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DECOMPOSITION OF THE CONTEMPORARY OAK WOOD (*QUERCUS* SP.) IN CONDITIONS OF THE WET ARCHAEOLOGICAL SITE IN BISKUPIN

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SYNOPSIS. The authors investigated changes which occurred in the heartwood of the contemporary oak wood (*Quercus* sp.) left for two years in wet peat – in conditions in which the remains of the Lusatian culture fortified settlement in Biskupin are deposited. The degree of the degradation of the wood tissue was determined on the basis of the mass loss, some selected physical properties, chemical composition and colonisation of wood by microorganisms.

KEY WORDS: physical properties, chemical composition, microorganisms

INTRODUCTION

The kind, range and intensity of degradation of lignocellulosic materials depend, primarily, on the type of environment and occurrence of specific degradation factors (Eriksson et al. 1990, Ważny 1993). The occurring abiotic and/or biological degradation processes in the timber tissue lead to changes in the structure as well as to alterations in the physical, chemical and mechanical wood properties. The rates and extent of the wood tissue decomposition depend not only on the conditions in which wood is kept but also on the capacity of the settlement of wood by microorganisms, their invasiveness, enzymatic activity, adhesion to the substrate and competitiveness in the fight for food (Gajewska 1994). In conditions of wet archaeological sites characterized, among others, by high levels of ground waters as well as low oxygen content, wood can be degraded only by bacteria and soft-rot

fungi (Björdal et al. 1999, Blanchette 2000). The degradation rates as well as the level of the observed alterations are reduced considerably in these conditions as confirmed by numerous artefacts discovered in the course of excavation works.

In Poland, one of the best known examples of wood durability are the remains of the Lusatian culture fortified settlement in Biskupin (8th century BC). Following excavation works, the archaeological constructions were left on their sites, either in the ground or in water. Unfavourable changes taking place in the environment in which the archaeological material is deposited can result in the intensification of wood degradation. The greatest threats are associated with the lowering of the level of ground waters and aeration of soil (Björdal and Nilsson 2002). Realising the necessity of a systematic control of conditions existing in wet sites, various monitoring programs were introduced in many countries with the aim to monitor basic parameters in the environment in which wood is deposited (Corfield 1994, Caple et al. 1997, Gregory et al. 2002, Hogan et al. 2002, Matthiesen et al. 2004). A review of the employed research methods was carried out by Jordan (2001). A research project was initiated in Biskupin in 2003 the aim of which is to monitor selected water and soil parameters as well as to determine the state of preservation of the archaeological wood (Babiński and Prądzyński 2004). Initial results of these experiments were presented in earlier publications (Babiński et al. 2004, Zborowska et al. 2005). Because of difficulties associated with the determination of the current rate of degradation of the Biskupin wood (Babiński and Prądzyński 2004), the authors decided to investigate changes taking place in the contemporary wood buried in the environment of decomposition of archaeological wood. The deposition of contemporary wood in conditions of a wet archaeological site has already been practiced, among others, in Great Britain (Powell et al. 2001) with the aim to assess the extent of degradation of wood on the basis of microscopic observations.

The objective of this research project was to identify microorganisms, estimate the degree of wood tissue colonisation, determine the mass loss, changes in some selected physical properties and the chemical composition of the contemporary oak wood following a two-year period of deposition in conditions identical to those of the archaeological wood in Biskupin. The results of the performed investigations were also supplemented with the data from the monitoring of basic parameters of water and soil.

MATERIALS AND METHODS

Investigations were carried out on the wood of 68-year old oak (*Quercus* sp.) growing in the Gołąbki Forest District in the neighbourhood of Biskupin (Kujawsko-Pomorskie Voivodeship). The experimental material, cut out from the log of approximately 240 mm diameter, derived from the outer part of the heartwood zone extending across the annual rings from 29 to 56 (the last heartwood annual ring). The samples were cut out from wood dried to the moisture content of about 12%. The dimensions of the experimental samples (at moisture content of 12%)

were as follows: 150 (L) × 10 (T) × 10 (R) mm. Part of the experimental samples, before burying them in the soil, was vacuum-impregnated with water (10 cycles; 4 h at the pressure of 50 hPa and 20 h at atmospheric pressure/cycle) to the moisture content of about 60-65%.

Both dry (D) and wet (W) samples (40 pieces of each) were buried in the archaeological site No. 4 in Biskupin in the layer of peat at the depth of 50 and 100 cm (at the level other wooden constructions from the Lusatian settlement are deposited). Another set of 40 wet samples was additionally placed in a peaty layer at the bottom of a trench with archaeological wood filled with water (Table 1).

Table 1. Designation of samples, moisture content and places of deposition of oak wood

Samples	Wood moisture content before deposition [%]	Place of deposition
D-50	11.57	peat at the depth of 50 cm
W-50	60.26	peat at the depth of 50 cm
D-100	11.57	peat at the depth of 100 cm
W-100	59.52	peat at the depth of 100 cm
W-T	62.94	bottom of a trench filled with water

Throughout the experimental period, the level of ground water as well as the level of water in the trench, water reaction (pH) and conductivity were monitored and the soil temperature and redox potential was measured. The methodology of these measurements was presented in earlier publication (Babiński et al. 2004).

The experimental samples were recovered after two years of deposition in the above-described sites. The evaluation of the extent of wood tissue degradation was conducted on the basis of microbiological examinations, changes of the selected physical properties, the wood mass loss as well as chemical composition.

One sample from each buried wood batch was collected for microbiological examinations. The authors compared the capability for the surface (depth 1-1.5 mm) and internal (depth 3.5-5 mm) settlement of samples by soil eubacteria (relatively and strictly anaerobes), actinomycetes as well as yeasts and hyphal fungi. In order to isolate and identify the collected microorganisms, the following microbiological media were employed: nutrient agar with and without the addition of 10% mutton blood, McConcey's medium, Bunt and Roviry's medium supplemented with 1% starch and nystatin, King's B medium, Wilson-Blair medium, Dubos medium, medium according to Weimer and Zeikus (with the addition of filter paper as the sole carbon source), substrate for the nitrifying bacteria according to Coppier and de Barjac, denitrifying bacteria and ammonifying bacteria (with Winogradski salts) and nitrogen-fixing bacteria (medium according to Döbereiner) as well as Martin and Sabouraud's medium. Plate cultures of bacteria, actinomycetes and aerobic fungi were conducted under aerobic conditions at 28 and 37°C, respectively. Anaerobic bacteria cultures were placed in an aerostat in the presence of hydrogen and carbon dioxide, palladium catalyst and methylene blue as indicators of anaerobic conditions. Anaerobic mesophyllic bacteria cultures were carried out at the temperature of 30°C, and of thermophilic bacteria – at 55-60°C. In order to identify the selected bacterial isolates, the authors used Api-tests of the bioMerieux

Company and the classification according to Bergey's 'Manual of Determinative Bacteriology' (2000) and to identify fungi – systematics according to Barnett (1960-1965) and Fassatiova (1979).

The following physical properties were assessed: moisture content, maximum moisture content, conventional density (oven-dry mass/green volume) and wood longitudinal shrinkage. Waterlogged and oven-dry samples were weighed with accuracy of 0.0001 g and measured in longitudinal direction with accuracy of 0.01 mm. Volume of water saturated samples was determined by hydrostatic method.

Holocellulose, cellulose and lignin content as well as the amount of substances soluble in the ethanol-benzene mixture, cold and hot water and the content of mineral compounds (ash) were determined in the examined wood. Chemical analyses were carried out according to the methodology described in the Polish Standard (PN 92/P-50092).

RESULTS AND DISCUSSION

Basic macroscopic features of wood from which experimental samples were prepared are presented in Table 2. The characterisation of the environment of wood deposition is shown in Table 3.

Table 2. Macroscopic characteristics of oak heartwood

Characteristic	Mean value [mm]	Minimum value [mm]	Maximum value [mm]	Standard deviation [mm]	Variation coefficient [%]
Width of annual rings	1.81	0.72	3.39	0.78	43.21
Percentage of latewood	62.63	27.47	82.01	13.29	21.22

Samples buried at the depth of 100 cm (D-100, W-100) as well as the wood from the trench (W-T) were immersed in water throughout the investigated period. On the other hand, samples buried at the depth of 50 cm (D-50, W-50) remained above the ground water level from May to the end of October (collected in the piezometer). However, considering the conditions of the examined samples as well as the values of the redox potential, it should be presumed that, despite the observed periodical changes in the ground water level, the examined wood remained all the time in the wet peat in strongly reducing environment. Low salinity and the ground water reaction close to neutral (Table 3) failed to impact significantly the chemical degradation processes occurring in the examined wood. On the other hand, the water reaction in the trench was predominantly alkaline (pH even up to 8.77) which could have more significantly contributed to the chemical and biological degradation of the experimental wood. The redox potential (Eh) in the soil at the depth of 50 and 100 cm ranged from −250 to −150 mV, depending on the season of the year. Even lower values of this potential were recorded at the beginning of the experiment (Babiński et al. 2004). Soil Eh measurements

Table 3. Characterisation of the deposition environment of oak wood

Parametr	Place of deposition of samples		
	peat, 50 cm	peat, 100 cm	trench
Water level	from May to October below the level of samples deposition	above the level of samples deposition	above the level of samples deposition
Water reaction [pH]	6.27 ... 7.32	6.27 ... 7.32	6.37 ... 8.77
Water conductivity [$\mu S \cdot cm^{-1}$]	1070 ... 2090	1070 ... 2090	400 ... 970
Soil temperature [°C]	1.3 ... 20.2	2.6 ... 18.3	not measured
Soil redox potential [mV]	−250 ... −150	−250 ... −150	−250 ... −120 depending on depth

at the bottom of the trench filled with water were taken only during the last four months of the experiments and the recorded values remained at the same level of approximately −250, −200 and −120 mV, respectively, depending on the place and depth of the installed electrodes. On the basis of the obtained results, it can be stated that the examined samples of contemporary wood remained in comparable reducing environments characterized by limited oxygen content.

The results of microbiological investigations on the settlement of wood by bacteria, actinomycetes, yeasts and fungi are presented in Table 4. Considerable diversity was determined among the isolated bacteria occurring on the surface (1-1.5 mm) and internal (3.5-5 mm) zones of the examined samples irrespective of the initial saturation of wood with water and the depth of its deposition in the soil. The following genera of bacteria were identified in the heartwood of the experimental oak wood: *Pseudomonas*, *Bacillus*, *Clostridium*, *Serratia*, *Chryseomonas*, *Agrobacterium*, *Burkholderia*, *Enterococcus* and *E. coli*. No actinomycetes were found inside the wet wood samples buried at the depth of 50 cm (W-50) and in the trench (W-T) as well as in the surface and internal layers of wood deposited at the depth of 100 cm – both dry and wet. No nitrifying bacteria and nitrogen-fixing bacteria from the *Azotobacter* genus were found in any of the examined wood samples in contrast to numerous nitrogen-fixing bacteria of *Clostridium pasteurianum*. Among the cellulolytic microflora, the dominant were the relative mesophyllic, slime-producing anaerobes (*Bacillus polymyxa* and *Sporocytophaga* sp.) and strictly anaerobesmeso- and thermophilic bacteria of the *Clostridium* genus. The results of mycological investigations also revealed considerable variability of the isolated hyphal fungi. On the wood surface, fungi from the *Penicillium*, *Aspergillus*, *Trichoderma*, *Fusarium*, *Botrytis* and *Humicola* genera as well as yeasts from the *Candida* genus were identified. However, not all fungi occurring in the soil and on the surface of samples (e.g. from the *Fusarium*, *Trichoderma* and *Humicola* genera) managed to penetrate to deeper wood layers. It appears that the storage of samples in conditions of anoxia, at the low redox potential of the peat soil saturated with water could have influenced the limited degree of colonization and

Table 4. Colonization of oak wood by microorganisms

Sample		Bacteria	Actinomycetes	Fungi and yeast
1		2	3	4
D-50	a	*Pseudomonas* spp., *P. fluorescens*, *Bacillus* spp., *B. polymyxa*, *B. mycoides*, *Clostridium perfringens*, *Chryseomonas* spp., *Serratia marcescens*, *Sarcina lutea*, *Sporocytophaga* sp.	u/i G (+) rods	*Penicillium* spp., *Aspergillus* spp., *Trichoderma* spp., *T. viride*, u/i yeast
	b	*Bacillus* spp., *B. polymyxa*, *Serratia marcescens*, *Sporocytophaga* sp.	–	*Penicillium* spp., *Aspergillus* spp., u/i yeast
W-50	a	*Pseudomonas* spp., *P. fluorescens*, *Bacillus* spp., *B. mycoides*, *Clostridium* spp., *Cl. perfringens*, *Enterococcus* spp., *E. coli*, lac+ rods from *Enterobacteriaceae* family, *Sporocytophaga* sp.	*Streptomyces* spp., u/i G (+) rods	*Penicillium* spp., *Aspergillus* spp., *Trichoderma* spp., *Botrytis* spp., *Candida jovanica*, *Candida* spp., u/i yeast
	b	*Clostridium* spp., *Cl. perfringens*, *Bacillus* spp., *B. polymyxa*, *B. mycoides*, *E. coli* lac+ rods from *Enterobacteriaceae* family, *Sporocytophaga* sp.	u/i G (+) rods	*Penicillium* spp., *Aspergillus* spp., *A. niger*, *A. fumigatus*, u/i yeast
D-100	a	*Pseudomonas* spp., *P. fluorescens*, *Bacillus* spp., *B. mycoides*, *Clostridium* spp., *Cl. perfringens*, *Enterococcus* spp., *E. coli*, lac+ rods from *Enterobacteriaceae* family, *Sporocytophaga* sp.	–	*Penicillium* spp., *Humicola grisea*
	b	*Pseudomonas* spp., *Bacillus* spp., *Clostridium* spp., *Cl. perfringens*, *Enterococcus* spp., *E. coli*, lac+ rods from *Enterobacteriaceae* family, *Sporocytophaga* sp.	–	–

Table 4 – cont.

1		2	3	4
W-100	a	*Pseudomonas* spp., *P. fluorescens*, *Bacillus* spp., *B. polymyxa*, *B. mycoides*, *Clostridium* spp., *Cl. perfringens*, *Chryseomonas luteola*, *Burkholderia cepacia*, *Agrobacterium radiobacter*, *Enterococcus* spp., *E. coli*, lac+ rods from *Enterobacteriaceae* family, *Sporocytophaga* sp., *Cellulomonas* spp.	–	*Aspergillus* spp., *Penicillium* spp., *Trichoderma* spp., *T. viride*
	b	*Pseudomonas* spp., *Bacillus* spp., *Clostridium* spp., *Cl. perfringens*, *Sporocytophaga* sp., *Cellulomonas* spp.	–	*Aspergillus* spp.
W-T	a	*Pseudomonas* spp., *Bacillus* spp., *Clostridium* spp., *Cl. perfringens*, *Enterococcus* spp., *E. coli*, lac+ rods from *Enterobacteriaceae* family, *Sporocytophaga* sp.	*Streptomyces* spp., u/i G (+) rods	*Fusarium* spp., *Penicillium* spp., *Aspergillus* spp., *Trichoderma* spp., *T. viride*, *Candida jovanica*, *Candida* spp., u/i yeast
	b	*Pseudomonas* spp., *P. fluorescens*, *Bacillus* spp., *B. polymyxa*, *B. mycoides*, *Clostridium* spp., *Cl. perfringens*, *Sporocytophaga* sp.	–	*Aspergillus* spp., *Penicillium* spp., *Trichoderma* spp., u/i yeast

a – external zone (1-1.5 mm), b – internal zone (3.5-5 mm).

penetration of wood by the bacterial and fungal microflora. It may be assumed that the maintenance of these conditions will allow to protect the wood remaining in the site against colonization and degradation by a very numerous and diversified microflora of relative anaerobes. Unfortunately, these conditions will not protect the Biskupin wood against its settlement strictly by the anaerobes which exhibit high activity when the temperature exceeds 20°C.

Table 5 presents the comparison of physical properties and mass losses of the examined oak wood. Samples recovered after two years' deposition in the soil did not show distinct signs of decomposition (loss of wood tissue). The recovered wood was very hard. After drying, the wood adopted characteristic grey colour and no deformations or seasoning checks could be seen. The water content in wood increased from 11.57% (dry samples) and about 60% (wet samples) to the moisture content from about 81.92% (minimum value) to 117.42% (maximum value). The mean moisture content of individual wood batches was contained in the interval of 93.23% to 100.03%. On the other hand, the maximum moisture content deter-

Table 5. Physical properties and mass losses of oak wood

Property		Samples					
		control	D-50	W-50	D-100	W-100	W-T
Moisture content	x [%]	–	95.44	95.73	97.31	93.23	100.03
	min [%]	–	82.94	83.69	86.80	82.04	81.93
	max [%]	–	107.96	112.15	109.66	109.92	117.42
	s [%]	–	8.07	8.79	7.23	7.06	9.28
	v [%]	–	8.46	9.18	7.43	7.57	9.28
Maximum moisture content	x [%]	60.97	96.48	96.90	97.71	93.65	100.44
	min [%]	54.91	83.88	84.24	87.18	82.24	82.03
	max [%]	67.38	109.44	114.19	110.51	110.69	117.75
	s [%]	2.69	8.33	9.16	7.36	7.18	9.40
	v [%]	4.27	8.63	9.45	7.53	7.67	9.36
Conventional density	x [kg·m^{-3}]	616.48	618.69	616.97	614.76	630.85	605.12
	min [kg·m^{-3}]	569.05	568.56	556.13	568.86	566.37	542.25
	max [kg·m^{-3}]	676.39	671.61	671.05	658.05	681.41	681.81
	s [kg·m^{-3}]	34.92	33.27	36.87	28.85	28.96	35.45
	v [%]	5.66	5.38	5.98	4.69	4.59	5.86
Longitudinal shrinkage	x [%]	0.26	0.29	0.27	0.32	0.28	0.27
	min [%]	0.16	0.16	0.15	0.21	0.14	0.14
	max [%]	0.65	0.55	0.47	0.55	0.48	0.45
	s [%]	0.11	0.10	0.08	0.07	0.09	0.06
	v [%]	42.12	34.68	28.32	23.42	33.17	22.37
Mass loss	x [%]	–	2.20	0.94	2.05	1.34	3.53
	min [%]	–	0.88	0.40	1.32	0.85	2.48
	max [%]	–	5.12	1.50	4.28	1.70	4.73
	s [%]	–	1.21	0.26	0.76	0.20	0.67
	v [%]	–	54.91	27.77	36.78	14.84	19.08

x – mean value, min – minimum value, max – maximum value, s – standard deviation, v – variation coefficient.

mined following the saturation of wet samples using the vacuum method ranged from 82.03 to 117.75%, with mean values fluctuating from 93.65 to 100.44% (Table 5). The high water content in the difficult-to-saturate oak heartwood resulted from the long saturation time. Increased wood permeability caused by its degradation by bacteria cannot be ruled out. The conventional density of the examined wood ranged from 605 to 631 kg/m^3. A wide range of widths of annual rings (Table 2) and a small degree of decomposition caused that the mean conventional density of the wood buried in the site was, in several cases, slightly higher than the conventional density of the control samples. The observed slight differences between the conventional density and the maximum moisture content of individual batches indicate that none of these properties can be taken as the basis for the determination of the extent of wood decomposition in its initial phase.

As indicated by earlier investigations (Babiński 2005), the advancing wood degradation is accompanied by increased longitudinal shrinkage of the wood tissue. On the basis of the results presented in Table 5, it can be concluded that the contraction of oak wood following its two-year deposition in conditions of the archaeological site in Biskupin did not change significantly. Its average shrinkage ranged from 0.27 to 0.32%, whereas the shrinkage of the control samples amounted to 0.26%.

Mass losses of experimental samples were contained in the interval from 0.40 to 5.12%. The greatest changes were recorded in the case of the wood samples deposited at the bottom of the trench (W-T). Their mean mass loss amounted to 3.53. The degradation of the wood buried in peat was distinctly smaller. Irrespective of the depth, the decomposition of dry wood was higher than that of wet wood samples. The mean mass loss of dry samples amounted to 2.20% at the depth of 50 cm and 2.05 – at 100 cm. Wet wood samples underwent even smaller decomposition; mean mass losses ranged from 0.94% for the samples buried at the depth of 50 cm and 1.34 for those deposited 100 cm below the surface. The greater mass losses recorded in the case of dry wood (D-50 and D-100) should be attributed to its greater sensitivity to degradation. On the other hand, the comparable decomposition degrees of wet wood (W-50 and W-100; mean mass losses about 1%) and dry wood (D-50 and D-100; mean mass losses about 2) resulted from similar oxido-reductive conditions found at both depths. It can be presumed that the recorded losses of the wood substance were caused not only by the enzymatic degradation of wood (and/or, to a lesser extent, its hydrolytic degradation) but also by the extraction of substances soluble in water. In real terms, the mass losses of samples introduced in the wet state were even smaller. Additional investigations revealed that the loss of wood bulk caused by the saturation of samples with water during 10 days amounted from 0.61 to 1.33% (1.03 on average). In view of the above, it should be estimated that there were no changes in the mass resulting from the impact of the external environment in the case of samples introduced into the peat in the wet state (W-50 and W-100). In the remaining cases (D-50, D-100 and W-T), mean values quoted in Table 5 should also be corrected by about one percentage point. However, it was impossible to estimate the impact exerted on the obtained results by the content of mineral constituents and the degradation products of the major wood constituents before carrying out the chemical analyses.

The chemical composition of the examined oak wood is presented in Table 6. Only a slight reduction in the proportion of polysaccharide components was recorded in the experimental wood material left for two years in conditions similar to anaerobic. The holocellulose content, which in the control sample was determined at the level of 66.40%, ranged from 64.92% to 66.20% in the wood samples recovered from the archaeological site. Its highest decrease was observed in samples deposited in the trench (W-T), while the smallest changes occurred in the wood samples buried at the depth of 100 cm (D-100 and W-100). The content of cellulose also decreased from 38.54% to 37.70% and 37.93% for the wood deposited at the depth of 50 cm and to 36.14-36.56% – for the remaining samples. On the other hand, the percentage content of lignin increased distinctly. Whereas the content of lignin in the non-degraded wood was 25.98%, it increased to 26.36 and 26.89% in samples deposited at the depth of 100 cm and to 27.62 and 27.92% in the wood samples buried at 50 cm. Even greater proportion of lignin was recorded in the samples recovered from the trench filled with water (28.37%). The recorded increase in the lignin content, in relation to its proportion in the control samples, should be attributed exclusively to the faster degradation of polysaccharides (decreased content of holocellulose) much less resistant to the enzymatic degradation caused by the identified bacteria and fungi.

The total content of holocellulose and lignin in the analysed experimental material ranged from 92.38% (control samples) to 92.52-93.29% (samples deposited in the soil). The higher proportion of the major chemical constituents in the wood deposited in the archaeological site (despite the degradation of the wood tissue) can indicate an apparent increase in the content caused, among others, by the two-year extraction of water soluble constituents, including products of wood degradation. It should be presumed that these discrepancies should be attributed to slight differences in the chemical composition of individual wood batches and the intensity of the process of its degradation within external and internal layers of the experimental samples.

The degree of degradation of the examined wood tissue was also assessed on the basis of the content ratios of the major wood constituents. The ratio of the

Table 6. Percentage content of main components, extractive substances and mineral compounds in oak wood

Property		Samples					
		control	D-50	W-50	D-100	W-100	W-T
Holocellulose (H)	%	66.40	65.10	65.19	66.20	66.16	64.92
Cellulose (C)	%	38.54	37.93	37.70	36.56	36.14	36.30
Lignin (L)	%	25.98	27.62	27.92	26.89	26.36	28.37
Sum H + L		92.38	92.72	93.11	93.09	92.52	93.29
Ratio HŁ		2.56	2.36	2.33	2.46	2.51	2.29
Ratio CŁ		1.48	1.37	1.35	1.36	1.37	1.28
Substances soluble in:							
– ethanol-benzene mixture	%	3.49	3.60	2.97	2.50	2.40	2.58
– cold water	%	4.92	5.42	5.03	3.02	4.75	4.50
– hot water	%	9.78	8.25	7.74	7.70	8.78	8.36
Ash	%	1.07	1.15	1.05	1.11	1.12	1.17

holocellulose to lignin content (HŁ), which amounted to 2.56 for the non-degraded wood, decreased with the increasing carbohydrate degradation to 2.46-2.51 for the wood deposited at the depth of 100 cm, to 2.33-2.36 – for the wood from the depth of 50 cm and to 2.29 – for samples deposited in the trench filled with water. The obtained results correspond closely with the assessment of wood degradation carried out on the basis of changes in the holocellulose content. On the other hand, the ratio of the cellulose to lignin content (CŁ) verifies the earlier information about the extent of cellulose degradation. In the case of wood buried in the wet peat (irrespective of the depth and moisture content of the introduced samples), this ratio remained at the level 1.35-1.37 indicating the comparable degree of degradation of the principle wood constituent. On the basis of the same criterion, the wood derived from the trench (W-R) again turned out to be the most degraded material.

The content of substances soluble in the ethanol-benzene mixture as well as in cold and hot water remained on the comparable (frequently slightly lower) level with that determined in the control samples (Table 6). To a certain degree, this explains the above-mentioned increase in the content of the main wood structural constituents (total content of holocellulose and lignin). On the other hand, the total ash content in the control samples (about 1%) did not differ from its content in the wood deposited in the archaeological site. This means that it is possible to conclude that the content of mineral constituents did not have a significant influence on the conventional density and the extent of wood substance losses (mass losses) determined in the wood deposited in the anaerobic conditions.

CONCLUSIONS

1. Oak wood left in wet, strongly reducing soil environment in the archaeological site No. 4 in Biskupin was colonized by rich, aerobic and anaerobic bacterial and fungal microflora. Cellulolytic bacteria from the *Bacillus*, *Pseudomonas*, *Sporocytophaga* and *Clostridium* genera as well as fungi from the *Penicillium*, *Aspergillus*, *Trichoderma*, *Botrytis* and *Humicola* genera constituted the greatest threat to the experimental wood.
2. The recorded mass losses, physical properties as well as the content of the main chemical constituents indicate small extent of degradation of the examined oak wood after two years of deposition in the soil. The recorded changes developed in the result of the enzymatic decomposition of the hemicellulose system as well as the extraction of substances soluble in water.
3. Conditions existing at the bottom of a trench filled with water situated in the northern part of the site favoured faster degradation of oak wood in comparison with the material deposited in the wet peat.
4. The maintenance of anaerobic environmental conditions in the discussed site can reduce the occurrence of many microorganisms and minimise the speed of wood tissue degradation. This requires constant monitoring of changes

occurring in this environment and continuation of the investigations on wood degradation.

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