

The state of degradation of waterlogged wood from different environments

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Abstract: *The state of degradation of waterlogged wood from different environments*

The archaeological waterlogged 10th century oak wood from the Gęgnowskie Lake, as well as 11th century alder wood from Rawka river, are valuable historic relics. The assessment of the state of wood degradation will allow to propose the most appropriate conservation treatment in order to save this cultural heritage.

The aim of the research was to evaluate the degree of degradation of waterlogged wooden objects from two different environments – the lake and the river, by using traditional wet-chemical analysis method. The obtained results clearly show that wood excavated from the lake is better preserved than that from the river bank, which confirms, that the stable, anaerobic conditions in the lake prevent wood degradation, as is in the case of river bank.

Keywords: archaeological wood, wood degradation, waterlogged wood

INTRODUCTION

Waterlogged wood, excavated from lakes or rivers, is often found in a relatively good state. Such an environments promote the restriction of deterioration processes of wood due to the low temperature and low oxygen content in water, which limits the activity of aerobic bacteria, fungi and insects. However, in underwater conditions, the strong activity of anaerobic bacteria can be observed, causing decomposition of main polysaccharide wood components, like cellulose and hemicelluloses [Blanchette 2000, Björdal 2002, Tiano 2002]. Waterlogged wood objects usually look relatively unaltered, but the loss of wood substance, caused by cavitation, erosion, scavenger or tunneling anaerobic bacteria, decreases wood density and increases its microporosity and permeability. The physical, chemical and mechanical properties of wood deteriorate, wood structure changes into a spongy substance filled with water, making it strongly susceptible do destruction during excavation and preservation [Pizzo et al. 2010]. The drying process leads to considerable dimensional changes of wooden artefact, weakened cell walls often shrink and collapse, causing numerous crackings [Bugani et al. 2009].

In order to propose an appropriate conservation treatment and method, there is a need to obtain an accurate information about the wood deterioration mechanisms and the state of preservation of archaeological wooden object.

The aim of this study was to compare the state of degradation of waterlogged archaeological wooden objects excavated from two environments – the lake and the river, based on traditional wet-chemical analysis.

MATERIALS

The studied material was waterlogged archaeological oak wood (*Quercus* sp.) excavated from Gęgnowskie Lake, taken from three piles - the remains of the medieval bridge (dating back to the 10th century, plot No 2, pass No III), as well as waterlogged alder wood (*Alnus* sp.), excavated from the Rawka river next to the Sierzchow city, taken from the remains of the wooden platform (probably dating back to the 11th century).

The piles from Gęgnowskie Lake were embedded in the mud at the bottom of the lake and remained under water for the whole time. Both sapwood and heartwood were found on excavated beams. The sapwood zone was largely decayed, very soft, delicate, with a spongy structure. There was a partially degraded, although tougher and more cohesive heartwood zone directly under the sapwood one. The inner heartwood part was characterised by a dark, nearly black colour and a great hardness.

Wooden elements of platform from the Rawka river were partially covered by a layer of wet soil, partially remained in the opened air, moreover they were periodically flooded by river waters.

A part of each excavated wooden elements was milled on the laboratory cutting mill (Pulverisette 15, Fritsch GmbH) to obtain the powder. The powder was sieved and the finest fraction of it (particle size less than 0.5 mm) was examined using wet-chemical analysis.

METHODS

In order to evaluate the state of degradation of waterlogged wood, the traditional wet-chemical analysis was used. The recognition of changes in the percentage content of individual component of wood is allowed by this method, which helps in assessing the nature and extent of wood decomposition.

The chemical analysis included evaluation of the content of main chemical components in the archaeological waterlogged wood samples. Determination of cellulose was performed according to the Seifert procedure by using acetylacetone-dioxanehydrochloric acid [Browning 1967]. Holocellulose were obtained from wood with an acid solution of sodium chlorite by using the procedure described by Browning [1967]. The lignin content was determined according to the Tappi standard [TAPPI 2006]. Solvent extractive components and ash content were measured according to Tappi standards respectively [TAPPI 2007a and TAPPI 2007b].

RESULTS AND DISCUSSION

The chemical composition of archaeological oak wood from Gęgnowskie Lake is shown in Table 1. The obtained results present the percentage content of analysed components concerning the wooden material as a whole, thus the discussion on the chemical composition of wood, expressed in relation to its original weight before degradation, is not possible.

Table 1. The chemical composition of archaeological oak wood from Gęgnowskie Lake (expressed as a percentage of degraded wood dry matter).

Sample number	Substances soluble in cold water [%]	Substances soluble in hot water [%]	Substances soluble in 1% NaOH [%]	Substances soluble in organic solvents [%]	Cellulose content [%]	Lignin content [%]	Holo-cellulose content [%]	Mineral substances content [%]
1	1.8	2.2	18.6	4.2	39.5	25.2	67.1	2.0
2	0.9	1.9	20.2	3.3	39.9	22.2	67.5	1.7
3	1.5	2.3	19.0	3.4	39.6	24.1	68.7	1.9
4	1.1	1.9	19.6	3.6	38.6	24.9	66.2	2.0
5	0.7	2.0	20.3	2.7	38.7	26.2	66.5	1.9

All archaeological oak wood samples showed an average holocellulose content of 67.2%, being subtly lower than the holocellulose content in contemporary oak wood (CO) (70-80%, according to Prosiński 1984). The cellulose content was between 38.6% and 39.9%, similar to contemporary oak wood (38-40%, according to Prosiński 1984). The lignin content was between 22.2% to 24.9% in comparison with CO - 27%, what should be considered only as a natural variation in the content of major components within a species. Summarising, the amounts of the main wood components confirm quite a low rate of degradation of archaeological oak wood from Gęgnowskie Lake.

The content of substances soluble in organic solvents in archaeological wood samples was in the range of 2.7% and 4.2%, compared to 5.9% in CO [Prosiński 1984]. A long period of wood dwelling at the bottom of the lake affected almost complete leaching of substances soluble in cold water. The small amounts of this substances were estimated in archaeological wood between 0.7% and 1.8%, which is about 2-4 times less than in CO [Prosiński 1984]. The content of substances soluble in hot water was between 1.9% and 2.3%, which is much less than in CO (15%, according to Prosiński).

Drawing the conclusions about the state of wood degradation is possible only based on the numerical relationships between the ratios of the individual components: cellulose to lignin (C/L) and holocellulose to lignin (H/L) [Sandak et al. 2010]. In the collected wood samples no reduction of relationships between the ratios of components C/L and H/L were observed and the obtained results correspond to the values for CO (Table 2).

All the obtained results confirm quite a low rate of degradation of 10th century waterlogged oak wood excavated from the lake. Only the initial stage of the wood degradation process can be considered in case of examined objects.

Table 2. The ratio of cellulose to lignin (C/L) and holocellulose to lignin (H/L) of archaeological oak wood from Gęgnowskie Lake and contemporary oak wood (CO).

Sample number	C/L ratio	H/L ratio
1	1.56	2.66
2	1.79	3.04
3	1.64	2.85
4	1.55	2.65
5	1.47	2.53
CO	1.52	2.90

The chemical composition of archaeological oak wood from Rawka river is shown in Table 3.

Table 3. The chemical composition of archaeological alder wood from Rawka river (expressed as a percentage of degraded wood dry matter).

Sample number	Substances soluble in cold water [%]	Substances soluble in hot water [%]	Substances soluble in 1% NaOH [%]	Substances soluble in organic solvents [%]	Cellulose content [%]	Lignin content [%]	Holo-cellulose content [%]	Mineral substances content [%]
1	-	-	33,9	2,6	9,3	67,8	13,1	20,3

The cellulose content in archaeological alder wood was very low and has a value of 9.3%. The obtained result corresponds with the low value of the holocellulose content, which was also very low - 13.1%. Such a low amount of polysaccharides in wood confirms the high degree of degradation of alder wood tissue. The lignin content in archaeological

sample was 25.28%, which is similar to the lignin content in contemporary alder wood (CA), therefore the conclusion can be made that this component did not undergo significant quantitative changes. A long exposure of wood under the specific conditions affected the total leaching of substances soluble in cold and hot water.

Table 4. The cellulose to lignin (C/L) and holocellulose to lignin (H/L) ratios of archaeological oak wood from Rawka river and contemporary alder wood (CA).

Sample number	C/L ratio	H/L ratio
1	0.14	0.19
CA	1.81	2.82

The C/L ratio for the archaeological alder wood was 0.14, which is a 13 times lower than for CA (1.81). The similar situation can be observed in case of H/L ratio - for archaeological alder sample the value was 0.19, which is almost 15 times lower than for CA sample (2.82) [Fengel & Wegener 1984]. Such reduced C/L and H/L ratios indicate a significant decomposition of polysaccharides in wood tissue.

All the above obtained results confirm the advanced process of alder wood degradation. In case of this archaeological site it is worth to note, that the wooden object have not stayed in the same conditions at all times, like oak wood objects from Gęgnowskie Lake. It was periodically exhibited and submerged by water of Rawka river, as well as exposed for variable temperature and humidity, which resulted in rapid degradation of wood tissue.

Comparing the state of degradation of archaeological wooden objects from two different environments - the lake and the river, it must be stated, that the fundamental differences in the degree of degradation result both from the wood species (oak wood is much more resistant to degradation than alder wood) and the conditions under which the wooden objects remained for hundreds of years. Anaerobic, relatively stable conditions in the lake promote to preserve wood almost untouched for a long time, being a suitable place for *in situ* conservation. By contrast, the river bank, only temporarily flooded with water, exposes wood to the significant changes of temperature and humidity, which results in a rapidly proceeded degradation process. Archaeological wooden objects found in such a places should be excavated and properly conserved, to save their historical and cultural value for posterity.

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Streszczenie: *Ocena stopnia degradacji mokrego drewna archeologicznego pochodzącego z różnych środowisk. Dębowe, X-wieczne elementy przeprawy mostowej, zalegające na dnie Jeziora Gęgnowskiego, jak również olchowe, XI-wieczne pozostałości pomostu na brzegu rzeki Rawka, są zabytkami historycznymi. Ocena stopnia degradacji tego rodzaju mokrych, drewnianych obiektów archeologicznych jest, poza aspektem czysto poznawczym, pierwszym i niezbędnym krokiem, jaki należy wykonać, by móc zaproponować najbardziej skuteczną metodę ich konserwacji i w ten sposób ocalić cenne dziedzictwo kulturowe przed naturalnym zniszczeniem.*

Celem prowadzonych badań była ocena stopnia degradacji mokrego drewna archeologicznego, pochodzącego z dwóch różnych środowisk – z jeziora oraz z rzeki. Zakres badań obejmował tradycyjną, tzw. mokrą analizę chemiczną składników drewna. Uzyskane wyniki wyraźnie wskazują, iż drewno pozyskane z jeziora jest znacznie mniej zdegradowane, niż drewno wydobyte z nabrzeża rzeki. Fakt ten potwierdza tezę, iż stabilne, beztlenowe warunki wód jeziora skuteczniej zapobiegają biodeterioracji drewna, jaka ma miejsce w przypadku warunków panujących na brzegu rzeki.

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