

THE PRESENT CLASSIFICATION OF WOOD DEGRADATION FACTORS*

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Contemporary classification of biotic and abiotic wood degradation factors is presented in two aspects: etiological and symptomatic one.

INTRODUCTION

Contemporary rational wood application and use of wood constructions in the human economy require knowledge of their concentrations with the ambient environment. Wood is, beside stone, the oldest material with many specific advantages. Under suitable favourable conditions it can persist infinitely long, neither deteriorating nor worsening its nature under the ageing effect. This can be proved by numerous wooden things and elements of several thousand years of age, not revealing any changes in their structure and properties. However, wood kept under unfavorable conditions, not properly preserved as raw material or stuff in different stages at its, usage, transport, processing or exploitation of final products, can be subjected to the action of biotic or abiotic factors worsening its initial traits and properties, i.e. to degradation.

Thus it is indispensable to analyse the degree and form of endangering this material by degradation, while designing and execution of constructional, chemical and operation protective measures should be preceded by determination of foreseen spectre of biotic and abiotic degradation factors. At the same time the efficiency of protective measures is aimed more and more often at definite factors of the degradation. Beside the measures with a complex effect there are measures with narrow application range, requiring separate testing for different groups of the degradation factors. In this connection it seems to be necessary for more efficient wood application to work out a uniform classification of forms and types of wood degradation factors as well as determination of its terminology.

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The idea of bringing in order classification and notions in the scope of wood degradation is not new. Its general outline can be found in manuals on pathology and protection of wood [4, 14, 29, 40, 46 and others]. A more detailed systematics for some groups is presented by Seifert [59], Becker [6], Smith [6] (biotic factors), Sell [60], Feist [19], Thompson [64] (abiotic factors), Metzner and Bellmann [43], Ważny [67], Schmidt and Kerner-Gang [56] (both groups of factors) and many others.

METHODOLOGY

The present paper constitutes a proposal of the contemporary classification of biotic and abiotic wood degradation factors basing on the hitherto published works and discussions in two aspects: etiological (Tables 1 and 2)

Table 1

Biotic degradation factors – etiological classification
Biotyczne czynniki degradacji – klasyfikacja etiologiczna

Factors – Czynniki	Environments Środowiska			
	1	2	3	4
1. Bacteria – Bakterie (<i>Schizomycetes</i>)				
1.1. True bacteria – Bakterie właściwe (<i>Eubacteriales</i>)	+	+	++	+++
1.2. Actinomycete – Promieniowce (<i>Actinomycetes</i>)	–	+	++	+++
2. Algae – Glony				
2.1. Blue-green algae – Sinice (<i>Cyanophyta</i>)	–	+	+++	+++
2.2. Green algae – Zielonice (<i>Chlorophyta</i>)	+	+	+++	+++
2.3. Golden algae – Brunatnice (<i>Chrysophyta</i>)	–	+	+++	+++
3. Fungi – Grzyby (<i>Mycota</i>)				
3.1. Slime fungi – Śluzowce (<i>Myxomycotina</i>)	–	+	++	–
3.2. Zygomycetes – Sprzężniaki (<i>Zygomycotina</i>)	+	+	++	–
3.3. Ascomycetes – Workowce (<i>Ascomycotina</i>)	++	++	++	++
3.4. Basidiomycetes – Podstawczaki (<i>Basidiomycotina</i>)	++	++	++	–
4. Lichens – Porosty (<i>Lichenes</i>)	–	++	+++	–
5. Insects – Owady (<i>Insecta</i>)				
5.1. Beetles – Chrząszcze (<i>Coleoptera</i>)	+	+++	+++	–
5.2. Butterflies – Motyle (<i>Lepidoptera</i>)	–	++	++	–
5.3. Wasps, bees, ants – Błonkóвки (<i>Hymenoptera</i>)	–	++	++	–
5.4. Termites – Termity (<i>Isoptera</i>)	+++	+++	+++	–
6. Others animals organisms – Inne organizmy zwierzęce				
6.1. Molluscae – Małże	–	–	–	+++
6.2. Crustaceae – Raki	–	–	–	+++

Environments – Środowiska:

1. Under roof – pod dachem
2. In open air out of ground contact – na otwartej przestrzeni bez kontaktu z gruntem
3. In open air with ground contact – na otwartej przestrzeni w kontakcie z gruntem
4. In water – w wodzie

Table 2

Abiotic degradation factors – Etiological classification
 Abiotyczne czynniki degradacji – Klasyfikacja etiologiczna

Factors – Czynniki	Environments Środowiska			
	1	2	3	4
1. Chemical factors – Czynniki chemiczne				
1.1. Acids – Kwasy	+	+	+	+
1.2. Alkalis – Zasady	+	+	+	+
1.3. Oxygen and ozone – Tlen i ozon	–	++	++	–
1.4. Salts – Sole	+	++	++	++
1.5. Aerosols – Aerosole	–	+	++	–
1.6. Sulphur dioxide – Dwutlenek siarki	–	++	++	–
1.7. Other gases pollution of air – Inne gazowe zanieczyszczenia powietrza	–	+	+	–
2. Physico-chemical factors – Czynniki fizyczno-chemiczne				
2.1. Solar radiation – Radiacja słoneczna	–	+	+++	+++
2.2. Nuclear radiation – Radiacja nuklearna	+	+	+	–
2.3. Thermal radiation – Radiacja termiczna	++	++	+	–
2.4. Fire – Ogień	+++	+++	+++	–
3. Physico-mechanical factors – Czynniki fizyczno-mechaniczne				
3.1. Low temperature – Niskie temperatury	–	++	+++	+++
3.2. Physical action of water – Działanie fizyczne wody (deszcz, grad, śnieg)	–	+++	+++	–
3.3. Cyclic moisture – Zmienna wilgotność	+	+++	+++	+++
3.4. Air particulars – Pyły (piasek, kurz, zanieczyszczenia)	–	+++	+++	–
3.5. Sustained loads – Obciążenia statyczne	++	++	++	++
3.6. Periodical loads – Obciążenia okresowe	++	++	++	++
3.7. Impact loads – Obciążenia dynamiczne	++	++	++	++
3.8. Rubbing – Ścieranie	++	+	+	–

Environments – Środowiska:

1. Under roof – pod dachem
2. In open air out of ground contact – na otwartej przestrzeni bez kontaktu z gruntem
3. In open air with ground contact – na otwartej przestrzeni w kontakcie z gruntem
4. In water – w wodzie

and symptomatological one (Tables 3 and 4). In tables concerning etiological classification 4 basic occurrence environments of particular wood degradation factors are mentioned, viz.: 1. under roof, 2. in open air out of ground contact, 3. in open air with ground contact, 4. in water. The occurrence frequency in particular places is marked with symbols: – no occurrence, + weak occurrence, ++ medium strong occurrence, +++ strong occurrence.

In tables of symptomatic classifications the following changes in wood have been distinguished: colour, chemical changes, micro- nad macrostructure, density, physical properties and strength. The intensity degree of changes was denoted by symbols similar to the ones in the occurrence frequency. Not all degradation factors have been recognized and worked out satisfactorily. Some of them were assumed relatively late, the views concerning other ones changed in consequence of the science progress and therefore their introduction into the classification would require some supplementary explanations.

Table 3

Biotic degradation factors – Biotyczne czynniki degradacji
Symptomatical classification – Klasyfikacja symptomatologiczna

Factors – Czynniki	Changes in wood – Zmiany w drewnie					
	Colour Kolor	Chemical Zmiany chemiczne	Microstructure Mikrostruktura	Macrostructure Makrostruktura	Density Gęstość	Physical properties Właściwości fizyczne
1. Wood destroying bacteria – Bakterie niszczące drewno						
1.1. Tunneling bacteria – Bakterie tunelowe	++	+	++	+	+	+
1.2. Cavitation bacteria – Bakterie perforacyjne	++	+	++	+	+	+
1.3. Actinomycete – Promieniowce	++	+	++	+	+	+
2. Wood staining fungi – Grzyby barwiące drewno						
2.1. Moulds (surface discoloration) – Plesnienie (zabarwienie powierzchniowe)	+++	–	–	–	–	–
2.2. Sapstain (deep discolor, element.) – Zabarwienie głębokie pigmentowe	+++	–	+	–	+	+
2.3. Sapstain (deep discolor, second.) – Zabarwienie głębokie wtórne	+++	+	+	–	+	+
3. Other staining organisms – Inne organizmy barwiące drewno	+++	–	+	–	+	–
3.1. Algae – Glony	+++	–	+	–	+	–
3.2. Lichens – Porosty	+++	–	+	–	+	–
4. Wood destroying fungi – Grzyby niszczące drewno						
4.1. Brown rot – Rozkład brunatny	+++	+++	+++	+++	+++	+++
4.2. White rot – Rozkład biały	+++	+++	+++	+++	+++	+++
4.3. Soft rot – Rozkład szary	+++	+++	+++	+++	+++	+++
5. Wood boring insects – Owady niszczące drewno	–	+	+	+++	+++	+++
6. Marine borers – Organizmy wodne	–	+	+	+++	+++	+++

Table 4

Abiotic degradation factors – Abiotyczne czynniki degradacji
Symptomatical classification – Klasyfikacja symptomatologiczna

Factors – Czynniki	Changes in wood – Zmiany w drewnie						
	Colour Kolor	Chemical Zmiany chemiczne	Microstructure Mikrostruktura	Macrostructure Makrostruktura	Density Gęstość	Physical properties Właściwości fizyczne	Strength Wytrzymałość
1. Chemical factors – Czynniki chemiczne							
1.1. Acids – Kwasy	+	++	++	++	++	++	++
1.2. Alkalis – Zasady	+	+++	+++	+++	+++	+++	+++
1.3. Oxygen and ozone – Tlen i ozon	++	+	++	+	+	+	+
1.4. Salts – Sole	+	+	+	+	+	+	+
1.5. Aerosols – Aerosole	+	+	+	+	+	+	+
1.6. Sulphur dioxide – Dwutlenek siarki	+	+	+	+	+	+	+
1.7. Other gases pollution of air – Inne gazowe zanieczyszczenia powietrza	+	+	+	+	+	+	+
2. Physico-chemical factors – Czynniki fizyko-chemiczne							
2.1. Solar radiation – Radiacja słoneczna	++	+	+	+	+	+	+
2.2. Nuclear radiation – Radiacja nuklearna	+	+	+	+	+	+	+
2.3. Thermal radiation – Radiacja termiczna	++	++	+	+	+	+	+
2.4. Fire – Ogień	+++	+++	+++	+++	+++	+++	+++
3. Physico-mechanical factors – Czynniki fizyko-mechaniczne							
3.1. Low temperature – Niskie temperatury	–	–	++	++	+	+	++
3.2. Physical action of water – Działanie fizyczne wody (deszcz, grad, śnieg)	+	–	++	++	+	+	+
3.3. Cyclic moisture – Zmienna wilgotność	+	–	++	++	+	+	–
3.4. Air particular – Pyły (piasek, kurz, zanieczyszczenia)	+	–	++	+++	+	+	–
3.5. Sustained loads – Obciążenia statyczne	–	–	+	+	–	–	+
3.6. Periodical loads – Obciążenia okresowe	–	–	+	+	–	–	+
3.7. Impact loads – Obciążenia dynamiczne	–	–	+	+	–	–	+
3.8. Rubbing – Ścieranie	+	–	+	+	–	+	+

BIOTIC FACTORS

Bacteria as wood degradation factor were distinguished for the first time by J. Liese [40]. However it was not before much later that one explained their mechanism of functioning on wood taking into consideration experimental investigations under controlled conditions [28, 38]. Microstructure differences of wood allowed to divide proper bacteria into two groups: cavitation and tunnelling bacteria [48, 49]. There are also some important proofs for degrading effect of actinomycetes. In soil and water conditions numerous actinomycetes cause the cellulose decomposition and microstructure changes [3, 34, 53]. Both proper bacteria and actinomycetes occurring in wood require more detailed recognition with regard to their species composition.

Occurrence of wood-colouring fungi belongs to particularly tiresome problems in the forestry and wood industry. Hitherto classifications [12, 62] are based on ecological differences of the substrate, i.e. wood, not considering to a full extent etiological differences. At present the fungi are divided into ones causing superficial colouring, so-called moulding and relative colouring comprising often the whole sapwood and sometimes also parts of heartwood (blueing, browning ect.). In the framework of the first group hitherto inconsidered microorganisms, such as *Myxomycotina* [10, 37] and *Zygomycotina* [8] were introduced. In the second group division into two subgroups was performed. To the first subgroup colouring fungi developing exclusively on freshly cut wood with initial moisture (mainly of the *Ceratocystis* species) were assigned. In the second subgroup species developing in wood with secondary moistening, but also in fresh wood are considered. The occurrence of wood decomposing fungi is satisfactorily recognized and classified into white and brown rot caused by fungi of the *Basidiomycotina* subgroup and soft rot caused by *Ascomycotina* and *Deuteromycotina* [47, 59].

Also airborne (aerophytic) algae and crust lichens not considered hitherto as wood degradation factors have been included into the classification. Numerous examples of overgrowing wood with these organisms on timber yards and in constructions on in open air, particularly on ancient structures, induced the author to assume them as degradation factors causing steady superficial colouring of wood [5, 36].

ABIOTIC FACTORS

Abiotic factors of the wood degradation and the character of their effect are recognized to a less degree. Wood in open air undergoes usually the action of manifold factors connected with atmosphere and environment. They affect wood mostly in a complex way, leading to chemical, physicochemical and physico-mechanical changes, known in the literature as weathering factors [2, 20, 44]. The composition and share of different factors in this process depend

on the environment. It seems to be significant recognize the effect of particular elements of the above phenomenon.

The effect of acids and bases on the wood tissue is connected with specific media, most often of the chemical industry and has been recognized relatively well [18, 52, 58, 64, 66, 69].

Wood staying for a long time in the open air undergoes the effect of normal air elements: oxygen, ozone and carbon dioxide [17, 20, 63]. Of slow action, but of more and more significant importance are aerial industrial pollutions. The main compound, occurring most often in industrialized regions and urban agglomerations degrading the wood surface is sulphur dioxide (SO_2). An important degrading role is also played by other gaseous compounds, such as NO_2 , chlorine, ammonia and also aerosols [9, 30, 31].

The effect of salt on wood was recognized mainly with regard to salt wood preservatives means [63, 68, 70] or to natural salines [42]. The solar radiation and, first of all, ultraviolet radiation constitutes a proved factors of the wood degradation. Wood is pervious 0.02 of visible light and 0.28% of ultraviolet light to the depth of about 2.5 mm [11, 32]. In consequence of the ultraviolet action a photolysis of the wood tissue, i.e. photodegradation of wood occurs [16, 26, 45]. The isotopic radiation in a suitable dose leads to chemical and physico-mechanical changes of wood (radiolysis) [7, 13, 21, 57]. High temperatures (thermal radiation) and fire constitute a significant degradation factor of wood and wooden products. Their effect on chemical, physical and mechanical properties was a subject of many investigations dealing mainly with the effect of temperatures up to 180-200°C [15, 22-25 35, 54, 55, 65]. There is only scanty information about the effect of low temperatures on wood [27, 41, 50].

The water effect on wood, particularly in connection with temperature, as well as cycle moisture changes affect mainly physical properties of wood [22-25, 41, 50]. The water effect on wood is generally of physical character. Frequent swelling and shrinking caused by moisture fluctuations and a nonuniform distribution of moisture cause changes in micro- and macrostructure of cellular walls. Chemical changes occurring under the effect of water cannot occur without the share of catalysers. Similar degradation mechanism causes charges with external loads of a sustained, periodical and dynamical character as well as rubbing [33, 39].

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REFERENCES

1. Ahmed Kabir F. R., Nicholas D. D., Vasishth R. C., Barnes H. M.: Laboratory methods to predict the weathring characteristic of wood. *Holzforschung* 46 (5), 1992, 385-401.
2. Arnt U., Willeitner H.: Zum Resistenzverhalten von Holz bei natürlicher Bewitterung. *Holz Roh- Werks.* 27 (5), 1969, 179-188.
3. Baecker A. A. W., King B.: Soft rot in wood caused by *Streptomyces*. *Journ. of the Inst. of Wood Sci.* 9, 2(50), 1981, 65-71.

4. Bavendamm W.: Die Holzschäden und ihre Verhütung. Wiss. Verlagsgesellschaft MBH, Stuttgart, 1974.
5. Bech-Andersen J., Christensen P.: Studies of lichen growth and deterioration of rocks and building materials using optical methods. In: Oxley T. A., Barry S. (Eds.). *Bio-deterioration 5*. John Wiley and Sons Ltd. 1983, 568-572.
6. Becker G.: Aspects, results and trends in wood preservation. *Wood Sci. and Techn.* 8 (2), 1974, 163-183.
7. Becker G., Burmester A.: Veränderung von Holzeigenschaften durch-Strahlung. *Materialprüfung* 4 (11), 1962, 416-426.
8. Belin L. at al.: Trämögel. *Sveriges Skogsindustrieförbund*. 1984.
9. Besold G., Fengel D.: Systematische Untersuchungen der Wirkung aggressiver Gase auf Fichtenholz. *Holz Roh- Werks.* Teil 1: 41 (6), 1983, 227-232, Teil 2: 41 (7), 1983, 265-269, Teil 3: 41 (8), 1983, 333-337.
10. Buchwald G.: Pilze auf Holz – die keine sind. *Holz-Zentralblatt* 148, 1984, 2121.
11. Browne F. L., Simenson H. C.: The penetration of light into wood. *For. Prod. Jour.* 7 (10), 1957, 308-314.
12. Butin H.: Untersuchungen zur Ökologie einiger Bläuepilze an vorarbeiteten Kieferholz. *Flora* 155, 1965, 400-440.
13. Burmester A.: Holz, Kunststoff und Gammastrahlung. *Holz-Zentralblatt*, 90 (64-65), 1964, 243-244.
14. Cartwright K. S. G., Findlay W. P. K.: Decay of timber and its prevention. H. M. Stationery Office, London 1958.
15. Christoph N., Brettel G.: Untersuchungen zur Wärmedehnung von Holz in Abhängigkeit von Rohdichte und Temperatur. *Holz Roh- Werks.* 35 (3), 1977, 99-108.
16. Derbyshire H., Miller E. R.: The photodegradation of wood during solar irradiation. *Holz Roh- Werks.* 39 (8), 1981, 341-350.
17. Dick J. L., Murphey W. K.: Ozone degradation of wood surfaces. *Res. Briefs* 6 (2), 1972, 4-6, 19.
18. Evans P. D., Banks W. B.: The degradation of wood surfaces by dilute acids. *IRG on Wood Preserv. Doc. No. IRG (WP) 3326*, 1985.
19. Feist W. C.: Weathering of wood in structural uses. In: Meyer R. W., Kellog R. W. (Ed.). *Structural use of wood in adverse environments*. Van Norstrand Reinhold Co. N. York, 1982, 156-176.
20. Feist W. C.: Outdoor wood weathering and protection. In: Rowell R. M. and Barbour R. J. (Ed.). *Archeological wood: properties, chemistry and preservation. Advances in Chemistry Ser. 225*, Los Angeles, Washington, 1990, 263-298.
21. Frejdin A. S.: Effect of nuclear radiation on wood and their components. (Russ.). Goslesbumizdat, Moskau 1961.
22. Fridlay K. J., Tang R. C., Soltis L. A.: Effect of cyclic temperature on duration of board of solid lumber in bending. In: Itani R. J. (Ed.). *Proc. of the 1988 Int. Conf. on Timber Eng.* Madison 1, 1989, 390-394.
23. Fridlay K. J., Tang R. C., Soltis L. A.: Thermal effects on load-duration behaviour of lumber. Part I. Effect of constant temperature. *Wood Fiber Sci.* 21 (4), 1989, 420-431.
24. Fridlay K. J., Tang R. C., Soltis L. A.: Thermal effects on load-duration behaviour of lumber. Part II. Effect of cyclic temperature. *Wood Fiber Sci.* 22 (2), 1990, 204-216.
25. Fridlay K. J., Tang R. C., Soltis L. A.: Hydrothermal effect on mechanical properties of lumber. *Jour. Structural Engineering* 118 (2), 1992, 567-581.
26. Futo L. P.: Der photochemische Abbau des Holzes als Präparations- und Analysenmethode. *Holz Roh- Werks.* 32 (8), 1974, 303-311.
27. Gerhards C. C.: Effect of moisture content and temperature on the mechanical properties of wood: an analysis of immediate effects. *Wood Fiber Sci.* 14 (1), 1982, 4-36.
28. Greaves H.: The bacterial factor in wood decay. *Wood Sci. Techn.* 5 (1), 1971, 6-16.
29. Gorshin S. N.: Wood conservation. (Russ.). *Lesnaja Promyszlennost*, Moskwa 1977.

30. Gos B.: Physikalische und chemische Veränderungen in Kieferholz und Phenol – Resorcin – Harz infolge des Einwirkens konzentrierter aggressiver Gase. *Holztechnologie* 21 (1), 1986, 20-23.
31. Gos B.: Changes in glued wooden elements under the effect of aggressive gaseous media. (Pol.). Wyd. SGGW, Warszawa 1982, 112 pp.
32. Hon D. N. S., Ifju G.: Measuring penetration of light into wood by detection of photo-induced free radicals. *Wood Sci.* 11 (2), 1978, 118-127.
33. Karacabeyli E., Soltis L. A.: State-of-the-art report on duration of load research for lumbers in North America. In: *Proc. of the 1991 Intern. Timber Eng. Conference, London TRADA, Vol. 4, 1991, 141-155.*
34. King B., Eaton R. A., Baecker A. A. W.: A summary of current information on *Actinomyces* and wood. IRG on Wood Preserv. Doc. No. IRG (WP) 177, 1978.
35. Kollmann F., Fengel D.: Änderungen der chemischen Zusammensetzung von Holz durch thermische Behandlung. *Holz Roh- Werks.* 23 (12), 1965, 462-468.
36. Krajewski K. J., Ważny J.: Airborne algae as a wood degradation factor. IRG on Wood Preserv. Doc. No. IRG (WP) 1559-92, 1992.
37. Land C. J., Banhidi Z. G., Albertsson A. C.: Surface discoloring and blue staining by cold-tolerant filamentous fungi on outdoor softwood in Sweden. *Mater. Org.* 20 (2), 1985, 133-156.
38. Liese W., Greaves H.: Micromorphology of bacterial attack of wood. In: W. Liese (Ed.). *Biological transformation of wood by microorganisms.* Springer, 1975, 74-88.
39. Link C. L.: Statistical considerations in duration of load research. *Research Paper FPL – RP – 487, 20 pp, 1988.*
40. Mahlke Troschel, Liese. *Handbuch der Holzkonservierung.* Springer, Berlin, Göttingen, Heidelberg 1950.
41. Matejak M., Starecka D.: Einfluss des Gefrierens von Holz auf seine Druckfestigkeit. *Holztechnologie* 12 (3), 1971, 144-146.
42. Matejak M., Wilczek-Zielińska T.: Das Altern von Holz unter dem Einfluss von Salzwasser. *Holzforschung und Holzverwertung* 38 (1), 1986, 7-11.
43. Metzner W., Bellmann H.: Holzschutz. In: *Ullmanns Enzyklopädie der technischen Chemie. Bd. 12.* Verlag Chemie GmbH, Weinheim, 1976, 685-702.
44. Meyer R. W., Kellogg R. M.: Use conditions for wood – thoughts from the adverse environments Symposium. In: Lyon D. E. and Galligan W. L. (Eds.) *How the environment effect lumber design: assessment and recommendations.* USDA Forest Service, Madison 1980, 20-33.
45. Mon-lin Kuo Ninghe Hu.: Ultrastructural changes of photodegradation of wood surfaces exposed to UV. *Holzforschung* 45 (5), 1991, 347-353.
46. Nicholas D. D. (Ed.): *Wood deteriorations and its prevention by preservative treatments.* Syracuse University Press 1973.
47. Nilsson T.: Defining fungal decay types – final proposal. IRG on Wood Preserv. Doc. No. IRG (WP) 1355, 1988.
48. Nilsson T., Daniel G.: Tunnelling Bacteria. IRG on Wood Preserv. Doc. No. IRG (WP) 1186, 1983.
49. Nilsson T., Singh A. P.: Cavitation Bacteria. IRG on Wood Preserv. Doc. No. IRG (WP) 1235, 1984.
50. Noack D., Geissen A.: Einfluss von Temperatur und Feuchtigkeit auf den E-Modul des Holzes im Gefrierbereich. *Holz Roh- Werks.* 34(2), 1976, 55-62.
51. Raczkowski J.: Der Einfluss von Feuchtigkeitsänderungen auf das Kriechverhalten des Holzes. *Holz. Roh- Werks.* 27 (6), 1969, 232-237.
52. Rowell R. M.: Influence of chemical environment on strength of wood fiber. In: Lyon D. E. and Galligan, W. L. (Eds.). *How the environment effects lumber design. Assessments and Recommendations,* USDA Forest Service Madison 1980, 76-84.
53. Safo-Sampah S., Wilcox W. W.: The role of actinomycetes in the terrestrial degradation of wood. *For. Prod. Journ.* 38 (1), 1988, 42-46.

54. Sandermann W., Augustin H.: Chemische Untersuchungen über die thermische Zersetzung von Holz. Erste Mitt.: Stand der Forschung. Holz Roh- Werks. 21 (7), 1963, 256 - 265.
55. Schaffer E. L.: Influence of heat on the longitudinal creep of dry Douglas-fir. In: Meyer R. W. and Kellog R. M. (Eds.). Structural use of wood in adverse environments, 1982, 20 - 52.
56. Schmidt O., Kerner-Gang W.: Natural materials. In: Rehm H. J. and Reed G. (Eds.). Biotechnology, Vol. 8 VCH Verlagsgesellschaft, Weinheim, 1986, 559 - 592.
57. Seifert K.: Zur Chemie gammabestrahlten Holzes. Holz Roh- Werks. 22 (7), 1964, 267 - 275.
58. Seifert K.: Der chemische Einfluss schwach sauren milieus auf die Holzsubstanz. Holz Roh- Werks. 25 (7), 1967, 265 - 267.
59. Seifert K.: Zur Systematik der Holzfäulen, ihre chemischen und physikalischen Kennzeichen. Holz Roh- Werks 26 (6), 1968, 208 - 215.
60. Sell J.: Grundsätzliche Anforderungen an Oberflächenbehandlungen für Holz im Aussenbau. Holz Roh- Werks. 33 (9), 1975, 336 - 340.
61. Smith R. S.: Destructive agencies of wood - Fungi. Proc. AWPA 70, 1974, 81 - 88.
62. Tarociński E.: Problems of protecting pine sawn timber and lumber against blue-staining. (Pol.). Prace ITD 17,2 (54), 1970.
63. Thompson W. S.: Effect of chemicals, chemical atmospheres and contact with metals on southern pine wood: A review. Misissippi For. Prod. Lab. Research Rpt. No. 6, 33 pp, 1969.
64. Thompson W. S.: Adverse environments and related design considerations - Chemical effects. In: Meyer R. W. and Kellog R. M. (Eds.). Structural use wood in adverse environments. Van Nostrand Reinhold Co. N. York 1982, 117 - 129.
65. T o p f P.: Die thermische Zersetzung von Holz bei Temperaturen bis 180 C. Erste Mitteilung: Stand der Forschung. Holz Roh- Werks. 29 (7), 1971, 269 - 275.
66. Wangaard F. F.: Resistance of wood to chemical degradation. For. Prod. Journ. 16 (2), 1966, 53 - 64.
67. Ważny J.: Basis research in the pathology and wood protection in the Polish People's Republic. (Pol.). Sylwan 121 (11), 1977, 7 - 18.
68. Ważny J., Krajewski K. J.: Untersuchungen über den Einfluss von Holzschutzmitteln auf die Druck- und Biegefestigkeit des Kiefernholzes. Holztechnologie 28 (5), 1987, 239 - 243.
69. Williams R. S.: Effect of acidic deposition on painted wood. A review Journ. of Coatings Technology 63 (1), 1991, 53 - 73.
70. Winandy J. E.: Effect of treatment and redrying on mechanical properties of wood. In: Hamer M. (Ed.). Wood protection techniques and the use of treated wood in construction. Proc. No. 4735, For. Prod. Res. Soc. Madison, 1988, 54 - 62.

WSPÓŁCZESNA KLASYFIKACJA CZYNNIKÓW DEGRADACJI DREWNA

Streszczenie

Przedstawiona została współczesna klasyfikacja biotycznych i abiotycznych czynników degradacji drewna w dwóch aspektach: etiologicznym i symptomatologicznym.

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