubes. Knowledge of the manufacturing technology and preservation state of the cubes is expected to aid in the design of an appropriate conservation treatment and provide important pieces of evidence in identifying the origin and use of the cubes.
Light and Scanning Electron microscopy was used to document the morphological features of the material, while some basic physical properties were calculated gravimetrically. In addition, solubility and chemical composition of the cubes using Infrared Spectroscopy and Energy Dispersive X-ray analysis were determined.
Based on the results obtained, it appears that the material constituting the cubes is neither a charcoal nor some type of coal. It is indicated that the Kasos wreck cubes are more likely an industrial product which was made by compressing and shaping crushed coal with a binder. Similar cubes, called ‘patent fuel’ were commonly manufactured in the 19th Century in Cardiff, Wales, for heating purposes or energy production. Hence, the Kasos wreck cubes are unlikely to have originated from the Roman shipwreck. They most probably belong to a contemporary ship that also wrecked at the site.
Regarding the preservation state of the cubes, initial results showed that the material does not shrink during air drying, does not change texture and color and it does not become brittle; hence no immediate conservation actions appear to be needed.
Nonetheless, further analysis and testing are considered necessary for a more precise identification of the material and for a better understanding of its behaviour during and after air-drying.

Q/A:
Anthony Crawshaw: When you broke this sample up, did it smell? This will sound like a very peculiar question, but it's relevant because coal tar has a very distinctive smell, and anybody from the UK who has used coal tar will know the smell.
Evangelia Tzavela: When samples, when waterlogged or even dry, it didn't have the particular smell. But we find out without knowing that we may have a type of tar because as you saw before we place it in an oven and after a while it started smelling like rubber and then we realized that we have a mixture of materials and not a simple charcoal or coal.
Jennifer Wakefield: Thank you it was a very interesting presentation. Was GC-MS carried out on the extractable material? This may help to determine it's source. For bitumen selected ion recording GC-MS to identify steranes and triperpanes can be done to help determine the source of bitumen, I suspect something similar could be done with the extractable content of coal at least to identify the type of material if not the source.
Evangelia Tzavela: Unfortunately, we didn't have a GCMS. But we found many books about the creation of these products and the origin of the materials and because in Cardiff there are two coal fields. One producing bituminous coal, the other anthracite. We already know from which coal field this product was from. And we also know that for these products they only use these two coal fields. So, we already know.
DAWA SHEN: In the SEM-EDS results, it looks like there is iron in the lighter area in the EDS spectrum.

Amber revisited. Reconserving gelatine impregnated amber

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Since the beginning of the twentieth century and for the next 60 years, materials were used in Denmark for the conservation of amber which have proven to be fatal for the objects. Amber beads were impregnated with a mixture of glycerin and gelatine, which over time have led to creeping causing the surface to ‘curl up’ and peel off, whereby the beads fragment and completely crumble.
Moesgaard Museum received a grant from Slots-og Kulturstyrelsen’s (the Danish heritage Board) pool for collection care to reconserve well over 800 Neolithic amber beads. The aim of the project was to establish the most suitable method to remove the glycerin/gelatine mixture, reattach the surface of the beads and bring the beads to a stable condition. In addition, in cooperation with chemists at University of Århus, a gentle and fast method to detect

gelatine in the amber beads was developed which is useful as documentation of the conservation treatments is rarely available.

Q/A:
Angela Middleton: I just wanted to say you must be very, very patient and I was sitting here and my heart was going. Could you for those of us less familiar with the consolidant that you introduced later on the Regalrez, could you just say something about the basic composition?
Anna K.E: Tjeldén: Yes, well, if someone can fill in on that, but it is, a while ago I looked into this, but I think it's an acrylic that actually still makes it possible to do the FTIR provenance analysis of Baltic Amber. So, you can still observe the Baltic shoulder in the spectre amber, obviously.

Session IV: Salts and composites

How knowledge of materials changes everything previously planned

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Due to the European Heritage Year in 2018 at the German Maritime Museum a closer look was taken among others at the figurehead of the four masted bark CARLA. According to the available data, the figurehead was made in 1899 and donated to the museum in 1975. During cooperative scientific research with the Leibniz Institute for Materials-Oriented Technologies (IWT), more detailed information on the object should be obtained.
Nothing was known about the object history, just the notice that it was donated to the Museum in 1975 and that it was made in 1899.
The figurehead has a nice coloration which should be restored. To this end and also maybe to get some information about the object history, investigation of the paint layers was planned and carried out in order to clarify the originality and authenticity respectively of the paint layer and used colour scheme. Layer thicknesses and ingredients were determined using scanning electron microscopy with an attached X-ray microanalysis unit (EDX) at IWT Bremen.
Because the figurehead is wood based and a wood specialist just started at IWT, it was also thought to investigate the wood to identify the wood species. This was a useful coincidence because the investigation of the wood provides much new information of the object history and the state of preservation. Based on microscopic investigation the wood species of pine (*Pinus* spp.) could be identified clearly. Additional degradation patterns of erosion bacteria were found under microscope which classified the object as a waterlogged wooden artefact.
By FTIR-Analysis a preservation treatment with alum could be proven, which influenced significantly the current plan of preservation.

Q/A:
Elsa Sangouard: Do you know if there are any tangible plans now for retrieving these objects?
Jana Gelbrich: I'm in contact with the current conservators and the person in charge at the German Maritime Museum. At the moment and they have the large project to rebuild the new museum. So, the main focus for the conservators is transport and of course it is keeping in mind that there's some work needed for the object, but at the moment there are no real plans for it.
Jeanette Luceiko: I have a comment about the alum. Alum causes not only the acidity. The alum is a very big problem because it causes the catalytic reaction of the degradation of polysaccharides. So, it's not only to block the acidity of the wood. But, I don't know in which way, but to block the activity of alum.
Jana Gelbrich: I couldn't take samples from the inner part, where I would see maybe the reactions related to the cellulose parts or whatever, because we have normally sound wood; the degradation of bacteria is not as heavy as we know it from real archaeological finds.
Angeliki Zisi: Is there any plan to X-ray the statue just because it would reveal areas where there's alum.
Jana Gelbrich: As you saw it is quite a large object. It's not we who decide this. We have no such equipment and maybe the conservators should look for such equipment. I can talk to her, but I don't know how the decision will be.iIt is a good test and nondestructive.
Malin Sahlstedt: Do you know anything about when the colouring was done?
Jana Gelbrich: No, that was the result, they assumed that if there's any original colour there. There is no information then when the object sank into the water and when it was excavated or treated.

Quantifying iron in the treatment solutions of waterlogged organics using EDTA

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In recent years it has been identified that iron removal from waterlogged organics can be a key preventive step to post-treatment degradation. In order to find suitable options for this additional treatment, conservation personnel at The Mariners' Museum and Park in Newport News, Virginia, have been investigating chelators and reducing agents on wooden samples from the shipwreck USS *Monitor*. During chelator testing it was found that quantifying the amount of iron present as well as its formal charge in treatment or rinsing solutions was challenging. When chelators

complex iron, they reduce the ability to detect it with commonly used colorimetric test strips. Such semi-quantitative tests are inexpensive and relatively accurate when used to evaluate free iron cations but when this iron is chelated or simply chemically bonded, the test strips can fail to measure the iron. This paper highlights the challenges of using colorimetric test strips when chelators are used during treatment and discusses the development of a quantitative method utilizing ultraviolet and visible light spectroscopy as an alternative. This technique uses the Beer-Lambert Law to correlate chromophoric absorption of iron and ethylenediaminetetraacetic acid (EDTA) complexes to concentration. This method can quantify ferric iron in solution with a sensitivity as low as 0.6 ppm.
After being established, the technique was tested comparing iron measurements with ultraviolet and visible light spectroscopy and test strips on over 300 waterlogged organic object storage solutions. These solutions were deionised water making them optimal for measurement with colorimetric test strips. Measurements proved to be most accurate with ultraviolet and visible light spectroscopy which also has higher sensitivity and is fully quantitative. The colorimetric test strips showed lower accuracy and were, at most, semi-quantitative

Q/A:

Shanna Daniel: I just want a little bit of clarification. So, with the ammonium citrate were you adding EDTA, was that during just the sampling process or?

Molly K. McGath: That's not during that's after we have a sample.

Shanna Daniel: OK that's what I thought.

Molly K. McGath: Absolutely so we're not trying to do ammonium citrate chelation with EDTA as well and there are so many variables of what's going on.

Malin Salstedt: Will your investigations in any way determine what iron removal treatment you will need to use and if so, in what way?

Molly K. McGath: That's a very good question. There's some other people in the audience who have been working on this project too that there is work right now being done on which chelators for which organic specifically so not assuming that wood and rope and all sorts of other organics that we had to respond the same, that work is ongoing and actually we partnered with a local university to the Mariners Museum to try to look at other direct comparison between the different chelators using atomic absorption spectroscopy. So, shout out to the Hampton University and doctor Dewanna White and her students who are helping us with that. We don’t have an answer yet.

Elsa Sangouard: The experiment is going to at least help measure.

Molly K. Mc Gath: Help measure. It will be specific because that one's rope, but we're going to be doing different experiments on the different materials because. We have so many.

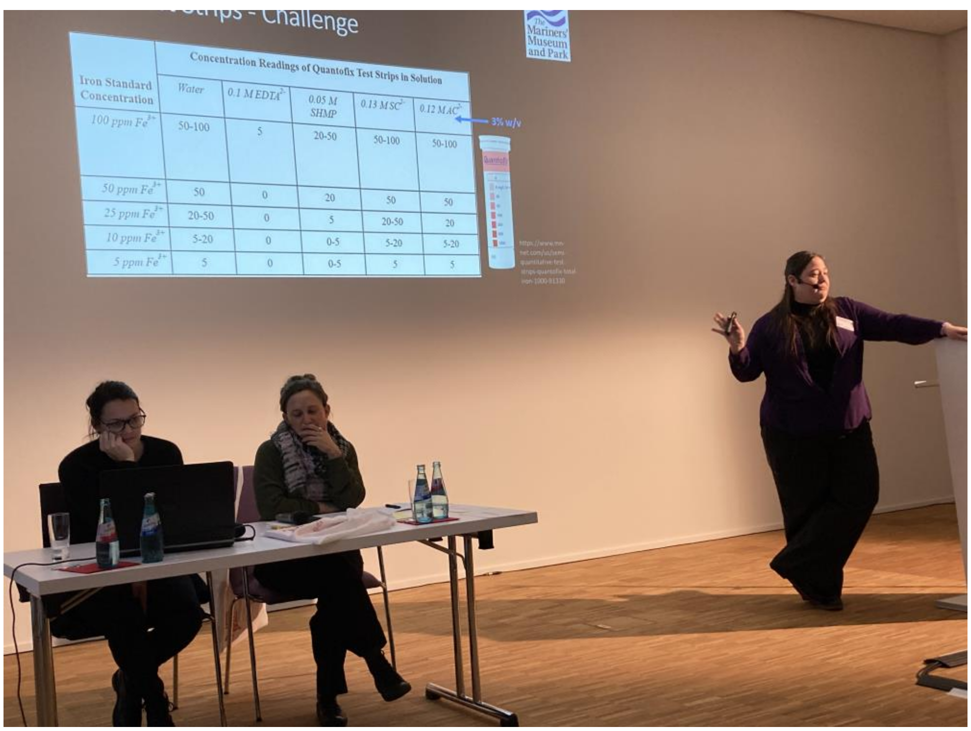

Fig. 4: Molly McGath presenting (photo Ida Hovmand)

Comparative testing of alkaline products for treatment of acidified marine wood

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In the early 1980s, over 300 timbers were recovered from the bow of the 'Ronson ship' in Manhattan, New York, USA and moved to The Mariners' Museum and Park, Newport News, Virginia. The ship was later identified as *Princess Carolina*, an 18th century vessel that is believed to be the oldest surviving, European-North American built, merchant ship. In recent years, staff noticed precipitates forming on the wood indicative of sulfuric acid formation. A comprehensive pH survey and environmental scanning electron microscopy with energy dispersive X-ray spectroscopic analysis revealed that localised acidification was occurring as a result of the oxidation of reduced sulfur forms deposited during burial. This condition predominantly arises in wood surrounding former fastener holes containing iron ions that are catalyzing the oxidation process. To determine a suitable approach for stabilising the timber collection, a comparative analysis of potential acid mitigation products in various solvents was pursued. Following a thorough literature review, five products were selected for testing: magnesium oxide, magnesium carbonate, and calcium carbonate nanoparticles as well as dolomite (calcium magnesium carbonate) and sodium carbonate. This paper describes the evaluation of these five products. The application method, solution concentrations, matrix penetration, long-term efficacy, cost, treatment time, and safety are highlighted. The results of this work indicated that magnesium carbonate nanoparticles were most efficient at mitigating formed acid as well as providing a buffer over time. Recommendations for concentration, solvent carrier, and application methods are detailed.

Q/A:

Jeanete Schramm: I just wanted to ask, did you observe any cell collapse after applying or drying from this solution?

Christina Altland: We did not assess the wood on a microscopic level. That would be a very good, interesting follow-up to see how it reacted to having so much solvent aqueous and non-aqueous solutions applied.

Angeliki Zisi: It's more of a comment. What you're doing is so relevant to what we are doing because before strengthening the very poor alum treated wood the acidity issue has to be addressed. So, the same problem but for different reason. We work with a similar protocol to yours: We're using calcium carbonate nanoparticles dispersed in isopropanol. And we also apply them with the syringe. We also let them dry for a day and then come back to them. We found them a bit difficult to penetrate, indeed more than maybe a few millimeters, not more than maybe a millimeter and 1/2. Our problem is that we can't add water right now in the solution, especially for the very powdered pieces of wood. But it is something that we would like to investigate.

Elsa Sangouard: I wanted to ask also, maybe did you want to mention any of the drawbacks?

Christina Altland: Yes, I would make it clear that all of the nanoparticles performed very well, especially what we were seeing in how far they were penetrating and raising the pH over untreated areas, but magnesium carbonate is the most expensive product and also you have the issue of nanoparticles requiring a lot more health and safety. And so when you are doing a large scale retreatment project like this, you have to bear in mind the extra time cost, the actual cost of getting the correct PPE. So that's all involved. Definitely a drawback to that, that's why we were looking for alternatives as well.

Malin Sahlstedt How long was it before you saw these precipitates appearing?

Christina Altland: We saw it a lot more like very quickly usually in the ethanol and I think it's because you know it's evaporating so quickly, but obviously it usually took more time because once we hit that threshold of 65%, oftentimes we had already plateaued for a lot of treatment and so we're just adding a lot of excess product that I think just wasn't penetrating into the wood as much. That's why we adjusted our treatment to be less intense and less time because it wasn't necessary to apply that much excess product for future application.

Angeliki Zizi: Very simply what we did. We're applying inside ziplock bags, so we put the fragment in the ziplock bag like sealed it, maybe double that and then just put the syringe through the ziplock bag. You have to clean the excess with isopropanol because it reacts with CO_2 of the of the atmosphere and then these yellow, white patches form. They crystallize very quickly and we need to aesthetically treat those areas. The process needs some refinements, definitely.

Zarah Walsh-Korb: Did you make the nanoparticles yourself or did you buy them?

Christina Altland: Well, so we did not make the nanoparticles. We bought them from US nanomaterial research company, something like that. It's in our paper. And then we made the slurries. So,we bought this chamber with gloves and things, which was actually fairly inexpensive. We did the amount that we needed for the concentration and then applied the solvent, swirled it and then added the rest of the solvent and then sonicated it in an ultrasonic bath right before we applied it to make sure it had even dispersion.

Zarah Walsh-Korb: Did you measure the dimensions? Do you know what dimensions the nanoparticles have?
Christina Altland: it should say in our paper.

Preventive solutions to treat waterlogged wooden artefacts contaminated by pyrite

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In recent years, museums as well as major conservation laboratories specialised in the preservation of archaeological organic materials worldwide have been faced with an organic's self-degradation phenomenon. A discolouration can appear on objects after treatment which is due to the presence of unstable salts such as pyrite, mackinawite, marcasite or greigite (FexSy). Once in contact with the air, after drying artefacts, these sulphide salt compounds oxidise to cause swelling and cracking of the wood and lead to catastrophic acidification of the material (pH 2).
For several years ARC-Nucléart has been developing two complementary preventive ways to treat wood collections contaminated by pyrite: i) an active approach to extract chemically metallic sulphide from within the artefacts and ii) a passivation solution to stabilise pyrite and prevent it from acidifying in the future. In both cases, the wood is in a humid state before freeze-drying.
ARC-Nucléart performed important investigations in 2020-2021 thanks to very pertinent samples involving true archaeological pieces of wood contaminated by diffused pyrite crystals, with open porosity. Previous studies were mainly performed using pure pyrite only. This expendable sampling comes from the Alise-Sainte-Reine excavation sites (Burgundy, France) and corresponds to elements of wooden pipes used to supply water to Gallo-Roman temples in the city of Alesia (2nd century A.D.).
i) Chemical extraction was performed using strong oxidants such as hydrogen peroxide or sodium persulfate (comparative study). The pH level is maintained in a slightly acidic range to create a suitable environment for the solubilisation of the ions. The extraction efficiency was measured by iron content measurements to monitor the ionic flow and pH of the solution.
ii) Chemical stabilisation was performed with alkaline salts. The principle of this approach is to diffuse an alkaline charge into and onto the wood to limit any future self-acidification of the pyrite. Three basic vectors were considered: calcium carbonate powder (with very low solubility), calcium hydroxide with a partial solubility and calcium carbonate powder associated with sodium hydrogen carbonate to obtain 'active calcium' in solution: calcium dihydrogen carbonate. A high synergistic added value was expected from the combination of both carbonate compounds in the treatment of waterlogged wood.
All these methods must be suitable for treatment of large volumes (several tens of thousands of liters), non-toxic for the environment (effluent wastewater systems) and affordable. Two main parameters were used to control the treatment: the pH of the solution and the concentration of iron ions. The characterisation work needed to define a final protocol involves pH measurements, X-Ray Diffraction, Scanning Electronic Microscope Energy Dispersive X-Ray.

Q/A:
Susan Braovac: In one of your slides, you said that when you were treating with the different calcium products you got precipitates in the bath.
Gilles Chaumat: Yes, yes.
Susan Braovac: Did you analyze them? Do you know what they were? Were they actual compounds or were they the acidification products that became insoluble?
Gilles Chaumat: So, during the experiments we used powder to have a high as possible surface exchange ratio. And we put the samples inside the beaker and without stirring the solutions. We didn't analyze the mineral products at the end of the experiments I think we can say with calcite, there is no transformation because the product is very stable with hydrogen, no carbonate. I don't know what happened. But with the calcium hydroxide, we know this product is not stable if there is a contact of the solution with the air, because we have a gas carbonic reaction and all the calcium hydroxide will be transformed into calcite. So, we reform this stable component.
Elsa Sangouard: Are you giving up on trying to extract pyrite altogether or are you trying other things?
Gilles Chaumat: We will continue to try to find other solutions to exploit pyrite because it is the best solution to solve the pyrite problem. So, no pyrite in wood, no problem for the future. But we stop trying to extract pyrite by using a strong oxidant, because we tested it for a long time. We succeeded in performing this extraction: we measure

iron content, we measure the sulphide contents but never we reach the total cleaning of the samples. So perhaps we search to find other reactants able to destabilize the pyrite, but more slowly and with pH less acid compared to a solution with hydrogen peroxide, for instance.

Session IV: Preventive conservation: storage, display and monitoring I

(Re)sinking history: Developing a strategy for the wet storage of ship timbers

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[2]Alexandria Archaeology, Alexandria, VA, USA

The recovery of historic ship remains is not unknown, but it is not an endeavor to embark upon lightly. Four ship hulls impacted by waterfront development were excavated in Alexandria, Virginia in 2016 and 2018. All four ship hulls were recovered terrestrially, below the water table, resulting from historic earthwork projects that extended the city's shoreline. The process that was developed for their recovery, study, conservation, and storage required a large collaborative effort among archaeologists, City planners, civil engineers, environmental managers, and conservators. One of the vessels was selected for conservation treatment. After a four-year period of wet storage in above ground swimming pools, the timbers from the remaining three vessels were submerged in a City stormwater management pond as part of a mid-term curation plan. This paper presents a case study that illustrates the complexity of a large-scale historic resource project in an urban setting and the importance of evaluating preservation decisions that allow the greatest range of options for future access and care.

Q/A:
Anastasia Pournou: Have you considered really reburying the pieces of wood in the sediment of the pond, because I feel that the environment, this ponding environment, it's a more oxygenated environment than the original environment. And I was wondering if you would have thought that maybe there would be fungi. Aquatic fungi growing there or bacteria? So, this is the first question. If you had the option to actually make a trench and bury the wood first, and secondly have you in any way assessed the condition of the wood before burial? So, you have a kind of a proxy to monitor during this type of in situ preservation?
Nicole Doub: We went ahead and we did a full survey of all the timbers that we selected as our examples that we're going to go back and revisit. So those were not just recorded visually, they were actually LIDAR scanned as well as 3D-photogrammetry was undertaken. We have a really good baseline for understanding, We also did penetration tests. That's the information that we're going to use when we revisit this year as well as every five years afterwards. We're actually going to have a good comparison over time. There is concern over the variation of the site, it's not a best-case scenario, there is a lot of sediment though. At the bottom of this pond is largely organic material, but there is a lot of sediment. Based on previous experience working with the Nanticoke ship which we reponded at a different facility, we actually ended up seeing quite considerable coverage developed in about 3 years' time. So, we're hoping to see a similar situation taking place here.
Anastasia Pournou: Are you expecting a naturally reburial?
Nicole Doub: We are hoping for natural reburial
Anastasia Pournou: More anoxic conditions? These conditions probably are not gonna favour the preservation of the material for 20 years as far as I know.
Nicole Doub: I should also say that these are very robust timbers. A lot of the timbers that we see, particularly in the Mid-Atlantic for this time period. It really is only those outer 2 inches or so that show any degree of actually being traditionally waterlogged. The timbers themselves are actually very robust. We found that just maintaining the moisture content does give you relatively long term stability. Interim stability, I would say long term.
Anastasia Pournou: But you haven't documented chemistry or the morphology?
Nicole Doub: We were not able to do so.
Anastasia Pournou: This would be nice to know; what is going on in the long term.
Nicole Doub: Is a municipal project.
Anastasia Pournou: I understand.

Angeliki Zisi: It's actually very useful this exercise with reburying the timbers. I think we need more of those to practice, maybe there will be more situations where there is no money to actually run a full conservation treatment of waterlogged wood. Were you considering various places to rebury? Did you make any analyses of the sediment and the water to determine that there were no chemicals present that could have a detrimental effect on the timbers? Did you check that there were no hazardous substances present in the timbers that could enter the pond environment? How safe do you considers the deposit to be?

Nicole Doub: I will admit, first of all, this is not a perfect ideal situation. It really hard to marry a bunch of different requirements from the city. So just to emphasize again, this is just within the confines of a city. We were not allowed to move the timber anywhere else. That's highly populated, very, very dense. We were limited with our available options. You know the ones that we might have preferred were restricted by environmental concerns and the city said that we could not utilize those spaces. The pond was very much a compromise, born of so much input from so many different organizations, which we were very fortunate to have. But in terms of actually monitoring, several different analyses of the different sites for pH, for products in the water. We got a lot of information from our stormwater management system. There are probably going to be some issues along those lines, however. I'm not going to deny that, but as I said, we had very, very limited options and we did the best that we could.

Angeliki Zisi: I'm sure you did. I have one more question. Because then you also spoke about monitoring? You said you had some wood you used for monitoring and I'm wondering if that w ood is also wrapped in those sheets?

Nicole Doub: Everything is wrapped so we just made sure to put it in a particular area that would be easier for us to recover.

Angeliki Zisi: And how do you monitor?

Nicole Doub: We went ahead and we did a lot of visual surveys as well as a full recommendation of the process. But we're also going to take some core samples of the material and do some density and penetration tests. So, one of the big things that we've had some discussions obviously with colleagues since I gave my talk and I maybe should have explained further that this is not the end for this project. This is how far we've reached so far, and it really is going to be the investigations moving forward with the monitoring to determine if we need to, how we need to proceed from there. If we do need to put some additional silk membranes, I got some very good feedback from colleagues. Thank you very much. And potentially you'll be putting some kind of deposit on top of it to provide some additional protection, but there's only so many resources that the taxpayer dollars are willing to put forward. And it's just something that we have to take step by step and to make our case for this collection. It is a constant process.

Fig. 5: Nicole Doub presenting (photo Ida Hovmand)

Alum-treated archaeological wood from Oseberg: Further preservation plans

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A significant portion of the wooden objects in the Oseberg collection was treated with alum salts in the early 1900s, resulting in a highly acidic wood which is actively degrading. From 2015 to 2020 the Saving Oseberg research project investigated retreatment strategies to preserve these objects. Here we will briefly present the results from both aqueous and non-aqueous methods, tested on 75 fragments chosen from the Oseberg collection. However, the main focus of this paper presents the work we have done in order to plan the way ahead with the many objects of this collection, which range from a wooden peg to complex structures like the sleds. This includes a workshop we held amongst our conservation colleagues at the Museum of Cultural History to receive input on the various retreatment methods which were tested, opinions on their application and which results were considered to be 'acceptable'. Based on the workshop results, we then undertook a collection survey in order to obtain a realistic overview of what we can do with the new knowledge gained through the Saving Oseberg project. Objects were sorted into retreatment groups, and plans are underway to re-conserve those that can withstand aqueous retreatment. Those objects that cannot undergo aqueous-based retreatment require further research to refine the retreatment methods' application and understand their long-term stability.
Q/A: no questions.

Development of storage methods suitable for waterlogged organic archaeological artefacts

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[1]ARC-Nucléart, CEA-Grenoble, France
[2]University of Pisa, Department of Chemistry and Industrial Chemistry, Italy
[3]Poznan University of Life Science, Poland
[4]Archaeological Museum in Biskupin, Poland

Organic archaeological artefacts are generally found in a waterlogged state that must be maintained until they are treated, since they are unable to tolerate air-drying. Part of the StAr JPI-CH project 'Development of storage and assessment methods suited for organic archaeological artifacts' 2020-2023 (Conservation, Protection and Use Call) focuses on the storage timeframe during which archaeometric data are collected and items are documented. Archaeometric study is the main method employed to scientifically establish the value and significance of an archaeological find. Conservation treatments involving cleaning, bulking process and drying may lead to loss of important information. Consequently, the most valuable archaeometric data are obtained from appropriately stored materials prior to treatment. Furthermore, we must consider the risk of accidental air drying and recurrent biological contamination, which is particularly high on the excavation site, where object packing is generally improvised and monitoring activity is poor.
One of the themes of the StAr project is the development of strategies that allow organic archaeological discoveries to be stored for long periods of time (several months) in a waterlogged state (*i.e.* under pre-treatment conditions), without compromising the scientific evidence they contain. The main specification of these processes is to keep microbiological contamination at a low level by using an additive in the water bath. The additive used must not be toxic, must not interact with organic materials, and must be commercially-available, affordable and capable of being thoroughly rinsed so the artefact can be cleaned afterwards (or, ideally, with no residue left within the artefact). Seven types of additive were considered: oxidant (hydrogen peroxide), acidic (azelaic acid), very basic (calcium hydroxide), basic (disodium carbonate), organic solvent (ethanol), neutral and hydrophilic salts (calcium chloride), biological/enzyme (lylozyme).
The experimental work was conducted for a period of six months to be representative of realistic conditions encountered during an excavation or in a conservation laboratory. The treatment efficiency was assessed via biological characterisation through the evaluation of microbe growth and contamination level. Microbiological analysis was performed by measuring the ATP (Adenosine TriPhosphate) concentration in the solution. This is a molecular biology technique based on the principle of bioluminescence, in which the amount of ATP in a sample can be easily and almost instantly measured in the field, indicating the number of living microorganisms present in the solution. The stability of the wood was assessed with different characterisation approaches: Py-GC/MS, XRD, pH, FTIR, SEM-EDX, water content, etc.). The protocols will be validated in a real archaeological excavation context (Biskupin site in Poland).
Q/A: no questions.

Session V: Poster presentation I

Preservation state analysis of wood samples from a well two thousand years ago

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In 2019, an ancient well was excavated in Yangquan city, Shanxi Province in the north of China. The site of the well is located to the southwest of an ancient city site named as Ping-Tan-Nao, which existed during the Warring States Period (476 BC-221 BC) to Han Dynasty (202 BC-220 AD). The well should have been an auxiliary facility of the city. According to the deposit in the bottom of the well, it was deduced that the well was abandoned in the period of the Western Han Dynasty (202 BC-8 AD), then was buried in a short period because of the low terrain. The diameter of the well is 4.5m and the depth is 10m. More than 400 pieces of wood bricks piled layer by layer was used to construct the wall of the well. The wooden bricks were joined with tenon and mortise joints and the section view of the well is nonagonal. This well is one of the biggest and best preserved in China. The construction technique is sophisticated and the nonagonal section view is very special. Well preserved different styles of tenon and mortise joints are living examples of ancient Chinese wooden architectures. In this poster, the preservation state of the wood of the well wall was evaluated. Three wood samples, YQ-4, YQ-5 and YQ-6 were taken from different depths of the well: upper part, middle part and bottom. Maximum Water content was measured to evaluate the degradation degree, but because the wood samples were exposed to the air for such a long time, the maximum water content of all samples is lower than 10%. The wood anatomic structure was observed through microscopy and scanning electronic microscopy (SEM). According to the anatomy results, the degradation degree increased from the upper part of the well to the bottom. For, YQ-4, the cell wall retained its original form and has apparent birefringence under polarised light. While YQ-6, the sample taken from the base, had degraded more seriously. From the images of SEM, it could be seen that the cell wall had separated from the middle lamella, and had deformed significantly. Only one sample showed evidence of inorganic residues, which means there is little inorganic deposit in the wood structures, and is in accordance with the condition of fresh water. FT-IR spectra of the samples were collected through ATR method. The peak area of 1365-1369 cm-1, representing C-H vibration from cellulose and hemi-cellulose, was compared with the peak area of 1507-1509 cm-1, representing C=C vibration of aromatic ring skeleton from lignin. The results show that YQ-4>YQ-5>YQ6, which means the degradation degree increased successively. This result is in accord with the results of microscopic observation. According to the results, we now know the wood degradation degree changed from top to bottom. Therefore, different conservation methods should be used during preservation.
Q/A: no questions.

Application of polymeric bandage in wet or waterlogged archaeological sites

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On archaeological sites, temporary strengthening materials are often used to fix or strengthen some fragile objects. Gypsum ($CaSO_4 \cdot 2H_2O$), gypsum bandage and polyurethane foam are the most commonly used materials. In China, menthol ((1R-(1α,2-β,5-α)) -5-methyl-2-(1-methylethyl) cyclohexanol) has also been used recently. These materials are effective in archaeological conservation in most scenarios, until we encountered the Nanhai I archaeological project. Nanhai I is a shipwreck which sank at the end of South Song Dynasty (1127-1279 AD), it was enclosed in a huge case and lifted as a whole in 2007, then moved into a purpose-built museum. In the museum, the case was put into a tank filled with seawater. Therefore, for Nanhai I, all of the objects, the surrounding sediment and clay are waterlogged or wet, and the whole archaeological environment is very humid. In this condition, the traditional temporary strengthening materials are invalid. For example, gypsum is very difficult to dry under humid conditions. Even if the gypsum had already dried and hardened, when the strengthened waterlogged objects were put into the water tank for desalination, the hardened gypsum will soften again. As for polyurethane foam, there is no problem in polymerisation and it could enclose the objects tightly, but when put into water, the buoyancy of polyurethane is too great to allow the object to stay submerged. The melting point of menthol is about 40 ºC,which means it can be easily melted.

The melted menthol can penetrate into the soil, where it is solidified, allowing the object to be lifted as a whole with the now strengthened soil. But under the situation of Naihai I, all of the objects are waterlogged or wet, and the hydrophobic menthol could not permeate into the waterlogged sediments around the objects as could be done with dry archaeological soil. As a result, it could not form an enclosure with the required strength. Therefore, a suitable temporary consolidation material is needed for working on wet or waterlogged archaeological sites. The kind of material should be readily available and be applied easily. It should set promptly, and most importantly, not be affected by water before and after setting. In this poster, the use of polymeric bandage at the Nanhai I archaeological site is presented. Polymeric bandage was invented to replace gypsum bandage in the 1970s. Fabric coated with polyurethane pre-polymer will be sealed, when in use, the soft bandage could cover the wounded part and harden quickly. The polymeric bandage is much lighter than gypsum bandage, and has good permeability, and will not deform when in contact with water, and there is no floating problem. With the aid of polymeric bandage, many fragile objects were lifted at the Nanhai I archaeological site, such as ropes, baskets, bamboo cases, broken jars. Polymeric bandage was also used to fix the broken objects, such as lacquer ware and wooden plates. Dozens of application cases proved that on waterlogged or wet archaeological site, polymeric bandage is a kind of ideal material for temporary archaeological conservation.

Q/A: no questions.

Session VI: Poster presentation II

The Degradation of Poly(ethylene Glycol) after 50 Years

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Poly(ethylene glycol) (PEG) has been used from the 1960s onwards for many waterlogged wooden shipwrecks that are discovered and restored. Originally, preliminary work was done between 1800 and 1950 largely on Scandinavian Viking ships. Alum (formula: $KAl(SO_4)_2 12H_2O$) was also used to preserve waterlogged wood to prevent warping, however over the next 50 years there were a number of complications, including the development of very low pH within the wood (1.0-2.5). In the 1960s, PEG (formula: $HO(CH_2CH_2O)_nH$)) appeared to be much more stable for preserving wood. The question remains: after the ships have been preserved for approximately 50 years, to what extent are these PEGs compromised? Our research group has obtained samples from two ships, the *Vasa* and the *Batavia*. The *Vasa*, which sank in 1628 in Stockholm harbour, was found in 1961 with nearly 95% of the wooden ship intact. It was conserved for the next 17 years by spraying with 4000, 1500, and 600 molecular weight PEG. The *Batavia*, which sank in 1629 in Australia, was found between 1972 and 1976. Only a portion of the stern section remained, and this was preserved for 3 years in vats with 1450 molecular weight PEG. Its surface was brushed with 6000 molecular weight PEG. PEG samples for both the *Vasa* and the *Batavia* were isolated via a soxhlet extractor from the wood with chloroform ($CHCl_3$). Approximately 50% of the PEG/wood sample was extracted into the chloroform. The gel permeation chromatography for both the *Vasa* and the *Batavia* confirmed that these were multiple samples (e.g. three-part samples for the *Vasa* (4K, 1.5K, and 0.6K) and two-part samples for the *Batavia* (6K and 1.4 K)). Next, matrix-assisted laser-desorption ionization time-of-flight mass spectrometry (MALDI-ToF MS) verified the exact molecular weights of these species. The majority of these were $HO(CH_2CH_2O)_nH$, however a fraction of these were carboxylic acid ($OCH_2C{=}OOH$) and formate ($OC{=}OH$). The first (carboxylic acid) is an oxidation of the alcohols at each end, but the latter (formate) is approximately half the molecular weight of the precursor, suggesting that this was a degradation product. One of these samples from the *Batavia* had somewhat more of these byproducts and lower molecular weight PEGs (via degradation of the formic acid), which was probably related to the amount of acidity in this sample.

Q/A:

N.N. Any idea as to what would cause the PEG molecules to break at the center versus degradation the ends?

Scott Grayson: Actually, if you look at it. What happens is the oxidation. Basically, any one of the oxygens you can get oxygen adjacent to the carbon. So that's the way it degrades. I thought initially it would just be at the ends, but what we see is actually in the middle and the formaldehyde is actually from the middle. I think the majority bit is probably formaldehyde oxidation. The only small bit is the alcohols through the ends

Lars Andersen: How did you find out that it is in the middle? I think that if it shouldn't be from the end, it must be random. These are very long chain molecules. How to find the middle and then just break there? Would be strange, wouldn't it?

Scott Grayson: I should say it's not in the middle, it's somewhere between the ends, right? I say middle, which means anything in between the ends.

New analytical method on shipworm degradation of marine archaeology

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When exposed to open seawater, waterlogged archaeological wood can be subject to rapid degradation by xylotrophic (wood eating) organisms such as shipworm (*Mollusca: Teredinidae*). Previous research has shown that such organisms are capable of degrading wooden structures very rapidly. This rapid degradation has implications both for the interpretation of the underwater archaeological record in terms of the site formation processes affecting a site/ wooden shipwreck and the conservation and management of underwater cultural heritage. Often the only sign that shipworm have been, or are active in a piece of wood is by the small holes they leave on the surface. These are where the shipworm starts to burrow into the wood and where the siphons used in respiration and filter feeding protrude out into the seawater. Only on sectioning or breaking the wood, or using X-ray imaging, can the extent of attack be seen. We investigated whether the freeware ImageJ could be used to develop an effective and non-destructive method to be used in situ to assess and quantify shipworm activity. The program ImageJ is an image analysis software developed to quantify different biological subjects, such as blood cells, cranial parts on lizards or specific parts of a maize stem based on visual analysis. Eight Pine (*Pinus sylvestris* L.) test blocks attacked by shipworm (*Teredo navalis*) were CT-scanned and for each shipworm tunnel in the wood the volume and size of the entry hole was analysed in order to correlate the size of the entry hole with the amount of damage done inside the wood. This information was used in the programming of ImageJ which was then tested on a complex artefact (a modern reproduction of a Viking Age broad axe handle which had been discarded in Copenhagen harbour) attacked by shipworm. Photos of the surface of the axe were used in the program to automatically count and measure the size of the shipworm entry/siphon holes on the surface of the wood. Our preliminary results show that the program can indeed give an indication of the severity of the attack. However, higher resolution images are needed, and the optimal underwater photographic conditions are currently being investigated. Our results show that the program is useful at characterising the entry holes of shipworm in the laboratory. However, it requires further investigation and optimisation in order to be used as a cost effective and non-destructive way of assessing shipworm attack on wooden shipwrecks and other wooden artefacts preserved in situ.

Q/A:
Maxx Former: I was just wondering if you would be able to see the difference between a shipworm attack and a woodworm attack that might have taken place before the object was submerged.
Anne Marie Hoier Eriksen: Not at the moment, not if you can't see the siphons then you don't know how old the attack is, but the actual degradation inside of the wood will be the same whether it's active or it's one that's been done 200 years ago. I mean, obviously, if it's an alive attack, the problem would be still ongoing, but in terms of what you see on the surface at the moment and then no, I mean you can't see whether it's alive or not.
Maxx Former: I was not necessarily wondering about whether it's alive or not, but whether a regular woodworm on the surface. If you could see the difference between that type of degradation. So woodworm eating the axe handle and it then becoming submerged or the axe being submerged and then being attacked by by torretto navale.
Anne Marie Hoier Eriksen: You mean a woodworm?
Maxx Former: Like any terrestrial woodworm.
Anne Marie Hoier Eriksen: I'm not really that familiar with the kind of holes of the terrestrial woodworm and the sizes of these. I mean, if they are similar to the shipworm holes, then it could be a problem. But if they're not, then I think the program will pick up because we only have intervals that fit with the shipworm whole size.

A review of analytical methods for assessing preservation in waterlogged archaeological wood and their application in practice

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Waterlogged archaeological wood can present management challenges due to its vulnerability to chemical and biological decay, both during burial and post-excavation. Decay processes also often leave it severely weakened and therefore susceptible to mechanical damage, meaning it must be handled with great care. Quantifying preservation and understanding active decay mechanisms is a critical step in informing the management and treatment of this unique cultural resource such that it is appropriately preserved and/or conserved. However, selecting a method of assessment isn't always straightforward. Whilst it is critical that assessments of preservation are as robust and sensitive as possible, heritage professionals are often limited by external constraints (e.g. time, availability of expertise and resources). A wide range of analytical methods can be applied to assess the state of preservation of waterlogged archaeological wood, and each can provide different information. This poster, based on a recently published review summarises some of the most commonly reported methods suitable for the analysis of waterlogged archaeological wood, ranging from widely used 'low-tech' methods, to assessment using advanced analytical instrumentation. Methods are evaluated in terms of the information gained weighed up against their cost, logistical considerations, and time investments, with the aim of supporting the development of an analytical strategy. By providing this critical evaluation, the review aims to help in the design of a scheme of assessment, whether this be prior to conservation, prior to reburial in situ, or in developing a better understanding of any immediate risks to waterlogged wooden artefacts. In this poster, we discuss some of the key factors that may need to be considered in determining the level of preservation assessment that is necessary. We highlight some of the analytical methods available, and illustrate these with examples from our own research, where assessment has been used for different purposes. We conclude that although an analytical strategy must be informed by the aims of assessment and any external restrictions, the best available analytical techniques should be employed to supply an accurate baseline against which future change can be measured. Critically, a multi-analytical approach is vital in obtaining a clear picture of the present state of decay, as no single technique gives the best assessment.
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Q/A: no questions.

Get on board: Microorganisms to preserve waterlogged wood

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Iron sulfides phases accumulated within waterlogged archaeological wood (WAW) artefacts buried in anaerobic environment. Iron sulfides then oxidised once exposed to different oxygen levels and relative humidity during or after the excavation. As a result, iron sulfides convert into iron oxides, iron sulfates, and sulfuric acid, reducing structural strength, mechanical properties, and integrity of wooden objects, even after consolidation. Microbial metabolites are here exploited for the preventive extraction of iron and sulfur species from still wet WAW.

A bio-based extraction method (BT) was developed by combining the complexing properties of siderophores (i.e., natural iron chelator) with sulfur-oxidising bacteria Thiobacillus denitrificans. This innovative method was compared with a chemical extraction method (CT = sodium persulfate + ethylenediaminetetraacetic acid (EDTA)). A first application on freshwater oak (Quercus spp.) and pine (Pinus spp.) WAW proved the efficiency of the proposed method.

Based on these encouraging results obtained on freshwater oak and pine WAW, freshwater lime (Tilia spp.) and beech (Fagus spp.) as well as marine oak and pine WAW were studied as 2 × 2 × 2 cm samples. The efficiency of BT on all these sets was evaluated with colorimetry, maximum water content (MWC), Attenuated Total Reflectance Fourier Transformed Infrared (ATR-FTIR) and Raman spectroscopies. Untreated samples (NT) which remained in deionised water served as control for BT and CT samples. No degradation of the wood was observed according to MWC and ATR-FTIR analyses, emphasising the innocuousness of BT towards wood components. Yet, some treated sets presented a different appearance after treatment ($\Delta E^* > 5$), in particular freshwater pine and beech biologically treated. Two-way ANOVA validated significant differences between the wood species ($p\text{-val} < 0.05$) but not among the extraction methods applied ($p\text{-val} > 0.05$). In addition to the wood species, two-way ANOVA highlighted that the burial site may also affect the extraction method ($p\text{-val} < 0.05$) with some different wood degradation states and other corrosion products formed. The difference is the highest between treated freshwater and seawater pine, freshwater pine being more altered. Such differences were not observed for freshwater lime, freshwater oak, and seawater oak ($p\text{-val} > 0.05$). Investigations are ongoing to understand the variables responsible for such differences, in particular with X-ray fluorescence and scanning electron microscopy. Still, Raman spectroscopy did not identify iron sulfides at the surface of any samples, independently of the wood species or the burial sites.

Therefore, the bio-based extraction method developed proved to be a serious alternative to chemical extraction methods for freshwater and marine WAW. Oak and lime wood species presented the most encouraging results. Further analyses are then considered to fully understand the extraction processes based on wood species as well as in-depth evaluation of iron and sulfur extraction with 5 × 5 × 5 cm oak samples.

Q/A: no questions.

Impact of iron and sulphur compounds extraction pre-treatment on standardized polyethylene glycol conservation of waterlogged wood

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The laboratories for the conservation of archaeological wet organics of the Archaeological Service Canton of Bern and the Swiss National Museum are participating in an interdisciplinary research project on the preservation of waterlogged archaeological wood under the lead of the University of Neuchâtel and the Haute Ecole Arc Conservation-Restauration.

The aim of the project is - before the bulking treatment of the wood with polyethylene glycol (PEG) - to reduce the agents which can at a later stage lead to acidification and salt efflorescence. To this end, a biological extraction method of iron and sulfur compounds using different siderophores and sulfur-oxidizing bacteria is being developed. This intervention intends to extract such compounds while the wood is still water saturated. Wooden samples that underwent this newly developed biological treatment are compared to a control group treated with ethylene diamine tetraacetic acid (EDTA) and sodium persulfate. A comprehensive assessment of the extraction performances and compatibility with standardized conservation protocols employed today will allow a versatile extraction method to be proposed to end-users.

For this reason, a standardized conservation protocol was developed to examine the impact of these extraction methods on the polyethylene glycol (PEG) consolidation as well as on the freeze-drying process. In particular, issues that may occur while applying these conservation processes during the limited timeframe of research projects are investigated and an eventual adaptation of these processes presented.

A well-established procedure in archaeological wet wood conservation was chosen for the conservation of the waterlogged sample sets. Tests were conducted on selected PEG solutions, which had been used for samples consolidation in order to determine their freezing and thawing behavior. These tests allowed to identify the impact of the iron and sulfur extraction pre-treatments on the critical temperature of PEG 2000 and to adjust the freeze-drying temperatures accordingly.

Q/A: no questions.

Use of a conductivity meter to monitor desalination

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Introduction: We routinely use a conductivity meter to monitor the desalination of objects, in addition to silver nitrate titrations and, in the past, a chloride meter using an ion selective electrode (ISE). A brief description of each method follows, ending with a comparison.

Conductivity: Solution conductivity is measured by passing an alternating current through the solution, in order to stop gas bubbles forming on the electrodes, which would cause an erroneous reading. Our instrument is a simple type, a Bluelab Combo Meter with some temperature compensation. Although solution conductivity generally increases with rising temperature we do not usually use a constant temperature for the measurements as we are looking for a trend in the readings, not an absolute value.

On placing an object to be desalinated into tap water the conductivity readings of the bath will start by rising rapidly, as salts diffuse into the solution, and then begin to level off as diffusion slows. When the user judges that further progress will be quicker by replacing the now salty water with fresh, a second cycle of rapid conductivity increase starts, followed by another levelling off, hopefully at a lower level. Eventually levelling off will occur at a level thought to be safe, which is checked by a silver nitrate titration to be below 50ppm chloride, and the object can then move onto the next stage of conservation. The last bath is in reverse osmosis water.

A limitation of the use of conductivity to monitor desalination is that there are substantial problems in basic solutions, as used for iron objects. One problem is that the conductivity of the hydroxide ions from the base is considerably higher than that of the salts whose extraction we seek to monitor. Another difficulty is that the hydroxide ions react with carbon dioxide from the atmosphere, to give a solution with a lower conductivity, due to the gradual change from hydroxide to carbonate. The resulting decreasing trend in conductivity opposes the increase in solution conductivity from the extraction of salts from the object, leading to difficulties in measuring the latter.

Chloride meter: Our chloride meter, a Radiometer PHM 240, uses a chloride ISE, together with a reference electrode and a temperature probe. After calibration with standard solutions and addition of a solution of Potassium Nitrate, needed to ensure constant ionic strength, the meter gives a direct reading of the chloride concentration. Because the calibration solutions need to have the same pH as the solutions to be measured, basic solutions need neutralising first, which we did using the pH facility of the meter. The progress of desalination is then monitored in the same way as described in the second paragraph for the conductivity meter, above.

We found that the chloride meter needed frequent recalibration, as often as weekly, in order to give reliable readings. In addition the chloride ISE and reference electrodes both needed careful storage and/or attention between uses if their readings were to be reliable. In short, somebody with time and some technical expertise was needed to keep the chloride meter ‘on the road’.

Silver nitrate titration: We use titration against a silver nitrate solution to give an absolute value for the chloride content of a desalination bath, as confirmation of the conductivity monitoring of the salt extraction. The method we use is a slight variation of the UNESCO procedure (UNESCO 1981). The end-point of the titration is when the initially precipitated white silver chloride is succeeded by red-brown silver chromate. Judgement of this end-point is somewhat subjective, so it is helpful if the same operator does the titration every time. Both silver and chromium compounds are poisonous and silver nitrate solutions will stain clothing, so the usual laboratory safety procedures are called for. Normal laboratory glassware is used.

Comparisons of methods: The conductivity measurements are quicker than a chloride meter or a silver nitrate titration. Conductivity measurements are also cheaper than a silver nitrate titration or measurements with a chloride meter, not only because of the reagents used but also because of the extra staff time involved with the latter two methods. The chloride meter, in particular, necessitates additional staff time to keep it running to the required standard of accuracy.

Q/A: no questions.

Not all silicone oils are born equal!

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The Problem. We needed to conserve a waterlogged sandglass which was made with different woods as well as glass. The silicone oil process, as described by the group at Texas A & M University (Smith, 2010), seemed a possible candidate. We could not get the process to work properly on test samples, which remained sticky despite our apparently following the instructions from Texas to the letter.
We came to the conclusion, with help from the Texas group, that the problem lay with the silicone oil (strictly, siloxane oil) that we were trying to use. Many of the silicone oils in general use have inert end groups, such as trimethyl silyl, $-Si(CH_3)_3$. Inert end groups give the silicone good resistance to heat and chemical attack, leading to many of the general uses that we are familiar with.
The Process. For the Texas silicone oil conservation process to work you need to have hydroxyl (-OH) groups on both ends of the siloxane polymer backbone. To get the oils to solidify you add a proportion of a cross-linking agent, Methyltrimethoxysilane, which has three reactive groups on it, giving it the potential to react with three hydroxyl groups, like those on the siloxane polymer. Addition of a catalyst, dibutyltin diacetate, leads to cross-linking, resulting in hopefully stable, but irreversible, consolidation.
The Solution. Our problem was that we were trying to use the available, and cheaper, silicone oils terminated with trimethylsilyl groups. Not surprisingly, given the above comments, the silicone oil refused to react, leaving us with an unsatisfactory result. The correct silicone oil, terminated with hydroxyl groups, has the CAS number 70131-67-8, whereas the incorrect silicone oil, terminated with trimethyl silyl groups, has the CAS number 63148-62-9. Once we switched to using the correct type of silicone oil, kindly supplied by Peak Polytech, we were able to achieve dry test samples. Despite this success on the test samples we decided to use Polyethylene Glycol treatment. This is mainly because the sandglass required repairs of the glass components and the issue with objects treated with silicone oil is that any repairs can only be done with the silicone oil or cyanoacrylates. Therefore, silicone oil treatment is advisable for use only on complete objects.
Conclusion. The moral of this tale? For the Texas silicone oil treatment to work the oil must have the CAS number 70131-67-8. There are several other types of silicone oil, with different end groups and CAS numbers, but none of the others will work. There are a number of other polysiloxane suppliers in addition to Dow Corning, such as Peak Polytech in the UK.

Anthony Crawshaw: I should add that we did get help from the team at Texas A&M. We said, we think this is the problem and they agreed.
Q/A: no questions.

Pitch and wood tar - historical materials and use in innovative technologies – a project that restores the meaning of historical products

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Wood tar and pitch are believed to have been produced in Persia and Mesopotamia as early as 7,000 years ago; then spread to Europe. Archaeological discoveries dating back to the Paleolithic or Mesolithic period prove that the dry distillation of wood and bark was the first ever process human-made technological and chemical. Relative tar and pitch abundance wood found in the Neolithic and Eneolithic periods may reflect the growing importance of tar wood in domestic activities, as well as in magic and practice. However, archaeological data indicate a significant increase in the use of wood tar, which took place only at the beginning of 4th century BC. The real avalanche of wood tar sent to the west of Europe dates from the 16th century to the 19th century inclusive. From Russia, Poland, Finland, and Sweden tons of these products they reached Danish, English, French, Dutch, Portuguese, and Spanish shipyards. Despite the infamous but probably necessary period of transition from natural products to petroleum products, tar and pitch are still produced in Eastern European countries using traditional methods. **The project entitled: "Pitch and wood tar - historical materials and use in innovative technologies" aims to restore the importance of pitch and tar in the consciousness of modern man as products with a rich history and meeting the needs of modern bioeconomy.** As part of the project, products of dry distillation (pyrolysis) of pine wood and birch bark will be produced using the traditional method (in clay pots) and the laboratory method (in pyrolysis furnaces). Their properties will be compared, thanks to which they were used in the past as lubricants, antiseptics, drugs, wood preservatives, etc., and the possibility of their application in the same products, while meeting the expectations of modern consumers, will be checked.

Q/A:

Anthony Crawshaw: This is an explanation as to why you may get odd results in your analysis of chemicals that are produced in a batch way like PEG. They even make a complete batch and then they stop and do another batch, when more is required. Now you know this is based on my experience in analyzing industrial chemicals and so in industry, what they do is define the chemical by the molecular weight by 4000 PEG, which is the middle of your distribution of the range of molecular weight and so you've seen those curves which show the distribution. You can also get a small amount of other material in your PEG and the reason for that is that the companies, when they measure their batches, they find that some batches are better than others. Some are a bigger spread and others will have a smaller spread, so they define the things by the average. That's what they were offered to sell you the PEG 4000. But it's molecular weight might be slightly different so in order to cope with that, what they do is to add a little bit more of a better batch to a poorer batch and vice versa, so you can get a. small amounts of stuff that doesn't apparently meet the specification, but it's within their legal obligation. Don't be too worried if you get something that's totally out of your expected range, it's defined not only by the centre of the molecular weight but how wide it is as well. So that was just an observation. If you get something on it might be entirely legitimate.

Study of two wooden boats from a mine

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Two wooden boats were found during drainage of the Main Hereditary Key Adit of the closed Guido mine in Zabrze, Poland, at a depth of about 22 m. The boats were built in the 19th century and were used to transport people and tools in order to carry out inspections of the mine. After being abandoned, the boats were flooded with water and sediments.

The boats were made of softwood with a length approximately 5 m, a width of 112/84 cm and a height of 50 cm. One of the boats was made of pine *(Pinus* spp.) and the other was made of Douglas fir (*Pseudotsuga taxifolia Britt*). The structure of the boats was simple: the bottom is made of three boards with 'tongue and groove' joins, the sides are of two boards, and with a trapezoidal bow and stern. The exterior of the bow and stern, as well as the adjoining parts of the sides, are clad with a metal sheet fastened with rivets and nails. Inside there are three wooden frames, reinforced with metal bars fixed with screws.

It was decided to mechanically separate the metal parts from the wood to allow better conservation of the wood. The operation was successful even with the removal of the sheet metal cover. X-ray examination showed the presence of nails deep in the wood, which were impossible to remove. Corrosion products were analysed by X-ray photoelectron spectroscopy (XPS) and showed the presence of carbon, iron in the form of oxides and hydroxides and calcium in the form of hydroxides and silicates.

The maximum water content tests showed different degrees of wood degradation of both boats. The maximum water content ranged from 71% to 250%. Samples were taken with the Pressler drill from several places of the one boat to a depth of 2 cm and analysed using X-ray fluorescence (XRF). The results showed the presence of various metals like calcium (Ca), iron (Fe), zinc (Zn), nickel (Ni), aluminium (Al), magnesium (Mg), strontium (Sr), manganese (Mn) and also sulphur (S). Quantitative studies on similar samples were performed using inductively coupled plasma atomic emission spectroscopy (ICP-OES). Studies have shown a dominant amount of iron and calcium compounds. These compounds are being removed with 2% Na-EDTA with the addition of boric acid to maintain the pH 7-8. Removal is controlled by measuring iron and calcium in the solution by ICP- OES on one boat and flame atomic emission spectroscopy (FAES) for measuring Fe ions and flame atomic absorption spectroscopy (FAAS) for Ca ions on the second boat.

At the same time, maintenance tests are carried out with the measurement of shrinkage of small elements after conservation by means of 3D scanning. Minimal wood shrinkage will be very important during the reconstruction of the two boats.

Q/A: no questions.

Conservation of waterlogged archaeological objects made of pine bark

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This poster presents an ongoing study that focuses on methods for impregnation and subsequent drying of waterlogged archaeological objects made of pine bark. The literature on conservation of bark material is limited and papers about pine bark are even rarer.

During an archaeological excavation of Medieval Oslo in Norway, some objects made of bark were found. The excavation was carried out from 2013 to 2018 by the Norwegian Institute for Cultural Heritage Research (NIKU). The objects, bark floats for fishing nets, were made of the outer bark of pine trees, most likely Scots pine (*Pinus sylvestris*). These waterlogged objects were assessed to be fairly well preserved. The identification of genus of the bark material was done by visual recognition and comparison of bark on modern pine trees.

Bark differs from wood in both structure and chemical composition. Conservation methods developed for wood may not be as successful on bark materials. Furthermore, bark material may vary between different genera of tree making it difficult to transfer theories and methods from one type of bark to another. Pine bark tends to detach in layers as a natural process. This adds to the conservation challenges as the material can delaminate further during conservation processes.

Bark consists of inner (phloem) and outer (rhytidome) bark that is distinct in both appearance and function.

An active periderm with living cells divides the inner and outer bark. Periodically new periderm forms and the older is pushed towards the outside. In pine bark the older periderms can be seen in a cross section as thin, light-coloured bands in the outer bark. Delamination seems to occur within these bands.

After consultation with colleagues within and outside of the Museum of Cultural History (KHM) in Oslo, three methods for impregnation and drying were found to be of interest: just freeze-drying, impregnation with high molecular weight polyethylene glycol (PEG) and freeze-drying and thirdly impregnation with Klucel G (hydroxypropylcellulose) in an aqueous solution followed by slow air-drying. Reattachment of delaminated layers after drying are not a part of this study, although it is an important part of the conservation.

PEG is well known in archaeological wood conservation as well as for other materials. For the PEG 2000 impregnation, our protocol for waterlogged wood is used with a final concentration at 30%.

Klucel G is used in paper and leather conservation. As a starting point, the concentration is set to 0,5% (w/w) Klucel G in water and impregnation time to 4 weeks. This procedure was selected after some pre-trials on test materials.

Alongside the objects, test material is impregnated and dried in the same manner. Modern bark, gathered locally from dead trees, is used due to lack of archaeological test material.

The treatment methods will be evaluated after drying, visually and also using scanning electron microscopy (SEM) and Fourier-transform infrared spectroscopy (FT-IR) on the test material. SEM will be assessed for its usefulness to evaluate extent of impregnation. FT-IR will also be used to see if it can indicate the extent of bark degradation as well as extent of impregnation of consolidant.

Q/A:

Ida Hovmand: When you say delaminates, is it in the ground or do you discover it when you take it up and it starts laminating and drying?

Emma Emanuelsson: It can pretty much start delaminating at anytime. This is natural processes for the tree to do, so it sort of delaminates on the tree where it's still a tree living, and when it's dead, at any point. But the goal with a different strategy is to stop or reduce delamination.

Ida Hovmand: Do you have any idea of how often this material has been used and for what the of type of objects?

Emma Emanuelsson: And my guess is that it's been used a lot. It's already available in northern Scandinavia. I think it's been used a lot.

Ida Hovmand: Do you have any of those types of objects in your collection already?

Emma Emanuelsson: Not that I know of.

Johanna Klügl: Even though birch, cork and pine bark are different, I would be very happy to exchange ideas with you.

Conservation of a medieval wooden causeway in the city centre in Berlin

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In the 1960s the area around Berlin's oldest square (Molkenmarkt) was modified into a car friendly district with a six-lane road and huge areas of parking spaces, removing the last traces of the historic centre. Urban plans developed by the Senate of Berlin led to a redesign with a vision for the coming years to build a new city district based on the original historical structures. Since 2019 excavations in this area has been carried out by the local state office for Heritage Protection Agency (Landesdenkmalamt Berlin). In early 2022 during building preparations accompanying new routes of power grids and gas pipes, wooden constructions were surprisingly discovered, belonging to a medieval street, along the alignment of the modern Stralauer Street. The causeway was found 2.5 meters beneath the modern floor level, embedded in densely packed and peaty ground.
The causeway is impressive even by today's standards, measuring about 65 m long and 6 m in width, which allows for two directions of travel. The three-layered wooden construction consists mainly of timbers made of pine (Pinus sylvestris L.), but also birch (Betula alba L.) and oak (Quercus robur L.) was used in minor quantities. Dendrochronological dating showed that the causeway was built from 1215 onwards and was used at least until 1237. It was necessary because of swampy conditions of the ground to guarantee a safe passage. It was constructed in a series of layers. The first layer, consisting of roughly worked trunks, was orientated transversely to the direction of travel. Some of the wood used suffered from core rot, making them unsuitable as construction-timbers in house building, but adequate enough for use in building the causeway foundations. The second layer, above, consisted of three trunks in the direction of travel, equally distributed to the width of the street and 9 m long. Finally, timber planks made up the top layer. Those planks have been split lengthwise, decorticated and were densely laid transversely to the direction of travel. Noticeably, only minor traces of usage could be observed. Maximum moisture contents (umax) could not be performed to date but will be expected to be in a wide range, since simple needle tests showed timbers ranging from Class I to class III wood. Due to its archaeological importance and because the wooden structure could not be preserved in situ, it was decided by the local state office for Heritage Protection Agency to lift and preserve a section of approximately 6 × 6 metres. The first step of the conservation process after excavation consisted of the construction of a pool located on an already excavated area nearby to prevent the delicate planks from the top layer from uncontrolled drying. The timbers of the second and third layer, are being regularly watered and are wrapped in plastic foil and geotextile stored on the ground. Future discussions are led by the question of a suitable method for conservation and the appropriate conservation results, given the actual circumstances regarding the limited technical and personnel infrastructure for the conservation of waterlogged wood.

Q/A:
Gillian Portius:Are there plans in place already for? Where it will be displayed and how it will be displayed?
Philipp Schmidt-Reimann: Yes, that's a very good question which I asked several times. And no. Of course, this is an important question because it will have consequences for the way to conserve it. On the other hand, if I don't know the question, I can choose how to conserve it and the construction of a display then have to stick to my way of conserving it. I try to put it positively. The answer is no.
Ida Hovmand:When you say you had to get through a few issues with bureaucracy, how long did it actually take you? Because, it sounds like it's not that long ago it was found?
Philipp Schmidt-Reimann: Well, you have to know that there are three different authorities involved. There's the local Heritage Department which is responsible for the excavation and that's a. Special thing in Berlin. Normally cultural aspects are ruled by federal governments, but there's one exception that the state museums where I work. So we have the local authorities, you have our institution as a government authority and the third one is who runs those buildings, which is another government institution. So, we have three stakeholders, and it took well, frankly saying it was a record, because it took about nine months to get this done, which is quite good. In the beginning I didn't believe that that I would make it in one year. But finally, we get it somehow, there's water now. There's a new floor and I have to thank my colleague Stefan Brather, who said? Well, the one colleague in Luxembourg, foreman Lorenz Bartel, got some tanks left. So maybe you asked him and asked him and he said yeah, OK, you can have them. So there was the fight with bureaucracy, but also networking in Germany to get support from nice colleagues.
Kate Sullivan: Conservation is very much a field where we think that we are all in this together.

Conservation of Archaeological Textile Fragments from 14th and 15th Century

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The work deals with the conservation of wet and dried textile fragments from archaeological excavations at Wenceslas Square in the New Town of Prague. The conservation procedures were chosen according to the results of the extensive research that was carried out on model samples made of silk, flax and wool that are the most common textile fibres among the archaeological findings. This research was focused namely on the cleaning, drying, consolidation and improvement of textile fragments flexibility. Archaeological textiles are usually fragile with fraying surface, therefore the model samples were artificially damaged to simulate these typical properties.

In case of the wet textile archaeological findings, it is crucial to keep them wet during the whole conservation procedure until the regulated drying. Unfortunately, the first aid is not correct sometimes and the drying of the findings can occur. Therefore, the conservators deal with wet as well as dry textiles. The decision about cleaning method (wet or dry cleaning) is crucial when conserving dried archaeological textiles. The wet cleaning is much more efficient, but in some cases can cause the damage of the textile. Therefore, the evaluation of the fragments sensitivity to the water is essential.

The conserved collection contained eleven fragments made of different textile materials (silk, plant material, horse hair, fur, wool) and with the different textile structure. The fragments were wet or dried, creased, heavily soiled, often without recognizable structure. The wet fragments were before conservation stored in the fridge and disinfected by 50 % ethanol and regularly checked. The fragments were greatly diverse, therefore the conservation procedure had to be chosen individually. The different cleaning methods (wet or dry) were used according to state of conservation of the fragments. All fragments were softened by glycerine, drying was carried out on the sieve or in the freezer. The fragments were adjusted in the frame on the polyester padding covered with linen cloth.

Q/A:

Gillian Porteous: I was very interested in the softening agent that you were talking about for when you were air drying textiles. I think you said it was glycerin. How do you find it?Can you speak a little bit more to how it changes the texture or the brittleness of the textile. If you air dry without versus with? What are the properties changes that you're observing?

Klára Drábková: I'm not sure. If I have understood the question properly, but we tried glycerin and also PEG 400. Glycerin seems to be more suitable because of the properties of the textiles right afterwards of the treatment and also from the long term point of view, because we tried, we used artificial aging to monitor long term behavior and if you take out the rest of the solution, it's not glossy. It's not greasy. It has a nice feeling. It's soft enough. It's looking pretty nice.

Morgan Creed: Was there a visible difference between freeze dried and air dried textiles? Were there any changes in brittleness?

Klára Drábková: Yes, if you do not use the softening agent and use air drying then it's quite stiff, the textile. After freeze drying, it's soft and nicely flexible.Therefore we recommend using a softening agent because and then freeze drying and air drying with a softening agent has real l similar appearances. .

Jennifer Wakefield: What was the method used for artificial aging you mentioned in your talk?

Klára Drábková: We used a standard for aging paper. Because as far as I know, there are no standards for artificial aging of textiles. Paper is cellulose, linen is cellulose. It was this way of thinking. It was dry aging 105 ℃ for four weeks and moist aging 80 ℃ and 65% relative humidity and also light aging.

Anthony Crawshaw: What humidity did you store your textiles with afterwards? The reason I ask is that we have been storing material at about 40 to 50% relative humidity which has been conserved with glycerol, and we find that the glycerol is picking up moisture even after freeze drying and so we end up with a solution of glycerol which is possible that we're getting mold growing in the glycerol.

Klaraa: We store the textiles at 50% relative humidity and we didn't observe any humidification of the surface. Colleagues from our microbiological department carried out the microbiological testing at the even higher relative humidity at 80%. And it was still OK.

Session VII: Preventive conservation: storage, display and monitoring II

New monitoring tools adapted to unstable waterlogged archaeological artefacts SensMat project related to preventive conservation)

Gerusa de Alkmim Radicchi[1], Gilles Chaumat[1], Marie-Dominique Bruni[1], Stephane Rioual[2], Benoit Lescop[2], Julien Pellé[2], Johan Becker[3], Dominique Thierry[3], Valerio Beni[4] and Stephane Hury[5]

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[5]Bassetti, Grenoble, France

The conservation of archaeological wood collections needs an ambitious and specific preventive conservation policy, especially when artefacts are contaminated by unstable salts, such as metallic chloride or sulfide. All mineral salts, unstable in the oxygen/humidity of air, are susceptible to suffer from chemical transformations inside the object, leading to severe degradation phenomena of the wood: swelling of the structure due to crystallisation and intensive acidification of the medium (pH < 2).
Additionally, environmental conditions foster these degradations through high levels of relative humidity/temperature, concentration of dust and volatile pollutants (sulfur dioxide, hydrogen sulfide, nitrogen oxide, organic acids). Identifying risky levels of air corrosivity produced by the combination of these factors remains a difficult task, not only because of the multiple origins of alteration factors, but also due to the lack of instruments and monitoring methods accessible to conservators.
This work aims to present the proposal of SensMat (Preventive Solutions for Sensitive Materials of Cultural Heritage), financed by the European Commission (Horizon 2020) under grant agreement N° 814596, to monitor indoor environmental corrosivity related to the conservation of archaeological wood. The project target is to develop and implement effective, low cost, innovative and user-friendly technologies, sensors and platforms, as well as to develop knowledge associated with the application of new sensing proposals and Decision Making Tools (DMT). The technology to monitor environmental corrosivity presented in this article consists of Battery-free Radio Frequency Identification (RFID) Binary tag EM (Electromagnetic Measurement principle), developed by UBO (Université de Bretagne Occidentale), and Printed Circuit Board (PCB) Based sensor node ER (Electrical Resistance measurement principle) developed by RISE (Research Institutes of Sweden), UBO and Institut de la Corrosion, and which uses LoRa gateway provided by TTI GmbH (Technologie-Transfer-Initiative) as communication system. The strategy consists of integrating the technologies to Case Studies (CS) preventive conservation monitoring as well as the data produced by the sensors and platforms to the DMT through TEEXMA, a customizable modular software. This software is developed by BASSETTI to capitalise on technical and scientific data from sensor measurements.
This work is focused on the presentation of the SensMat demonstration in the temporary archaeological storage room, in the Atelier de Recherche et de Conservation (ARC-Nucléart), the Case Study N° 1 (CS N°1). ARC-Nucléart is one of the institutions belonging to the Commissariat à l'Énergie Atomique et aux Énergies Alternatives (CEA) of Grenoble. Through this demonstration it has been possible to discuss a fast and friendly new approach to detect the chemical degradation processes involved in the oxidation of mineral.

Q/A
Katharina Schmidt-Ott: Are these sensors a further development of the oldEuropean Core Log project or is it just a similar setup? Because there was a project some years ago that was using more or less the same technology, but I think they also had lead as a third sensor besides silver and copper and it was problematic to further produce it so maybe that would be an interesting input.
Gerusa de Alkmim Radicchi: It's not exactly the first time, these kinds of sensors or similar, are applied to preventive conservation in general, not only in archaeology.
Katharina Schmidt-Ott: This is an independent project?
Gerusa de Alkmim Radicchi: Yes. This is a very huge project. For example, I mentioned the Institute de la Corrosion they had before Sensemat also a project involved with cultural heritage. It's a first step to develop systems for monitoring corrosion resistance. It becomes a kind of a network. They develop things at the same time they propose things to SenseMat , but independently. Malin Sahlste d: Did I understand correctly that these tools may be further developed for the monitoring and stability of pyrite?
Gerusa de Alkmim Radicchi: It is not exactly applied only for pyrite.The corrosivity is the product of the reaction of the dust, the temperature, the humidity. So if you really want to know if there is a product with sulfide, we need to

do kind of experiments in laboratory. The proposal is monitoring the quality of the atmosphere in general, but in the context of case study one, as we have a storage with a lot of wood, unstaple wood, the relation is kind of clear, but it's not only applied on the wood.

Dimensional stability in drying vs creep in PEG treated waterlogged wooden structures

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Polyethylene glycol (PEG) treatment is a common method to maintain dimensional stability when drying waterlogged wood artefacts. Although there is considerable practical experience in using this method, it has shown some drawbacks regarding the long-term dimensional stability, in particular for large and heavy wood structures. An object may look fine when showcased after treatment, but could deform significantly over the years due to creep. This presentation attempts to show the tradeoffs that have to be made considering both the short and long-term dimensional stability. The underlying physical mechanisms are presented and some of their governing equations. With a set of physical quantitative models, it would be possible to predict the effects of treatments and choose a scheme that is adequate for limiting long-term creep while preventing excessive shrinkage on drying.
Although PEG is very useful in preventing deformation during drying, as the PEG replaces the moisture in the wood, it impairs the mechanical properties of the wood, since it acts as a plasticizer. The mechanical properties in longitudinal directions, i.e. along the grain, is less affect, but in the transverse direction and in shear, the properties are significantly deteriorated. Structures with loads in these directions will thus be at risk. In some cases, it could be wise to consider a support structure that alleviates the deleterious loads.
Recent results for materials relevant to the Vasa ship show that the addition of PEG affects the creep behavior more than static properties, namely stiffness and strength. Only static mechanical testing is not sufficient to make sure that a certain treatment performs well also for long-term loading. Not only the softening effect of PEG accelerates creep, but also the added self-weight for larger structures contributes. With a constitutive material model for creep, the time dependent structural deformations can be predicted by finite element modelling, including effects of temperature and relative humidity. Such predictions could be compared with the dimensional stability on drying governed by diffusion of PEG. The molecular weight of PEG affects the time of impregnation and the hygroscopicity of the treated wood. Eventually, it comes down to the practitioner to judge which type of PEG to be used and the treatment time. We here advocate that the effects of long-term creep should be brought into the equation when making this judgement, at least for heavy wooden objects. In the future, also literally brought into the equation if predictive models can be developed to estimate the effects of PEG on creep deformation.

Q/A:

Susan Braovac: Because of the variability we know we have in all our wood, would it be possible to know if you make a finite model of something? Can it be applied to most woods, or does it really, really change with each and every type of timber and degradation? How much leeway do we have? If you make one model can it be applied to more?

Kristofer Gamstedt: Yeah, this if you ask an engineer that works on steel, wood is a nightmare and maybe even more so archaeological wood because of the variability, but there are methods being developed for new order materials, but basically the density has a lot of influence on the mechanical properties. So if you know the density and also if you know the microfibril angle, that is the angle of the cellulose you can make pretty good predictions of the mechanical properties. But then of course, there will be a lot of variations. One needs to take this into account to make statistical models, but I don't think the alternative is any better if we just go by how we feel and design things. If we use these methods we can probably make better predictions, although it's going to be a bit insecure, but I think it's still even if it's a challenging material, it's the way to go.

Susan Braovac: To continue making a model for each type of situation?

Kristofer Gamstedt: Yes, and actually if we do measure the density of the material and if you can get the orientation of the wood, we can make pretty good predictions.

New methodologies on the analysis of archaeological wooden structures. Establishing protective measures of Viking age ships and sledges prior to construction work and relocation processes

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The Viking Ship Museum in Oslo, part of the Museum of Cultural History, University of Oslo, is under reconstruction. The existing museum will be considerably enlarged, and the spectacular ships and sledges will be transferred into the new adjacent building. During the construction work and the relocation process, the objects will be exposed to deformations and vibration. This paper describes the work carried out to meet a satisfactory level of object protection during the operations. This includes relevant conservation history, current storage situation, object geometry, material composition, weight, structural and dynamic behaviour, and shows how this information is used to tailor an adequate protection strategy for the large and complex archaeological wooden structures in question.
Q/A: no questions.

Session VIII: Sustainability

Conservation treatment of Mongolian ships using the trehalose method

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[4]Hayashibara. Co., Ltd.Naka-ku, Okayama City, Okayama, Prefecture, Japan
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We are using the trehalose impregnation method to conserve the bulkhead plank (5670 × 700 × 150 mm, camphor tree) of a Mongolian warship (sunk in 1281) excavated from the Takashima underwater site. The impregnation process was completed in March 2021. Currently, the surface is being treated. This paper focuses on records and the information of the entire bulkhead plank conservation process. Following the progress of the conservation process, the following points will be reported. Impregnation tank: Design and performance of the impregnation tank, solar thermal collector, and adjustable impregnation tank. Before the impregnation process: Measurements of the moisture content of the bulkhead plank, weight measurements etc. During the impregnation process: Temperature and concentration control and measurement of the weight of the bulkhead plank. At the end of the impregnation process: How the bulkhead plank is removal from the impregnation tank. Solidification process: Weighing and recording of appearance. Surface treatment: Introduction and effects of steam cleaners and other device used.
During the solidification process, the bulkhead plank was subjected to a hot and humid environment with humidity exceeding 30 °C and 70 % RH during the summer months, but no problems were found with the iron or wood.
Q/A:
Ida Hovmand: I think this is a very, very good example of a sustainable project. It is using so much less energy. Do you know the cost of the trehalose for the treatment of the bulkhead?
Akiko Miyake: 22.000 Euro (4000 kg).
Margrethe Felter: Confirming that the impregnation device is solar powered? What's the solar power used for? Is it used to keep the tank warm?
Kouij Ito: We use it to make the water hot. Then we transfer the water to heat the tank. We showed it in a WOAM newsletters one year ago.
Anthony Crawshaw: You said you had a new desalination monitor. What was it? How did it work?
Kouij Ito: We are doing the experiment with this desalination process monitor. So now we are doing analysis using XRF to monitor process. In this experiment, we do not analyze conductivity, but XRF or EDX to monitor desalination.

Morgan Creed: How is dirt removed from the trehalose so it can be reused?
Kouij Ito: There are two ways to eliminate dirt, one is to use a membrane to filter. Then we can remove the dirty things from the trehalose solution. The other one is to crystallize it again. So, when we crystallize the trehalose again slowly, then we can get the clean clear high purity crystal again. Then we can use it to make a solution again. Because the trehalose is stable in acidic condition and stable for heating, so it doesn't degrade during the process.

Recycling of used PEG solutions by vacuum drying

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This study investigates whether high molecular weight polyethylene glycol (PEG) solutions used for waterlogged wood impregnation can be purified using microfiltration and solidified by vacuum or conventional oven drying. Three used PEG solutions were purified with microfiltration and activated carbon, and analysis of total ash content, pH, conductivity, and spot tests for selected ions were performed before and after. Solidification treatments were carried out on new PEG (both solid and in solution) at different temperatures to find optimal process conditions and to assess PEG degradation during treatment. The latter was done by melting point determinations, thin-layer chromatography (TLC), ATR-FTIR spectroscopy, and MALDI-TOF. It was found that the combined microfiltration and activated carbon treatment only removed limited amounts of impurities from the used PEG solutions. Analysis of total ash content and spot tests for selected ions were shown to be well-suited, simple, and low-cost methods for determining inorganic impurities. Vacuum drying was found to be the most efficient way to solidify PEG and from the results, it is clear that the solidification process should be terminated at the point where no more water is left, and that the temperature should be kept below 120˚C to avoid degradation. Before implementation, the optimal drying time needs to be established individually for each workshop wanting to solidify used PEG to secure optimal PEG quality and minimise energy consumption. Melting point determination was shown to be an efficient way to assess the degradation of PEG and it is advised to use this method when deciding if the quality of PEG solutions is high enough to be reused.

Q/A:
Laure Meunier:We are actually dealing with the microfiltration of the PEG solution and there are several parameters we try to ensure while performing filtration . We try to be under 1 milligram per liter of iron in our PEG solution. So if we see that it's increasing, we immediately make some iron catching resin to remove and to assess that iron is always at the lowest state, so it is an infiltration. So, we also use iron catching resin because it is complementary to carbon and to physical filtration as you tried. As there is no system developed for us we have to take one from the industrial food supply and adapt it to our purposes.
Lasse Nedergaard Mikkelsen: Yes, that would have been nice to have that as well. I didn't.
Liane Albrecht: We are in contact with a company, that recycle PEG solutions. We took a sample of the of the solution and we saw there was a little bit of oxidation. We are figuring out how it can be used. We try to inform our colleagues in Germany. The company has to calculate how many liters of PEG they need to process so they don't lose money. We also have to calculate how many liters we can collect in one year m. Maybe in three years, at the next WOAM you will hear more.
Zarah Walsh-Korb: I had a question about your microbial tests and you said you took nine weeks? Did you consider maybe just adding a few drops of your material to growth media and see if it would be much quicker? It would grow in a day or four days for yeast?
Lasse Nedergaard Mikkelsen: I was working during the COVID pandemic, so I only had one day a week.
Zarah Walsh-Korb: Yeah, of course. In these scenarios that matter, it just would be quite interesting.
Lasse Nedergaard Mikkelsen: Yeah, but otherwise it would have been a better way.
Zarah Walsh-Korb: It would be quite interesting as well, because maybe then later you could actually determine what bacteria or what yeast or what fungus was actually present.
Ida Hovmand: How many of you are recycling PEG? Four hands were raised.

Designing sustainable consolidants: An evaluation of two bio-based consolidants

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Sustainability is an oft repeated parameter in discussions concerning materials design. Ideally, materials should be made in a circular manner using low environmental footprint reagents, with sustainability of the processes and minimal (or no) end-of-life waste. In light of the current climate crisis, this is an important consideration in every field, heritage conservation included. In fact, sustainable conservation of cultural and natural heritage is seen as a key step in achieving Goal 11 ('make cities and human settlements inclusive, safe, resilient and sustainable') of the Sustainable Development Goals (United Nations 2015). Yet, the majority of the consolidants employed to conserve and sustain wooden cultural heritage objects are not sustainable themselves and the move towards sustainability is filled with obstacles, not least how do we find the most appropriate sustainable alternatives? Moreover, how exactly do we define a sustainable consolidant? For the purposes of this paper, a sustainable consolidant is one which is obtained primarily from biomass, requires minimal resources to prepare it for use and can be decomposed at end-of-use.

To enable better decision-making around sustainable consolidant design, I have analysed two bio-based consolidants that I have designed, (1) a synthetically functionalised chitosan/guar gel, and (2) a composite of a bacterially produced poly(3-hydroxyalkanoate) (P3HB) and chitosan, to assess environmental impact in terms of energy use and greenhouse gas (GHG) emissions. The processes used to prepare the raw materials were examined, their energy use and emissions were estimated (where possible) based on literature studies, and the energy and emissions required to process these materials in the lab to the final consolidant were assessed. Although not an exhaustive study, and really just the beginning of a more in-depth analysis of bio-based consolidants, it provides insight into design processes to enable more appropriate decision-making related to the environmental footprints of designed bio-based consolidants going forward.

Q/A:

Margrethe Felter: Where do you start when you are choosing your biobased consolidants? Which starting point and which chemical you choose and then you start all your extra.

Zarah Walsh-Korb: It's usually whatever the problem is. I always go to try to chitosan as the first choice. In the first case it was iron saturation, so we needed to look at functional groups that would chelate the iron. Then we needed to see what sort of functional groups were available. And we picked these chitocels and then we had to look and see how we would back them on to end and what terminal groups they had that would allow us to stick them onto some polymer and then basically the selection made itself. We had to make it easy, functionalization. So there were only a few options and chitosan, and with one of them. And it's so cheap and readily available. In the other case we actually started with polyhydroxybutyrate, poly-3-hydroxybutyrate because of its mechanical properties, because that's what we wanted for the bone consolidation, but we ended up adding in chitosan towards the middle of the project because the manipulation was just too energy intensive. We thought and have to it diluted down a little bit to try and maintain the properties.

Angeliki Zisi: How many of you and your team exist?

Zarah Walsh-Korb: At the moment it is just me. When I was in Strasbourg, we were five. I had a team with four students and me, that was great. And now I'm on my own.

Angeliki Zisi: And in Europe? Do we have any in other continents or do you feel lonely? Are other people doing this sort of work?

Zarah Walsh-Korb: I'm not alone in the world. There are some other people there. There is a group from Warwick in the UK also doing some work looking at polymers derived from pine extract. They're looking at some interesting polymers. There is definitely work going in this direction, maybe not so much focus on polysaccharides more on using chemicals derived from tannage. Of course, there's also Hartmut Kutzke with the lignin derivatives

Angela Middleton: Did you say what you're proposing the first material you introduced to be used as a consolidant for? So, the second one, the hydroxylapetite for bone. But what was the 1st application?

Zarah Walsh-Korb: The first one we used when we started off trying to make like actual wood consolidant that would go into the body of the material, but we had issues with basically filtering, cell filtering, because it bound the iron so well. It did exactly what we wanted, but because of that and its mechanical properties it started to get really thick. And then it wouldn't go into the wood. So, we started to use it as a surface cleaning to remove and surface accretions of iron from the surface of dagger handles and things like.

Morgan Creed: Has the reversibility of the two new consolidants been tested yet?

Zarah Walsh-Korb: No.
Jennifer Wakefield: More of a note. I'm also investigating polysaccharides. My concern is future analysis as the material is so similar to that of wood. There is compound specific isotopic analysis available now but it is still a concern of mine. I feel it is an area that requires discussion and consideration.
Zarah Walsh-Korb: Yes, this is actually a massive issue and it's kind of another reason why like chitosan so much because chitosan has a amine group on it. And cellulose doesn't and so you can tell where the chitosan is and where the cellulose is. With the first material we did some studies with the high resolution infrared and we actually had to go to Shincatron for this, but it seems like IR has kind of caught up in the meantime. So, you can get some interesting results from benchtop IR, but we wanted to look quite deep in the wood and we did this high resolution infrared and we could clearly see where the chitosan material was and where the cellulose was. Because of this amine group, they followed the amine in the material and they were able to tell the difference so this was actually. It's kind of why chitosan is so interesting for these applications. Because you can't identify them and tell the difference from cellulose.

Lifetime Achievement Award Recipients

David Grattan

Fig. 6: David Grattan's Lifetime Achievement Award celebrations in Ottowa hosted by ACO Kate Sullivan (photo David Hanington).

David Grattan has had a profound influence on the development of the treatment of waterlogged wood and spent most of his working life at the Canadian Conservation Institute. He was one of the pioneers in the field of conservation of waterlogged wood. His research, published in articles and books, has for many years been standard texts for conservation students and researchers looking for new topics to explore. Despite the fact that he has been retired for more than 10 years he still follows the Group's work. Even though it may not be timely, it is highly appropriate that we should recognise and celebrate his work.

In 1981, David started his involvement in ICOM by co-hosting the first Waterlogged Wood Working Group meeting in Ottawa as a working group within ICOM-CC. Shortly after that Meeting he became the coordinator of the group and served two terms. In 1996 he was elected Chair of the Directory Board for ICOM-CC, a position he held for two terms until 2002. Over the years David published many papers and book chapters, and edited several ICOM-CC conference proceedings and CCI Symposium publications. David laid the foundations for the vibrant conferences and published conference publications that the WOAM Working Group enjoys today.

David was in the forefront of research into the treatment of waterlogged wood when few treatments options existed and he was instrumental in understanding how the treatments actually worked. His distinguished career started with the WWWG of ICOM-CC where he had a leadership role in getting the group going and whose influence helped to form the working group we have today.

Kristiane Strætkvern, National Museum of Denmark

Fig. 7: Kristiane with her Lifetime Achievement Award (photo I. Hovmand).

Kristiane is described by a proposer as 'an excellent communicator, and is therefore a gifted and successful proponent for our field, skills which she has been able to take to the highest levels within the international ICOM community. As a colleague, she is extremely approachable, friendly and fun to work with, and very supportive of others. She is very well-organised, but at the same time flexible and open. She inspires respect and admiration and simply makes you want to do your best.'
Kristiane graduated in Conservation from the Royal Danish Academy and is currently project leader at the Danish National Museum. Due to her years of working in the section of conservation of waterlogged organic objects at the Danish National Museum, Kristiane has enormous practical skills: she has been involved in several large complex conservation and exhibition projects of boats and ships. Her enthusiasm for archaeological and organic materials, her commitment and her organisational skills are particularly valuable.
During her career, Kristiane has served 3 terms (2002-2005, 2005-2008 and 2008-2011) as coordinator of this ICOM-CC working group. She then became a member of ICOM-CC's directory board (2011-2014) followed by two terms as chair (2014-2017 and 2017-2020). She has until last year been the spokesperson for the International Committees of ICOM. She been involved in planning and executing several WOAM Interim meetings including the Interim Meeting in Copenhagen in 2004 as well as the 50th fiftieth ICOM-CC anniversary Conference at the 18th Triennial Conference, Copenhagen, Denmark, in 2017. Her latest conference achievement was the ICOM-CC Triennial in Beijing in 2021, which took place virtually because of the Covid-pandemic.

Dilys Johns, University of Auckland in New Zealand

Fig. 8: Dilys Johns with her Lifetime Achievement Award (photo Dilys Johns).

Dilys has consistently reminded us that artefacts are our links to the people who shaped and used the objects and perhaps more importantly about our obligation to the present day communities as the custodians of the objects. In 1987 she instigated and set up a unique, national facility for conservation in her home country.
One proposer writes:
Dilys has been a contributing member of WOAM for many years and served as an ACO for nine years (3 terms). Her focus on the conservation of waterlogged wood in the context of New Zealand has led her to a deep understanding of the material and has helped her to create ties to the archaeological community that have extended conservation's reach and led to a number of important scholarly contributions.
Her use of satellite treatment facilities to maintain those connections and to reinforce the connections of the objects to the places and peoples where they were used and found has been inventive and inspirational and serves as a model for all of us when planning the conservation of materials from indigenous or otherwise marginalised communities.
Perhaps Dilys' most important contribution to the WOAM community has been to continually remind us of the social value of the material we care for, rather than merely its material, scientific or archaeological values. Her early insistence on the use of Maori terminology reminds us of the connection between the objects we treat, their makers and the modern community.

Bursary Recipients

We were able to give bursaries to 4 emerging conservators:

Fig. 9: Evangelia Tzavela, Greece (photo I. Hovmand)

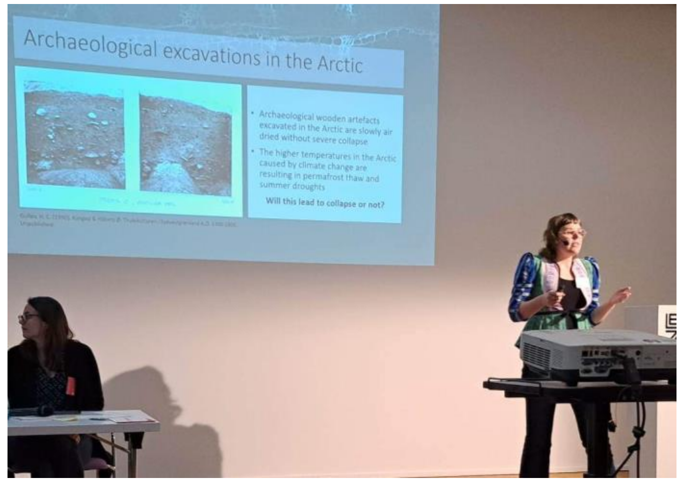

Fig. 10: Nanna R. Lauridsen, Denmark (photo L. N. Mikkelsen)

Fig. 11: Lasse N. Mikkelsen, Denmark (photo N. R. Lauridsen)

Fig. 12: James Harvie, UK (photo I. Hovmand)

Official newsletter of the Working Group specialised in Waterlogged Organic Archaeological Materials from the International Council of Museums Committee for Conservation (ICOM-CC).

Editors
Mags Felter, Ida Hovmand

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