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PHYSICAL AND CHEMICAL PROPERTIES OF CONTEMPORARY PINE WOOD (*PINUS SYLVESTRIS* L.) IN CONDITIONS OF A WET ARCHAEOLOGICAL SITE IN BISKUPIN

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SYNOPSIS. Investigations were carried out on the contemporary wood of Scots pine (*Pinus sylvestris* L.) recovered following a two-year period of deposition in conditions of a wet archaeological site in Biskupin. The impact of the natural environment on the examined wood was assessed on the basis of: its infestation by microorganisms, mass loss, selected physical properties and chemical composition. The comparison of the investigated parameters revealed small differences of the examined characteristics of pinewood subjected to the two-year long experiment.

KEY WORDS: wood degradation, microorganisms, chemical composition

INTRODUCTION

Huge quantities of the historic wood from Biskupin have posed a serious conservatory challenge from the very beginnings of the archaeological work on that site. Long-term investigations conducted on the peninsula of the Biskupin Lake resulted in mechanical damage and biological degradation of historic wood tissue. Despite undertaking numerous conservatory attempts (Piotrowska 1999), the achieved results were far from satisfactory. It turned out that the best solution, in accordance with world trends, was to leave the wooden relics under the layer of soil.

The reburial of the excavated wooden remains comprises the re-deposition of archaeological materials under a layer of sea sediments or in the environment of wet peat maintaining the deficit of oxygen (in anoxic or anaerobic conditions) which restricts the growth of bacteria and other harmful organisms (Curci 2006). However, this kind of wood storage requires comprehensive analysis of the conditions in which the historic wooden tissue is to be left as well as continuous monitoring of the site.

Long-term deposition of historical objects is by no means a new idea. First reports describing this method of wood conservation come from 1980s (Jong 1981, Jespersen 1985). These studies comprised, primarily, monitoring of basic environmental parameters of the sites of the re-burial of historical objects. However, real evaluation of the impact of long-term storage conditions of the archaeological wood can be arrived at only by studying changes caused by this type of environment in this raw material. Therefore, only deposition in this environment of wood, both contemporary and archaeological, of recognized properties will make it possible to follow the activities of microorganisms in this particular site (Waddell 1994, Gregory 1998, Powell et al. 2001, Björdal and Nilsson 2003). In the case of investigations carried out so far, the determination of the effect of the environment on wooden objects was limited, to a considerable extent, to the visual evaluation of the degree of their degradation (Gregory 1998) or microscopic observations (Powell et al. 2001, Björdal and Nilsson 2003). The supplementation of the investigations carried out so far with the analyses of physical and chemical properties of wood will allow scientists to compare the progress of degradation processes during the period of its storage. These types of investigations were performed on contemporary oak wood (Babiński et al. 2006) and cellulose material obtained from beech wood (Zborowska et al. 2007) buried in the region of the Biskupin Lake peninsula.

The objective of the performed investigations was to identify microorganisms, evaluate the extent of wood tissue colonization, determine mass losses, changes of selected physical properties and chemical composition of the contemporary pinewood following its two-year storage in conditions of the deposition of Biskupin archaeological wood. The results of the above-mentioned investigations were supplemented with the data from the basic water and soil parameters monitoring.

MATERIAL AND METHODS

Wood of a 99-year old Scots pine tree (*Pinus sylvestris* L.) which grew in the Gołąbki Forest District in the neighbourhood of Biskupin (kujawsko-pomorskie region) was used in the presented experiment. Basic macroscopic characteristics of the examined pine wood are given in Table 1.

Table 1. Macroscopic characteristics of the examined pine wood

Characteristic	Mean value	Minimum value	Maximum value	Standard deviation
Width of annual rings [mm]	1.51	0.42	6.66	0.78
Percentage of latewood [%]	37.63	13.66	57.39	9.18

Preparation and location of samples

Samples measuring 150 × 10 × 10 mm (L × T × R) with annual increments running parallel to the tangential direction were divided into two groups. The samples from the first group (3 batches of 40 pieces) were saturated with water – 10 cycles of 4 hours each at the pressure of 50 hPa and 20 h at the atmospheric pressure. The final moisture content of the saturated samples ranged from 129 to 134%. Samples from the second group (2 batches of 40 pieces) were not subjected to water saturation and their final moisture content was about 12%. Wood samples prepared in this way were left for the period of two years in a layer of wet peat or at the bottom of a pit filled with water both situated in the area of the Biskupin archaeological site. The choice of the site and the place of burial of experimental samples were imposed by the place of deposition of wooden remains of the Łużyce culture from the 8th century BC. The dry and wet samples were left in the wet peat at the depth of 50 and 100 cm, whereas at the bottom of the pit filled with water, only wet samples were deposited (Table 2).

Table 2. Designation of samples, moisture content and places of deposition of pine wood

Samples	Wood moisture content before deposition [%]	Place of deposition
D-50	12	peat, at the depth of 50 cm
W-50	129	peat, at the depth of 50 cm
D-100	12	peat, at the depth of 100 cm
W-100	134	peat, at the depth of 100 cm
W-T	133	bottom of pit filled with water

Monitoring of environment

Throughout the duration of the experiment, the following parameters were monitored at the place of sample deposition: the level of ground water and the level of water in the pit, water reaction (pH), soil temperature and redox potential. The methodology of the performed measurements was presented in another study (Babiński et al. 2004).

Evaluation of the degree of wood degradation

The degree of degradation of pinewood buried for two years at the Biskupin site was assessed on the basis of:

– Microbiological investigations, i.e. identification of microorganisms as well as determination of the extent of external (to the depth of 1-1.5 mm) and internal (to the depth of 3.5 to 5 mm) wood colonization,

– Selected physical properties, i.e. moisture content, maximum moisture content, wood conventional density and longitudinal shrinkage,

– Mass losses,

– Chemical composition, i.e. content of holocellulose, cellulose, lignin, substance soluble in the mixture of alcohol and benzene as well as in cold and hot water.

The performed microbiological investigations comprised the determination of the colonization capability of the examined wood by soil proper bacteria (facultative and obligate anaerobes), actinomycetes as well as yeasts and hyphal fungi. The following microbiological substrates were employed in order to isolate and identify the occurring microorganisms: nutritive agar with/without the addition of 10% de-fibred ram blood, McConkey medium, Bunt&Rovir substrate with the addition of 1% starch and nystatin, King's B substrate, Wilson'Blair's medium, Dubos's medium as well as the medium according to Weimer and Zeikus (with the addition of filter paper as the only carbon source), the substrate for the nitrification bacteria according to Coppier and de Barjac, de-nitrification bacteria according to de Barjac and ammonification bacteria (with Winogradski's salts), N_2 fixing bacteria (medium according to Döbereiner) as well as Martin's and Sabouraud's medium. Cultures of bacteria, actinomycetes and aerobic fungi were carried out in aerobic conditions at the temperature of 30°C. Anaerobic bacteria cultures were conducted using an aerostat (BBL) in the presence of H_2 and CO_2, palladium catalyser and methylene blue as indicators of anaerobic conditions. Cultures of mesophilic anaerobic bacteria were carried out at the temperature of 30°C and those of thermophilic ones – at the temperature of 55-60°C. Api tests of the bioMerieux Company and Bergey's systematics (Manual of Determinative Bacteriology, 2000) were used for the identification of the selected bacterial isolates, while fungal identification was performed employing the systematics developed by Barnett (1960-1965) and Fassatiova (1979).

Wood moisture content was determined by the drier-gravimetric method after drying the samples to the constant mass at the temperature of 105°C. Wood maximum moisture content was determined on the basis of the mass of samples saturated with water many times at the pressure of 50 hPa and the mass of absolutely dry wood. Wood conventional density was determined on the basis of the mass of absolutely dry wood and the volume of the sample in the state of maximum saturation with water determined by the hydrostatic method according to the formula given below:

$$d = \frac{m_0}{V_{\max}} \cdot 1000$$

where: d – conventional density [kg·m^{-3}],
m_0 – mass of absolutely dry wood [g],
$V_{\max}$ – wood volume in the state of maximum saturation with water [cm^3].

Longitudal shrinkage has been defined by measuring the distance between two steel pins inserted perpendicularly into tangential and radial sections of the sample. The pins, 85 mm apart from one another, were hammered into wet wood directly before drying the wood to absolutely dry state. The measurement error is 0.01 mm. Longitudal shrinkage has been calculated according to the following equation:

$$\beta_L = \frac{l_1 - l_0}{l_1} \cdot 100$$

where: β_L – longitudal shrinkage [%],
l_1 – pin distance in wet wood,
l_0 – pin distance in dry wood.

The loss of wood mass left in natural environment for the period of two years was calculated according to the following formula:

$$UM = \frac{m_0 - m_1}{m_0} \cdot 100$$

where: UM – mass loss [%],
m_0 – absolutely dry matter of wood prior to burying [g],
m_1 – absolutely dry matter of wood following a two-year period of deposition in peat [g].

The chemical composition of investigated wood was determined by use all material without division on more or less degraded part, in accordance with the Polish Standard PN 92P/P 50092.

RESULTS

The performed measurements of water levels in the area of the Biskupin Lake peninsula revealed that the samples buried in peat at the level of 100 cm (D-100 and W-100) as well as those deposited at the bottom of the pit (W-T) were all submerged in water during the entire experimental period. On the other hand, wood samples placed 50 cm under the surface (D-50 and W-50) stayed in water during the period from autumn to spring, whereas from May until the end of October, they remained above the ground water table, in the layer of moist peat. The ground water reaction (pH) ranged from 6.27 to 7.32. Higher groundwater reactions – with maximum values of 8.77 – were recorded in the water from the pit. The soil temperature changed in the interval ranging from 1.2 to 20.2°C. The redox potential which ranged from −250 to −150 mV in the examined soil and from −250 to −120 mV in the pit filled with water pointed to the reducing conditions of the experimental environment in which the wood samples were buried.

The wood samples recovered after two years of deposition were characterized by a slightly darker colour in comparison with the control samples. However, no deformations or desorption cracks typical for degraded wood were found in them.

The results of bacteriological investigations of the pine wood samples deposited for the period of two years in anoxic conditions are presented in Table 3 and those of mycological analyses – in Table 4.

Table 3. Colonization of pine wood by facultatively anaerobic bacteria, strictly anaerobic *Clostridium* spp. bacteria and *Streptomyces* spp. Actinomycetes

	Samples									
	D-50		W-50		D-100		W-100		W-T	
	A	B	A	B	A	B	A	B	A	B
Bacillus spp.	+	+	+	+	+	+	+	+	+	+
B. mycoides	+	+	+	+	+	+	+	+	+	+
B. polymyxa	+	+	+	+	+	+	+	+	+	+
Cellulomonas sp.	−	−	−	−	−	−	−	−	+	+
Clonothrix fusca	−	−	−	−	−	−	−	−	+	+
Clostridium spp.*	+	+	+	+	+	+	+	+	+	+
Clostridium perfringens red. *sulphates*	+	+	+	+	+	+	+	+	+	+
E. coli	−	−	+	+	−	−	−	−	+	+
Enterobacter sp.	−	−	+	+	−	−	−	−	+	+
Enterococcus faecalis	−	−	−	−	−	−	−	−	+	−
Nitrosomonas sp.	+	−	+	−	+	−	+	−	+	−
Pseudomonas sp.	+	+	+	+	+	+	+	+	+	+
P. aeruginosa	+	+	+	+	+	+	+	+	+	+
P. fluorescens	+	+	+	+	+	+	+	+	+	+
Proteus vulgaris	−	−	+	−	−	−	−	−	+	−
Sporocytophaga sp.	+	+	+	+	+	+	+	+	+	+
Streptomyces spp.	+	−	+	−	+	−	+	+	+	+

A – external zone (1-1.5 mm), B – internal zone (3.5-5 mm).
*Meso- and thermophilic cellulolytic bacteria from the *Clostridium* genus.

Table 4. Colonization of pine wood by hyphal fungi and yeasts

	Samples									
	D-50		W-50		D-100		W-100		W-T	
	A	B	A	B	A	B	A	B	A	B
Aspergillus spp.	+	+	+	−	+	+	+	+	+	−
A. fumigatus	−	−	+	−	−	−	−	−	−	−
A. niger	−	−	+	−	−	−	−	−	−	−
Candida sp.	−	−	+	+	+	−	+	−	+	−
C. jovanica	−	−	+	−	−	−	−	−	−	−
Fusarium sp.	−	−	+	−	−	−	−	−	−	−
Penicillium spp.	+	+	+	+	+	+	+	+	+	−
P. notatum	−	−	−	−	−	−	−	−	+	+
Rhodotorula sp.	−	−	−	−	−	−	−	−	−	+
Saccharomyces spp.	−	−	+	+	+	−	+	−	+	−
Trichoderma spp.	+	−	+	−	+	−	+	−	−	−
T. viridae	+	−	+	−	−	−	−	−	+	−

A – external zone (1-1.5 mm), B – internal zone (3.5-5 mm).

Both Gram-positive and Gram-negative bacteria differing with regard to their morphological, physiological and taxonomic traits were found in the examined wood samples. The identified bacteria colonized not only the external wood layer – to the depth of 1.5 mm but also its internal part to the depth of 5 mm, irrespective of the fact whether the stored wood was buried dry or wet. The identified bacteria included, among others: facultative anaerobes from the *Pseudomonas, Bacillus, Escherichia, Enterobacter, Nitrosomonas, Sporocytophaga* genera and actinomycetes from the *Streptomyces* genus as well as obligate anaerobes from the *Clostridium* genus. The isolated microorganisms were characterized by the ability to carry out many biochemical processes, such as, among others: fermentation of mono- oligo- and polysaccharides, ammonification, proteolysis, nitrification, de-nitrification, sulphite reduction and production of hydrogen sulphite. Cellulolitic *Bacillus polymyxa*, *Sporocytophaga* sp. bacteria as well as meso- and thermophile bacteria from the *Clostridium* genus capable of cellulose, hemicelluloses and lignin degradation could have been responsible for the decomposition of pine wood. Pinewood samples deposited for 2 years at the bottom of the pit filled with water were found to be colonized even by a wider range of bacterial settlers. Apart from the bacteria mentioned above, these samples were also infected with faecal enterococci *Enterococcus faecalis*, rod-like *Proteus vulgaris*, thread-like *Clonothrix fusca* as well as the cellulolitic bacteria from the *Cellulomonas* genus.

Nitrification bacteria of the *Nitrosomonas* sp., which belong to the so called amonox group, were found to be present in all the examined wood samples but only on their surface layer, whereas de-nitrification bacteria, e.g. from the *Pseudomonas* and *Clostridium* genera were determined also inside wood samples. The observed dark colour of wood samples could have been caused, among others, by the reduction processes of sulphates into hydrogen sulphide and the production of dark-coloured sulphides by the bacteria of *Clostridium* genus. It was further demonstrated that, apart from saprophytic bacteria, also pathogenic as well as conditionally pathogenic bacteria were identified, among others bacteria from *Enterobacteriaceae*, *Pseudomonadaceae* and *Clostridiaceae* genera.

On the basis of mycological investigations it was found that, in anaerobic conditions, the experimental pinewood was colonized by few types of microscopic fungi. It was observed that pinewood samples were colonized during the two-year period of storage more readily when they were introduced into the soil wet. They were colonised, primarily, on their surface by lignocellulosic hyphal fungi from *Aspergillus*, *Trichoderma* and *Fusarium* genera. From the external and internal pinewood surfaces lignocellulosic *Penicillium* spp. fungi as well as yeasts from the *Saccharomyces* and *Candida* genera were isolated. Inside wood samples buried dry, the presence of lignocellulosic fungi of the *Penicillium* and *Aspergillus* genera were determined. Fungi of *Penicillium* spp. and *Rhodotorula* sp. yeasts were identified inside the wood stored at the bottom of the pit filled with water. The internal layer of pinewood samples deposited in the pit with water was completely free of yeasts but was settled by numerous bacteria and only one species of hyphal fungi, namely *Penicillium notatum.* Microscopic fungi colonizing wood belong to saprophytic fungi but some of them can be pathogenic, for example fungi from the *Aspergillus, Trichoderma, Fusarium* and *Candida* genera.

Microbiological investigations on the settlement of lignocellulosic pine substrates and their degradation also allow to determine the degree of succession of microorganisms and their diversity (Kundzewicz et al. 1993, Gajewska 1993, Gajewska 1994, Gajewska et al. 2005, Gajewska et al. 2006). Pinewood degradation depends not only on the types of the colonizing microflora, on their ability for adhesion to the substrate, penetration, infestation but also on, among others, their ability to proliferate in wood, enzymatic activity of strains, degree of their sporulation in very specific conditions of the environment described earlier (refers to: anoxia, low redox potential, temperature and reaction – pH). It appears that the accumulation of sulphides produced by obligate anaerobes of the *Clostridium* genus or by facultative anaerobes of the *Proteus* genus can impede or limit the growth of heterotrophic bacteria and fungi as facultative anaerobes and, by doing so, show pinewood conserving activity.

Table 5 presents physical properties and mass losses of the experimental pinewood. The mean moisture content of the experimental pinewood wood, both the one buried in the dry state (wood with the initial moisture content of 12%) and the wood buried in the wet state (initial moisture content of 132%) after a two-year period of storage in the archaeological site ranged from 124 to 142%. The highest moisture content was determined in the samples deposited at the bottom of the pit filled with water.

The maximum moisture content, which is a sign of the degree of progress of degradation processes, is one of the most frequently determined physical properties of degraded wood (Hoffmann 1982, Babiński 1997, Björdal 2000, Prądzyński and Cichocka 2002). The mean maximum moisture content of the experimental pinewood changed within a very narrow interval of 145 to 151%, with the lowest value determined for wood samples buried in wet state at the depth of 50 cm and the highest one – for the wood samples left at the bottom of the pit filled with water. The comparison of the obtained results with the maximum moisture content determined in the control samples (141%) indicates slight changes of the analysed property. The lack of clear degradation of the wood tissue is confirmed by the values of the conventional density of the examined samples. The lowest mean conventional density determined for wood samples left in the pit filled with water was 462 kg·m^{-3}, while the highest one determined for the material buried in wet state in peat at the depth of 50 cm amounted to 475 kg·m^{-3}. Comparing the above values with the conventional density of the control samples (483 kg·m^{-3}), it can be said that the considered property decreased only slightly.

The physical properties discussed so far allow to differentiate the examined samples from the point of view of the intensity of wood degradation. In comparison with the values determined for the control samples, the greatest differences regarding wood properties were observed in the case of wood samples left at the bottom of the pit filled with water (W-T). Values similar to the initial ones were obtained for wood samples buried wet in peat at the depth of 50 cm.

The next property, namely longitudinal wood shrinkage, failed to reveal significant differences between the analysed sample series. The obtained values fluctuated within the interval ranging from 0.14 to 0.18%. The longitudinal wood shrinkage of the control samples was 0.12%. Therefore, it can be said that this wood property

Table 5. Physical properties and mass losses of pine wood

Property		Samples					
		D-50	W-50	D-100	W-100	W-T	control
Moisture content [%]	min	105	121	113	126	125	
	max	146	144	141	154	162	
	mean	124	132	127	141	142	
	s	10	6	8	8	10	
Maximum moisture content [%]	min	131	129	139	139	138	126
	max	170	153	161	162	167	169
	mean	150	145	149	151	151	141
	s	12	6	6	8	9	10
Conventional density [kg·m^{-3}]	min	424	456	438	439	427	426
	max	508	513	488	488	491	521
	mean	465	475	467	463	462	483
	s	25	15	14	17	18	23
Longitudinal shrinkage [%]	min	0.11	0.12	0.14	0.13	0.14	0.11
	max	0.20	0.21	0.26	0.22	0.22	0.15
	mean	0.14	0.16	0.18	0.17	0.17	0.12
	s	0.02	0.03	0.03	0.03	0.02	0.01
Mass loss [%]	min	1.57	2.14	3.04	2.28	3.61	
	max	2.96	3.25	4.47	3.99	5.53	
	mean	2.23	2.83	3.54	3.12	4.41	
	s	0.48	0.35	0.37	0.52	0.50	

min – minimum value, max – maximum value, *s* – standard deviation.

did not change in the course of the two-year period of wood deposition in natural conditions.

The mass decrement (UM) shows which part of wood underwent decomposition and/or was extracted from the degraded object (sample). The highest mean UM value amounting to 4.41% was determined for wood samples left in the pit filled with water (W-T). This can probably be attributed not only to the high activity of microorganisms resulting from the higher oxygen content but also to a more unrestricted extraction of water soluble wood constituents. Values slightly lower were determined in the samples buried in peat at the depth of 100 cm. Wood samples buried in the dry state were characterized by the loss of wood substance amounting to 3.54% and those saturated with water – to 3.12%. The lowest losses of wood substance were recorded in the case of wood samples buried in peat at the depth of 50 cm. The mass decrement of wet samples amounted to 2.83%, while that of dry wood samples – to 2.23%.

Figure 1 presents the percentage proportion of major chemical constituents of pinewood subjected to the experiment. The percentage proportion of the carbohydrate constituents in the examined sample series left in the natural environment fluctuated within a narrow interval ranging from 69.40% to 71.05%. The comparison of these results with the percentage proportion of holocellulose in the control

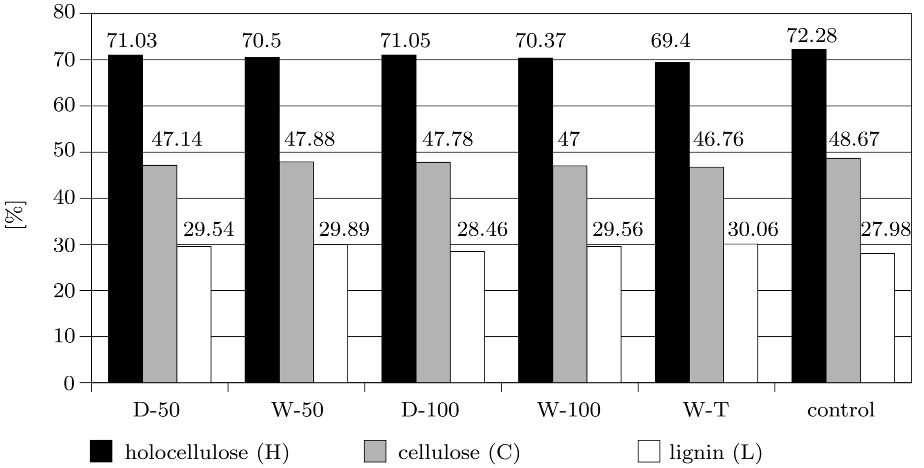

Fig. 1. Percentage content of main chemical constituents of pine wood

material (72.28%) reveals only a sight decrease in the polysaccharide content in the material subjected to the described two-year experiment. The highest loss of holocellulose took place in wood samples left in the pit filled with water (W-T) as 69.40% carbohydrates were determined in this material. The results obtained for the wet wood samples buried in peat at the depth of 50 and 100 cm were only slightly higher and reached 70.50 and 70.37%, respectively. The highest proportions of polysaccharides were determined in dry wood samples buried in peat at the depth of 50 and 100 cm. In comparison with the control material, the content of holocellulose in these two cases decreased by approximately 1 percentage point. Also the determined differences in the cellulose contents were small. The proportion of this main wood constituent, following its two-year long exposure to the effect of the natural environment, ranged from 46.76 to 47.88% and the content of cellulose in the control sample was only slightly higher amounting to 48.67%. Again, the lowest cellulose content was determined in the wood samples left in the water-filled pit (W-T). The consequence of the decrement of polysaccharide components was an apparent increase in the lignin percentage content, as this wood constituent remains resistant to numerous soil microorganisms and hydrolytic processes (Wróblewska 1994, Grattan and Mathias 1986, Zborowska et al. 2005). The content of this wood constituent increased in the examined wood samples from 27.98% to, respectively: 29.54 and 28.46% for the materials D-50 and D-100 buried in the dry state at the depth of 50 and 100 cm. In the case of wood samples buried wet in peat at the depth of 100 cm, the content of lignin was almost identical (29.56%), whereas in the case of wet wood samples buried in peat at the depth of 50 cm, the content of lignin was 29.89%. As expected, the highest lignin content (30.06%) was determined in the pinewood samples left at the bottom of the water-filled pit (W-T).

The determination of the percentage proportion of the main wood constituents makes it possible to assess the value of the ratio of holocellulose and cellulose content to the content of lignin (H/L and C/L) (Grattan and Mathias 1986, Babiński 2005, Waliszewska et al. 2007). The H/L and C/L values for the experimental wood are presented in Figure 2. The ratio of the holocellulose proportion to the lignin proportion in the series of control samples was determined at 2.58. The H/L ratio in the case of the wood used in the two-year experiment ranged from 2.32 to 2.50. The lowest value indicating the most advanced degradation of carbohydrate constituents was determined for the material designated as W-T left in the pit filled with water. Values of the H/L ratio were found slightly higher (2.36 and 2.38, respectively) in the case of pinewood samples buried wet in peat at the depth of 50 and 100 cm (W-50 and W-100). In comparison with the control samples, the smallest changes in the H/L ratio were found in the case of wood samples buried dry in peat at the depth of 50 and 100 cm. The ratio of the cellulose content to lignin content (C/L) for the undegraded wood amounted to 1.74. This ratio determined in the samples exposed to the influence of the natural environment ranged from 1.56 to 1.68. Again, as in the case of the H/L ratio, the lowest values of the C/L relation were determined for the wood left in the pit filled with water confirming yet again its most advanced degradation. In the case of wood samples buried dry at the depth of 100 cm (D-100), the high C/L ratio reaching 1.68 confirmed their slight degradation changes suggested earlier on the basis of the content changes in the holocellulose and the value of the H/L ratio.

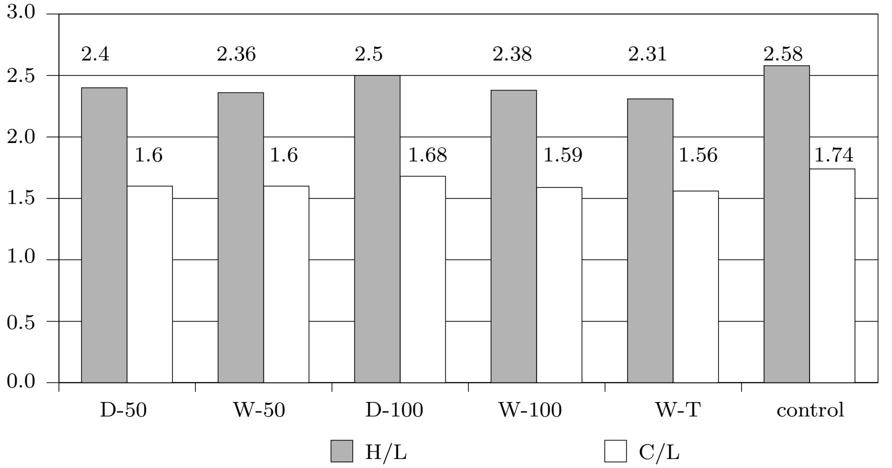

Fig. 2. Ratio of holocellulose to lignin (H/L) and cellulose to lignin (C/L) of pine wood

The analysis of the secondary wood constituents, whose results are presented in Table 6, included, among others, the determination of the percentage proportion of substances soluble in the mixture of alcohol and benzene. In the case of the control wood samples, this fraction constituted 2.64%. The content of extractable substances in wood samples following their two-year storage in natural conditions decreased by more than half and fluctuated within the interval ranging from 1.04 to 1.25%. Also the content of wood constituents soluble in cold water decreased considerably ranging from 0.62 to 0.77%. On the other hand, the proportion of

Table 6. Percentage content of extractive substance of pine wood

Samples	Substances soluble in:		
	alcohol benzene mixture	cold water	hot water
D-50	1.19	0.77	1.14
W-50	1.15	0.62	1.35
D-100	1.07	0.67	1.08
W-100	1.04	0.64	1.11
W-T	1.25	0.73	1.35
Control	2.64	1.89	1.20

wood constituents soluble in hot water determined in the experimental wood samples remained on the level found in the control samples fluctuating from 1.11 to 1.35%.

CONCLUSIONS

1. On the basis of the performed investigations similar values were found in the basic physico-chemical parameters of the environment in which the wood samples were buried.
2. The performed bacteriological and mycological investigations revealed considerable diversification of the bacterial and fungal microflora occurring in the examined pinewood. The highest activity of the examined bacteria was found in the case of wood samples left at the bottom of the water-filled pit.
3. The comparison of physical properties, mass decrements and chemical composition revealed small differences of the examined characteristics of pinewood subjected to the two-year long experiment.
4. Further investigations on the degradation of contemporary wood tissue in conditions of the deposition of the Biskupin archaeological wood will reveal if the initial results signal long-term trends.

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