Saving Oseberg Phase II
Annual Report 2017

UiO : Kulturhistorisk museum

Version	Date	Authors	Rationale
1	08.05.2018	Louis Boumans, Fabrizio Andriulo, Susan Braovac, Guro Hjulstad, Jeannette Łucejko, Caitlin McQueen, Eleonora Piva, Malin Sahlstedt, Calin Steindal	First version

Saving Oseberg Phase II Annual Report 2017
Saving Oseberg Team
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University of Oslo – Museum of Cultural History
Project 000208 Saving Oseberg
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0 Introduction

In the course of the first year, the SO-II team worked out a Project Plan document with an Annex 1 [REFS] listing the tasks and deliverables in more detail. Both documents are updated regularly as needed. In this report, tasks and achievements are presented in the same order as in the Project Plan, Annex 1 (Saving Oseberg Team, 2017b).

An important part of the work done in 2017 consisted of finishing tasks that had started in SO Phase I. This concerns complementing chemical analyses of alum-treated wood as well as reporting on technical and organizational aspects of SO-I.

Figure 1 lists the staff members who worked in the project in 2017, as well as the staff planned for the remainder of the project.

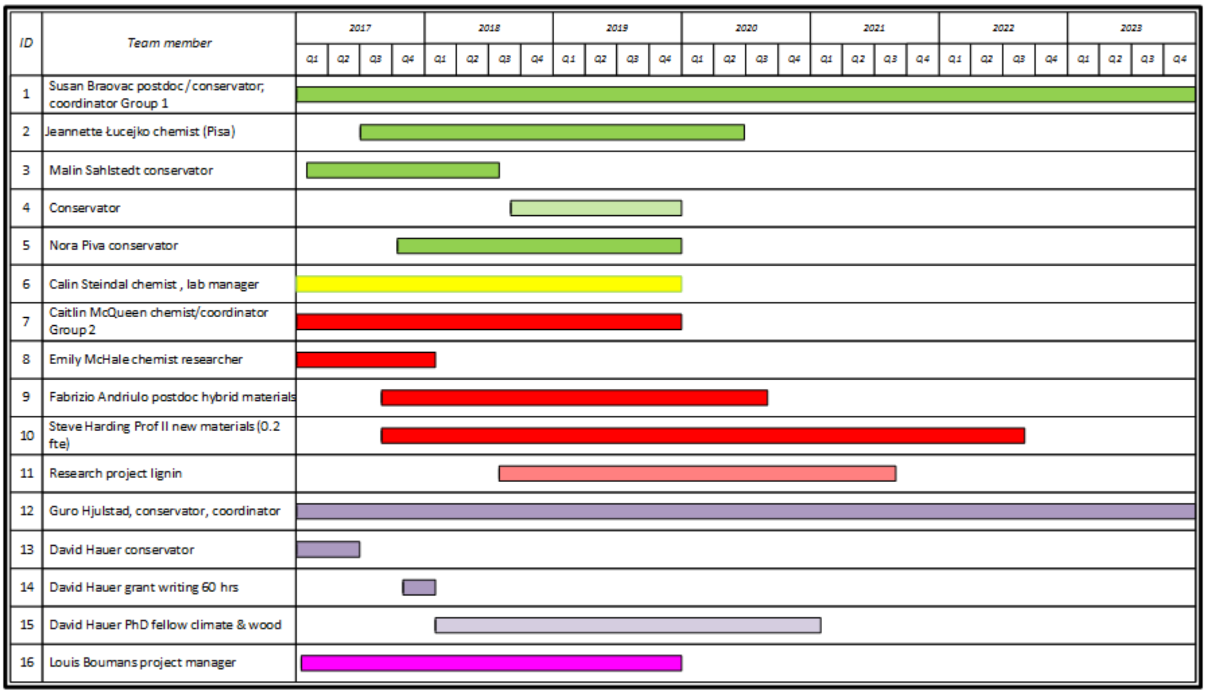

Figure 1. Staff contracts in Saving Oseberg Phase II.

1 Continuing chemical characterisation and research

1.1 Iron and linseed oil investigations

Results of the chemical analyses of 'less complex' alum-treated wood without iron rods or nails and without linseed oil coating was largely carried out during SO Phase I and finished in the first months of SO-II. The results were reported in two reports: *Saving Oseberg January 2013–September 2016 Technical Report, Part 1: Analyses and characterization of alum-treated wood without other additives* (Łucejko et al., 2017; 114 pp.), and more succinctly in the *Saving Oseberg Phase I Report on Scientific Results 2013–2016* (Saving Oseberg Team, 2017a; 33 pp.). Conclusions on chemical characterisation of the 'less complex' wood are repeated here:

> "Alum-treated wood from the Oseberg displays extensive loss and degradation and in particular depolymerisation and oxidation of wood polymers, extreme deterioration of cell walls and high levels of sulphuric acid that have not been observed in non-alum-treated samples from Oseberg.
>
> Overall the distribution of the inorganic components in alum-treated wood samples is variable and does appear to correlate with the degree of wood degradation.
>
> These results strongly support alum-treatment as the major cause of the poor condition of the Oseberg artefacts.
>
> Alum itself decomposes in hot aqueous solutions, such as those used in treatment, to form alunite, mercallite and sulphuric acid, which have been observed in varying amounts in the wood samples. So far there is no convincing evidence that these compounds form post-treatment.
>
> Fluctuating RH conditions causes redistribution and potentially changes in composition of the inorganic salts, however alum salts themselves did not show moisture uptake.
>
> The alum in the wood is not 100% potassium alum, as originally thought, as it also contains significant amounts of ammonium alum. Therefore the properties and reactivity of ammonium alum needs to be considered in addition to those of potassium alum in any new model studies performed.
>
> There is evidence that alum and/or its decomposition products react with iron joiners to form new salts that migrate into the wood. Although such iron salts caused mechanical damage to the wood in some cases, it is still unclear whether they pose serious chemical concerns." (Saving Oseberg Team, 2017a: 11-12)

A complementary report on the chemical characterisation of complex wooden objects is planned for June 2018 (Deliverable 1.1.1). However, major parts of that work were already finished and published. Analyses of alum-treated wood with iron parts and/or linseed oil continued in 2017. Results of the investigations into metal compounds were published in McQueen et al. (2018). From the abstract:

> "We have found that corrosion of iron rods used in reconstruction has formed iron(II) sulfates, which have migrated into the alum-treated wood to form sulfates containing combinations of potassium, aluminium, iron(II) and iron(III) cations. Reactions of alum were also evident from the presence of alunite in some samples. Areas with significant abundances of zinc sulfates, zinc sulfide and elemental sulfur were also detected."

Findings on the effect of linseed oil varnish are published in a second paper (Lucejko et al., 2018). From the abstract:

> "The results showed that, although the wood was highly depleted of carbohydrates, it was better preserved than previously analysed Oseberg artefacts not treated with

linseed oil. Results from GC/MS and HPLC-ESI-Q-ToF suggested that the linseed oil played a mitigating role towards wood degradation. The behaviour of the lipid material, more oxidized on the wood surface than in the core, was opposite to that usually encountered in archaeological wood, suggesting a selective oxidation of the oil."

1.2 Ammonium alum

A method to quantify the amount of ammonium in alum-treated samples using FTIR spectroscopy has been developed and performed on a number of samples. A report on the presence and consequences of NH_4-alum in Oseberg artefacts and effect on pH by heating NH_4-alum solutions is planned for June 2018 (Deliverable 1.1.2).

1.3 Understanding acidity

A report on assessing acidity of Oseberg samples by titration and pH has been drafted and should be finalised soon (Deliverable 1.1.3). The conclusions from the present draft suggest that the presence of aluminium in these samples is a complicating factor, limiting the amount of useful information that can be obtained from titrations and pH measurements. Though possible, it is not clear that further investigations would help elucidate matters, and it would certainly be time-consuming and require several more well-characterised samples. Therefore, further titration experiments are not planned.

1.4 Carbohydrate degradation patterns

In accordance with recent studies [1, 2] which investigated the use of aluminium-based compounds such as alum ($KAl(SO_4)_2 \bullet 12H_2O$) and aluminium sulphate ($Al_2(SO_4)_3$) as a catalyst in conversion of sugars into more simple furans, alum and aluminium sulphate result in dual acidic materials, containing Lewis and Brønsted acidic sites, able to catalyse the reactions of isomerization and dehydration of saccharide materials like glucose or cellulose. This contributes to explain the drastic degradation conditions of alum-treated woods in the Oseberg collection, where the holocellulose content is almost absent.

We are investigating aspects of carbohydrate deterioration caused by the alum salt during treatment (i.e. 24 hours in hot solutions). This will give further insight into initial degradation mechanisms in the wood, which in turn are related to the rate of decay studies. Samples are naturally degraded tissue papers from Lund and Oslo, which had been used to pack alum-treated objects, as well as model paper samples prepared in 2009, which have never been published. The fresh and archaeological wooden samples treated with alum and sulphuric acid were also investigated.

[1] D. Gupta, E. Ahmad, K.K. Pant, B. Saha, RSC Adv., 7, pp. 41973–41979, 2017.
[2] L. Zhou, H. Zou, J. Nan, L. Wu, X. Yang, Y. Su, T. Lu, J. Xu, Catalysis Communications, 50, pp 13–16, 2014.

1.5 Chemical markers of wood degradation

The method for the detection of markers is under development. The idea is to combine the separation power of the high pressure liquid chromatography (HPLC) with mass spectrometry in order to identify the separated compounds.

1.6 Oxygen consumption

Data is being collected for second round of experiments focussing on alum-treated wood with different levels of iron and more of a range of alum-treated archaeological pieces from Oseberg. An overall report of both rounds of experiments is planned for December 2018 (Deliverable 1.2.1).

1.7 Alum stability

To investigate the effect of relative humidity (RH) and temperature (T) on the stability of alum, samples of potassium and ammonium alum as well as alum-treated fresh birch and Oseberg wood were subjected to different T-RH regimes, and analysed by X-ray diffraction. These experiments are finished in 2017, and indicate that alum crystals are stable in normal climate conditions, but that $KHSO_4$, a decomposition product from alum treatment found as a minor component in several objects, is very sensitive to small T and RH changes. This work is documented in report *D1.3.1_report_on_XRD_studies_of_alum_20180131.docx*, which serves as the basis for a journal publication.

1.8 Rate of decay study

To study the rate of decay of alum-treated wood, samples of wood treated with alum between 1880 and 1940 have been collected from museums in Lund and Copenhagen. These samples will be compared so as to compare to Oseberg wood and fresh and archaeological wood treated in 2009 and 2012. Non-destructive chemical analyses of these samples have almost been completed in Oslo, and samples will be sent further to Pisa, where they will be submitted to destructive analyses. A meeting among those involved is planned at the end of May, 2018, to compare results so far, and make decisions about the most appropriate techniques for analysis in Pisa.

cf. ‘RATE OF DECAY working document.docx

2 New materials

2.1 Hybrid Materials of consolidants + $Ca(OH)_2$ nanoparticles

Postdoc Andriulo started his project in August 2017, and delivered a detailed project description (D2.1.1).

Hybrid materials for non-aqueous treatment of alum-treated wood are being developed. The consolidant chosen for the treatment is Tetraethyl orthosilicate (TEOS). This material is highly brittle upon drying, causing cracking due to high capillary pressure (according to Young-Laplace equation). It is therefore necessary to add a flexible backbone to the consolidant in order to counteract its brittleness. Thus, the systems developed are composed of TEOS in conjunction with Poly(dimethylsiloxanes) hydroxy terminated (PDMS-OH). The flexibility is improved by introducing PDMS-OH in quantities below 30% by mass. The systems are further improved with the addition of a de-acidifying component (nanoparticles $Ca(OH)_2$). The amount of nanoparticles necessary is still being tested.

The systems are currently in development phase and only lab tests have been performed. Retreatment of archaeological wood with the finalised systems are planned to be carried out in 2018.

2.2 Lignin-based consolidants

As McHale delivered her thesis within three years, her project was extended in 2017 with a Completion Grant. However, her thesis needed major revisions, and submission of the new version is planned for April 2018. The citation below is from the abstract of the 2017 draft version of the thesis.

> "A range of conditions for the synthesis of lignin-like oligomers, namely dehydrogenated polymers (DHPs) from isoeugenol has been investigated. The conditions which provided a DHP most suited for consolidation were: bulk addition of isoeugenol polymerised at pH 10 with a water soluble copper salen catalyst and a reaction time of five days. These conditions gave a DHP with an average molecular weight of 1.6 kDa, as determined by analytical ultracentrifugation (AUC). Analysis by NMR spectroscopy showed that the DHP had a lignin-like structure with β-O-4′, β–β′ and β5′ connections present.
>
> Solutions of this DHP with concentrations of 5, 10 and 20 w/w% in ethyl acetate were found to thoroughly penetrate 1 cm^3 samples of waterlogged archaeological wood (density of 0.146 g/mL, maximum water content of 620%) after 14 days of impregnation, as determined by FTIR spectroscopy and pyrolysis gas chromatography mass spectrometry. This indicated that DHPs penetrated waterlogged archaeological wood well, although, no impregnation material could be seen by SEM, suggesting that it coats the cell walls upon drying. Samples treated with the DHP were found to shrink considerably less in volume (25-40%) than untreated samples when air dried (75-85%), suggesting consolidation. SEM analysis confirmed that they were consolidating the wood, providing enough strength to maintain cell shape.
>
> In order to avoid the use of organic solvents, and reduce the environmental impact and risk of the treatment, *in situ* polymerisation of isoeugenol was investigated. Polymerisation of isoeugenol with a copper salen catalyst *in situ* was found to be unpredictable, with long reaction times needed and dimers and trimers formed. The *in situ* polymerisation of vanillin with horseradish peroxidase (HRP) was also investigated but it was found to not polymerise. However, the *in situ* polymerisation of isoeugenol with HRP showed promise. The formation of the oligomeric/polymeric materials within the wood following this reaction was determined by FTIR spectroscopy. The oligomers remaining in solution were characterised by FTIR and NMR spectroscopy as well as by AUC, which showed that they had an average molecular weight of 0.4-0.9 kDa and a lignin-like structure rich in the β5′ moiety." (McHale, 2018: i-ii)

A student in conservation studies, Alice Søstrand, set out to perform a treatment experiment with McHale's lignin-like polymer in order to assess whether it reduces shrinkage of archaeological wood. Difficulties arose in reproducing the synthesis at a large enough scale. Some experimental work was nonetheless carried out, and a report by Søstrand is expected in the form of her master's thesis in the course of 2018.

The SO-II project is currently considering ways to continue the research on lignin-based wood consolidants in collaboration with external research partners.

2.3 Silane-based consolidants

A non-aqueous treatment using Si-based materials is under testing. Out of selection of four different silanes, triethoxymethylsilane was paired with poly(dimethylsiloxane) (PDMS-OH). The idea is that the silane will act as a coupling agent between wood and PDMS-OH, which will give flexibility to the system. Different formulations, sample types and impregnation methods have been tried. Application to of fresh wood samples does not seem to yield a measureable effect, regardless of impregnation method (immersion at under atmospheric pressure or under high pressure). Preliminary results of the silane treatment applied to laboratory degraded wood show several modification at the sample level: improvement of the cutting profile, minimal size changes and an increase of the rate of deformation. More formulations and a larger array of samples are being currently tested.

NB: D2.3.1 report on preliminary investigations is due 2018-09.

2.4 Chitosan and aminocellulose

SO-II collaborates with the University of Nottingham, where PhD fellow Jennifer Wakefield investigates the application of chitosans and aminocellulose for the consolidation of archaeological wood, under the supervision of Stephen Harding. This work is funded by the Engineering and Physical Sciences Research Council (EPSRC).

Chitosan was previously researched in SO Phase I (Christensen et al., 2015). Wakefield used analytical ultracentrifugation (AUC) to determine if the molecular weight may have affected the penetration. The molecular weight was then reduced and the chitosan re-characterised. The next step, now that a chitosan of suitable molecular weight was found, was to make it organic soluble. A few methods were investigated, and finally the addition of silyl groups was chosen and this was scaled up in preparation of the next stage: testing penetration and consolidation on wood. Simultaneously, a water-soluble treatment was also sought, so this reduced molecular weight chitosan was made into a salt and characterized.

Aminocellulose, a molecule similar to chitosan and cellulose, was kindly donated from a lab in Germany. This was again characterised. Modification was attempted to make it organic soluble, but in the end it was decided the modified chitosan would be the organic-soluble option and aminocellulose would be the water-soluble option. Interaction studies have started to see whether aminocellulose would be used in conjunction with PEG and interaction with lignin and modified chitosan is to follow.

In 2018, Wakefield is visiting the SO-II lab to collaborate more closely with the team in Oslo, and to carry out treatment experiments on artificially degraded wood.

3 Retreatment development

Both aqueous and non-aqueous systems will be tested on Oseberg woods. Conservators in Europe generally have most experience with aqueous treatments, as archaeological wood is generally found in a waterlogged state. We have chosen to apply two established methods: polyethylene glycol (3000 and 2000) with freeze drying and Kauramine with air drying.

Non-aqueous methods to deacidify and consolidate the wood require more work, as we don't have a lot of experience with these methods. We are currently testing deacidification using alkaline nanoparticles. We have also chosen a polyvinyl butyral (Butvar B98) for consolidating. Current trials are underway on archaeological wood, which, if successful, will be applied to Oseberg wood.

3.1 Test fragments for retreatment

Oseberg wood fragments for testing different retreatment options have been selected and described. The selection is complete for test of aqueous retreatment methods; some more fragments need to be added for the non-aqueous retreatments. Test fragments have also been selected for the alkaline nanoparticle tests. The fragments are documented in a spreadsheet (D3.1-Test fragments working doc.xlsx), to which further samples and measurements will be added in 2018–2019.

Fragments for retreatment were chosen from a group of objects which had previously been selected as representative of the various condition states in the collection. They were assessed and divided into three categories as low, medium and high risk objects in view of a standard aqueous treatment of desalination in distilled water, PEG / Kauramine impregnation and vacuum freeze-drying / air-drying. The assessment was made by visual inspection and based on experience from previous classification models for retreatment and actual retreatment results for alum-treated wooden objects, where objects without visible signs of degradation fared well through retreatment, while objects with visual signs of highly degraded wood, such as surface flaking/friable surfaces and material loss, were unacceptably changed through material disintegration in retreatment (Häggström et al., 2013; Braovac, 2015). The distribution of test fragments according to risk profile for aqueous retreatment is given in Figure 2.

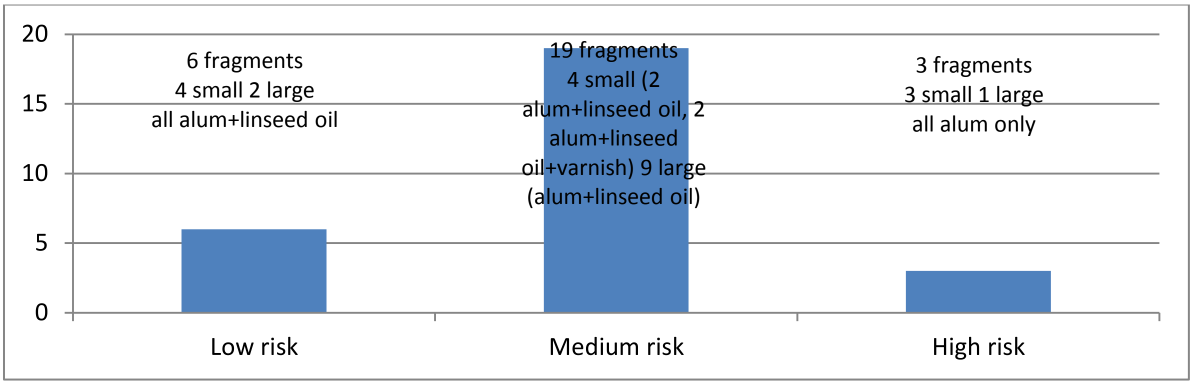

Figure 2. Distribution of test fragments relative to risk group for aqueous retreatment tests.

3.2 Documentation of objects before and after treatment

The methodology is documented in section "3.2 Documentation of objects before, during and after retreatment" in the living document *_1a-Retreatment protocol-CommonWorkingDoc.docx*. The deliverable *D3.2.1 Report on documentation methods and stored data.docx* contains a hyperlink to the aforementioned living document.

The following pre-treatment documentation of Test Fragments involves the following information, which was collected before retreatment:

- Museum catalogue information, wood type where possible, dimensions, weight, original treatment, risk category, visual degradation signs, surface pH and colour measurements. Additionally each object was sampled such that potential future chemical analyses of samples before and after treatment are comparable.
- 3D scanning / photogrammetry (of selected fragments), photography, X-radiography
- X-ray tomographic microscopy of selected samples at the Paul Scherrer Institute (PSI) has been prepared and is planned to take place in April and June 2018.

3.3 Physical support and pre-consolidation during treatment

Screening meshes were used as physical supports during immersion for some fragments that became very weak. That is, the objects were not packaged into foams, such that they were visible throughout the immersion process, which decreases risk of damage. If larger fragments will be immersed in the future, a more rigid support system will be required. Additionally, pre-consolidation using TEOS (tetraethyl orthosilicate) is currently being tested for the most degraded fragments which are unlikely to survive immersion for desalination / impregnation with PEG. This is based on promising results reported in literature (Bisulca, 2014).

3.4 Aqueous treatments

Deacidification/desalination: 28 test fragments were desalinated in successive water baths; water baths simultaneously deacidify the wood.

The method is documented in section 3.4 of the living document *_1a-Retreatment protocol-CommonWorkingDoc.docx*. The deliverable *D3.4.1 Protocol aqueous retreatment with PEG or Kauramin, updated with work progress.docx* contains a hyperlink to the aforementioned living document.

Impregnation using PEG 3000 was undertaken on small fragments. As our supply of PEG 3000 was very low, several tons of new PEG was ordered for the general archaeological conservation of wood at the museum. Thus for larger fragments still under desalination, PEG 2000 will be applied. Results should not be very different from those where PEG 3000 was used. Eight fragments have so far been completely retreated with PEG 3000 and will be documented as planned.

The Kauramine treatment was undertaken by Markus Wittköpper of the Römisch-Germanisches Zentralmuseum, Mainz. He kindly donated his time to retreat two alum-treated Oseberg fragments which had been coated with linseed oil. The fragments were desalinated in Oslo and then given to Wittköpper for further treatment. In Mainz the fragments were scanned in 3D before and after the retreatment. Similar fragments have also been impregnated with PEG 3000. The treatment results will be compared.

3.5 Non-aqueous treatments

Removal of alum salts (desalination) will not be undertaken on test fragments undergoing non-aqueous treatments. The aim is to deacidify using alkaline nanoparticles ($Ca(OH)_2$) suspended in isopropanol. Four test fragments are currently being tested. The application methods considered are by drop application and by immersions. Long-time stability of nanoparticles with alum is also being investigated by Raman, SEM, and XRD.

The polymer Butvar B98 was chosen as a test consolidant for non-aqueous treatments. It has been used on dry wood previously with good results. See for example Schniewind (1990) and Spirydowicz et al. (2001). This work has been started on archaeological wood using toluene. The final solvent type will be decided upon as work proceeds.

New materials for non-aqueous treatment (lignin, silane, nanocomposites, etc) are not yet ready for Oseberg wood.

3.6 Development of methods for the evaluation of retreatment

Mechanical strengthening, dimensional change and chemical stability are the most important parameters to evaluate the success of a retreatment, but the first two are challenging. Mechanical tests for evaluation of a conservation treatment on wood are not well-developed, and so, we are developing our own using the fruit penetrometer, the tape test, and the shake test. So far work has focussed on the fruit penetrometer.

Dimensional changes on irregularly shaped fragments are best documented digitally using 3D-scanning and photogrammetry. The 3D scans are time-consuming, so we applied this method to only a few fragments.

Photogrammetry was thought to be a more effective, less resource-demanding technique. However, the use of photogrammetry requires expertise not currently present in the SO-II team. In 2017, the SO-team did not succeed in mobilising sufficient expert support from other museum staff. In 2018, we need to find a solution in the form of a workable division of labour between the SO conservation scientists and the photographers at the museum. Part of this solution can be one of the conservation scientists dedicating time to learning photogrammetry skills. However, this will requires resources like course materials, and less time can be spent on other research activities.

Chemical stability will be monitored by pH measurements, but other more advanced methods, such as Py-GC/MS, IR, Raman, XRD, may also be relevant and will be used if necessary.

3.7 Standard degraded wood samples, archaeological waterlogged samples

Artificially degraded wood for testing purposes was produced by means of acid and base treatment of fresh birch staves (so-called *pinnekjøttpinner*). The method is documented in the file *_1a-Retreatment protocol-CommonWorkingDoc*, and in a separate report (which includes figures), *D3.7 Standard degraded wood-w figures*.

Generally this method is still under development to fine-tune different parameters, but so far about 50 18 cm long staves have been degraded. The density of the degraded samples ranges from 40–55% of the initial density of the wood. This degraded wood is currently being used as test material in studies of silane consolidants and for aminocellulose and chitosan. They are also being used to develop mechanical testing using the fruit penetrometer.

4 Decision model and retreatment protocol

This work is planned to start in the second half of 2018.

5 Preventive conservation

The conservators working on dust, lighting, climate and support systems have also been involved in planning for the new Viking Age Museum at Bygdøy. This work is closely related to the preventive conservation work in Saving Oseberg II.

5.1 Dust issues

Dust samples was collected in the Viking Ship Museum at 14 sites with 30 day intervals and the amount of dust accumulated was expressed as percent area coverage by using digital image processing (ImageJ).

A set-up to analyse the airflows in the current Viking Ship Museum was discussed and worked out with the specialised company Pentiaq (http://www.pentiaq.se/). Two types of tracer gasses are used. Tracer gas A is used to calculate the infiltrated air and tracer gas B is used for tracking the airflow in the museum. The measuring period is 5 weeks. Each week, tracer gas B is moved to a new wing and new samplers are deployed at 20 sites in the museum. Unfortunately, the first set of samplers might have been contaminated and we are now doing control measurements. A new measuring period will be executed in September when the heating system in the museum is switched off.

The research on dust accumulation is conservator Guro Hjulstad’s research assignment for obtaining her master’s degree at the UiO, conservation studies. The final report will be delivered in the course of 2019.

5.2 Light

A first set of time-lapse photography of the sun’s light path on the Oseberg and Gokstad ship has been executed.

5.3 Indoor climate

A report of the 2017 data collection for temperature and relative humidity is expected April 2018.

Documentation and conservation large artefacts: This work is planned to start in 2019.

A PhD project on the effect of indoor climate on three-dimensional changes of large wooden artefacts was prepared in the second half of 2017. Three applicants were interviewed. The successful candidate, David Hauer, started in February 2018, and was enrolled in the PhD program of the Faculty of Humanities. Supervisors: Prof. Dr. Francesco Caruso, Conservation Studies, IAKH, UiO; Prof. Dr. Kristofer Gamstedt, Department of Engineering Sciences, Applied Mechanics, Uppsala University;

Prof. Dr. Geir Vestøl, Faculty of environmental science and management, Norwegian University of Life Sciences.

An elaborate project plan was delivered as part of the application procedure. An updated version will be delivered to the Conservation Studies department.

5.4 New support systems for Viking ships

After long and meticulous preparations, the first time weighing of the Oseberg ship was finally carried out in February 2018. For this purpose, 68 load cells were mounted under the ship's keel and the vertical supports under the hull. The final total weight was 4,219 kilos.

MCH's communication officers have been very successful in attracting public attention with a competition to estimate the ship's weight (https://www.nrk.no/kultur/vikingskip-veies-for-forste-gang-1.13879268), and a long article in *Aftenposten A-Magasinet* December 2017 (https://www.aftenposten.no/amagasinet/i/KEkeG/Kunsten-a-flytte-et-vikingskip).

6 Project Management

6.1 Day-to-day management

Day-to-day management by the project manager proceeded as planned with almost weekly consultations with head of department Torunn Klokkernes, representing the project owner.

Relatively much effort went into hiring of new team members, with support of the museum's HR department:
- Malin Sahlstedt, conservator from 1 Feb 2017–31 May 2018 (recruitment process in 2016)
- Malin Sahlstedt, conservator, temporary contract 1 Jun–30 Jul 2018.
- Stephen Harding, Prof. II 0,2 fte from 1 August
- Fabrizio Andriulo, postdoc hybrid materials, from 15 August 2017
- Eleonora Piva, conservator, from 16 October 2017
- David Hauer, 60-hour contract for proposal writing, November 2017–January 2018
- David Hauer, PhD fellow preventive conservation, starting 1 February 2018

Guest researchers in 2017:
- Amandine Colson, Deutsches Schiffahrtsmuseum, Bremerhaven, working on 3D imaging of deformation in museum ships; exchange funded by DAAD.
- Alice Søstrand, master's student at IAKH, UiO, carried out experiments at the SO-II lab under the supervision of McHale.
- Jeannette Łucejko, project collaborator in Pisa, was registered as a guest researcher of UiO to facilitate her access to the university's facilities.

Collaboration agreements:
- UiO MCH with University of Pisa, covering the work of Jeannette Łucejco, signed 17 Jan 2017;
- UiO MCH with CSGI (Center for Colloid and Surface Science), University of Florence, covering collaboration on Andriulo's research on the application of alkaline nanoparticles, signed 11 Dec 2017.

Letters of support in connection with grant applications were sent to Dr. E. Platania (NFR) and A. Colson (DAAD). Both agreements with external partners and support letters are archived in ePhorte 2017/2276.

6.2 Reporting

Reporting: Seven one-page status reports were sent to the museum board in 2017. In addition, Saving Oseberg Phase I was concluded with an administrative report (Klokkernes and Boumans, 2017) and a technical report (Saving Oseberg Team, 2017a). The R&D project (FoU) with Statsbygg on 3D scanning and deformation monitoring of the Viking ships, carried out in 2016, was likewise concluded with a technical and financial report (Øya et al., 2017). An extensive technical report was written on the chemical characterisation of alum-treated wood without further additives (Łucejko et al., 2017).

In addition to reports, a Project Plan was written in two parts: an overview of the whole project, and a document describing in more detail the tasks, the time planning, and documentation of progress in deliverables (Saving Oseberg Team, 2017c; Saving Oseberg Team, 2017b). The planning documents are versioned and the latest version is presented at each meeting of the Steering Group.

All reports and planning documents are archived in the university's archiving system ePhorte under 'saksnummer' 2017/6982.

6.3 Meetings

Team meetings were held almost every week, usually with participation of the team members in Pisa and Nottingham through video link. The SO-II project manager had almost weekly meetings with the head of the department of Collection management, representing the project owner.

The Saving Oseberg Steering Group (SG) was officially established 5 May 2017, and meetings with the SG, the project manager and the head of department were held in June, September and November. Business papers of the meetings are archived in ePhorte 2017/5406.

A 'focus meeting' on chemical characterisation of the Oseberg wood was held in May 2017.

The SO Reference Group (RG) was established for Phase II, largely continuing from Phase I. No RG meeting was held, but RG members were informed about the progress through sharing of reports, plans and scientific publications.

6.4 Grant applications

The University of Oslo has funds for the strategical recruitment of scientists who will help develop a research field. SO-II successfully applied for these funds covering Prof. Stephen Harding 0.2 fte position as Prof. II for two years, including salary and research costs (620 400 kr). As a result, Prof. Harding was appointed in a five-year 0.2 prof. II position starting August 2017. He will focus on the development of polymer materials for the conservation of archaeological wood.

The section Conservation Management was granted one of the museum's PhD fellow positions to be part of SO-II, preventive conservation, to do research on museum indoor climate and its effect on the deformation of large wooden objects. David Hauer started in this position in February 2018. The research training is managed by the Department of Archaeology, Conservation and History, Faculty of

Humanities. Salary and research costs are managed by the MCH, but are separate from the SO-II preventive conservation project 000286.

From November 2017 to January 2018, Boumans and Hauer worked on the first stage of a two-stage H2020 application for an Innovation Action grant in Preventive Conservation. This proposal, 3DEMON, was concerned with the development of new products and services for monitoring and preventing deformation of large wooden objects in museums. UiO-MCH coordinated this application; partners included the University of Uppsala and other museums housing historical ships. In addition, UiO was partner in another application responding to the same call for proposals: ACTIVISM. That proposal dealt with active vibration damping techniques, and was coordinated by the Cultural Heritage Agency of the Netherlands. This work was supported by UiO funds (prosjektetableringsstøtte, aka PES2020). Unfortunately, neither of the applications passed the evaluation of the first stage. However, we expect that this work will benefit future grant applications.

6.5 Financial report

In the course of 2017, a new project number (000286) was created to distinguish the finances of the preventive conservation project from the alum project (000208) in a more transparent manner. Table 1 shows the expenditures of 2017 compared with the budget for this year. Overhead costs of the last four months were not booked in 2017, and will instead be booked in 2018. The reservation for this is shown in the right-most column of Table 1.

Table 1. Financial report SO-II projects 000208 and 000286. The second-last columns shows the expenses in 2017; the cost items where spending deviated considerably from the planning are highlighted in yellow.

Sum of Beløp Sted	 Tiltak	Budsjett 2017	Regnskap 2017	reservation OH 2017
000208 Saving Oseberg	000888 Avregning/overføring	-2314	-2314	
	120701 Work package 1/Arbeidspakke 1	-10000	-10000	
Emily	730058 SO Focus topic 3b -PhD	35	69	
Susan	730059 SO Focus topic 3a-Post doc-kons	1026	943	
Calin	730076 SO II - Forsker - Gruppe 1 og 2 Analyse og Lab	930	826	85
Caitlin	730077 SO II - Forsker - Gruppe 2 - Uorganisk	985	883	85
Nora	730078 SO II - Konservator I - Gruppe 1	184	136	30
vacancy	730079 SO II - Konservator II - Gruppe 1			
Fabrizio	730080 SO II - PostDoc Nano og nøytralisering	337	280	35
vacancy	730081 SO II - PostDoc Lignin og nye materialer		1	
Steve	730082 SO II - Professor II	-493	-528	15
Louis	730083 SO II - Prosjektleder	1121	955	100
	730084 SO II - Administrasjon SAS	392	392	
	730085 SO II - Drift gruppe 1 og 2, utstyr og laboratorium	1300	406	
	730086 SO II - Samarbeidsprosjekter - partnere	620	7	
	730087 SO II - Samarbeid - Univ. i Nottingham - Drift, etc		54	
	730088 SO II - Forsker - Univ. i Pisa - Lønn, drift og reise	565	555	
	730089 SO II - Referansegruppe	250	160	
	730090 SO II - Sluttseminar, publikasjon		12	
	730091 SO II - Uforutsette utgifter	427	19	
Totalt 000208 Saving Oseberg		-4634	-7146	350
000286 SO-forebyggende	000888 Avregning/overføring	-4663	-4663	
Guro	730093 SO II - FK - Personalkostnader	1424	1094	70
	730094 SO II - FK - Stipendiat - treteknologi, fuktdynamikk & bevegelse			
	730095 SO II - FK - Drift - Støvproblematikk	150	9	
	730096 SO II - FK - Drift - Treteknologi og klimaspesifikasjoner	300	71	
	730097 SO II - FK - Drift - Sikring av store gjenstander	100	73	
	730098 SO II - FK - Referansegruppe	100	51	
	787000 Uforutsette utgifter	-17		
Totalt 000286 Saving Oseberg		-2605	-3364	70
Totalsum		-7239	-10509	

Important divergences from the planning (marked yellow in Table 1) include the lower spending on laboratory equipment and maintenance (cost place 730085) and on external collaboration projects

(730086). The former is due in part to delays in hiring staff, and in part to overestimation of the costs. As for the collaboration projects, the collaboration with NIBIO on Dynamic Mechanical Analysis (DMA) in particular did not start as foreseen, due to technical challenges. The options for DMA work are currently being reconsidered, but some collaboration with NIBIO in this field will take place in 2018–2019.

As for Preventive Conservation, spending on dust research (730095) and wood technology & climate (730096) is postponed to 2018.

The end date of SO-II is 31 December 2019. However, not all existing obligations end that date. The contract of Łucejko in Pisa ends 31 June 2020, and the contract of postdoc Andriulo with UiO continues until August 2020. Harding's position as Professor II with the MCH continues into 2022. Also the planned work on the development of new consolidant polymers may extend beyond 2019.

We are currently starting to plan the work of SO Phase III, starting in 2020, and the transition from Phase II to Phase III in terms of budget and activities. In Phase III, main activities are oriented towards actual retreatment of the Oseberg collection. An updated budget for 2018-2019 will therefore be included in the next version of the Planning document.

7 Dissemination in 2017

Public outreach

SO-II participated in the museum's yearly "Family Day", aka *Turist i egen by* in April with information stands at the Viking Ship Museum, showing various aspects of wood degradation and conservation methods.

Scientific publications

Andriulo, F., Giorgi, R., Steindal, C. C., Kutzke, H., Baglioni, P. & Braovac, S. (2017). Hybrid nanocomposites made of diol-modified silanes and nanostructured calcium hydroxide. Applications to Alum-treated wood. *Pure and Applied Chemistry,* **89**, 29-39. https://doi.org/10.1515/pac-2016-1014

McHale, E., Steindal, C. C., Kutzke, H., Benneche, T. & Harding, S. E. (2017). In situ polymerisation of isoeugenol as a green consolidation method for waterlogged archaeological wood. *Scientific Reports,* **7**, 46481. http://dx.doi.org/10.1038/srep46481

McQueen, C. M., Tamburini, D., Łucejko, J. J., Braovac, S., Gambineri, F., Modugno, F., Colombini, M. P. & Kutzke, H. (2017). New insights into the degradation processes and influence of the conservation treatment in alum-treated wood from the Oseberg collection. *Microchemical Journal,* **132**, 119–129. http://doi.org/10.1016/j.microc.2017.01.010

Zoia, L., Tamburini, D., Orlandi, M., Łucejko, J. J., Salanti, A., Tolppa, E.-L., Modugno, F. & Colombini, M. P. (2017). Chemical characterisation of the whole plant cell wall of archaeological wood: an integrated approach. *Analytical and Bioanalytical Chemistry*, 1-13. http://dx.doi.org/10.1007/s00216-017-0378-7

PhD Thesis

Andriulo, F. (2017). *Nanotecnologie per il restauro di legno archeologico trattato con allume. (Nanotechnologies for the restoration of alum-treated archaeological wood).* PhD, University of Florence.

Posters at conferences

Łucejko, J., Nasa, J. L., F. Modugno, S. Braovac & Colombini, M. P. Protective effect of linseed oil varnish on archaeological wood treated with alum. Non-destructive and microanalytical techniques in art and cultural heritage (poster). TECHNART, May 2-6 2017, Bilbao.

Łucejko, J. J., F. Modugno, Colombini, M. P., McQueen, C. M. A. & Braovac, S. Degradation processes in alum-treated wood from the Oseberg Viking collection: the Saving Oseberg Project (poster). AIAR 2017, 8-10 March 2017, Firenze

McHale, E., Harding, S. & Benneche, T. Branching Out: Using the chemistry of trees to preserve archaeological wood (poster). Analytical Ultracentrifugation Meeting 2017, 2017-07-23 - 2017-07-28, Glasgow.

McQueen, C., Tamburini, D. & Braovac, S. FTIR microscopy for analysis of treated archaeological wood samples. TECHNART 2017: Non-destructive and microanalytical techniques in art and cultural heritage, 2017-05-02 – 2017-05-06.

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Braovac, S. (2015). *Alum-treated wood. Material characterization. A case study of the Oseberg finds.* Doctoral thesis, The Royal Danish Academy of Fine Arts, Schools of Architecture, Design and Conservation.

Christensen, M., Larnøy, E., Kutzke, H. & Hansen, F. K. (2015). Treatment of waterlogged archaeological wood using chitosan-and modified chitosan solutions. Part 1: Chemical compatibility and microstructure. *Journal of the American Institute for Conservation,* **54**, 3-13. http://dx.doi.org/10.1179/1945233014Y.0000000034

Häggström, C., Lindahl, K., Sahlstedt, M. & Sandström, T. (2013). *Alum-treated archaeological wood: Characterization and re-conservation.* Gotland: Riksantikvarieämbetet.

Klokkernes, T. & Boumans, L. (2017). Sluttrapport Saving Oseberg Fase I 2013–2016. Oslo: Universitetet Oslo - Kulturhistorisk museum.

Lucejko, J. J., La Nasa, J., McQueen, C. M., Braovac, S., Colombini, M. P. & Modugno, F. (2018). Protective effect of linseed oil varnish on archaeological wood treated with alum. *Microchemical Journal*, 106-110.

Łucejko, J. J., Tamburini, D., Braovac, S., McQueen, C. M. & Gambineri, F. (2017). Saving Oseberg January 2013–September 2016 Technical Report Part 1: Analyses and characterization of alum-treated wood without other additives. University of Oslo, Museum of Cultural History.

McHale, E. (2018). *Development of lignin-like oligomers for the consolidation of waterlogged archaeological wood.* PhD, University of Oslo.

McQueen, C. M. A., Tamburini, D. & Braovac, S. (2018). Identification of inorganic compounds in composite alum-treated wooden artefacts from the Oseberg collection. *Scientific Reports,* **8**, 2901. https://doi.org/10.1038/s41598-018-21314-z

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Saving Oseberg Team (2017b). Saving Oseberg Phase II – Annex 1: Tasks and Deliverables, v.1. Oslo: University of Oslo – Museum of Cultural History.

Saving Oseberg Team (2017c). Saving Oseberg Phase II Project Plan 2017–2019, v.1. Oslo: University of Oslo – Museum of Cultural History.

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