# Biodiversity of Fungi, Causing Wood Biodeterioration In Buildings In Poland Against The Background Of Research Conducted In Other European Countries.

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## Abstract

The paper presents the results of surveys on the diversity of wood-destroying fungi in buildings and wooden engineering structures outdoors in Poland. The respondents reported a total of 48 species and genus of wood-degrading *Basidiomycetes*. The greatest species diversity of wood-degrading fungi was found on open-air engineering structures (33 species), the second location in terms of biodiversity was unused residential buildings (30 species), the lowest biodiversity was found in the used residential buildings (21 species).The most common fungi in the buildings were *Serpula lacrymans* (24.8%), *Coniophora puteana* (14.1%) and *Fibroporia vaillantii* (13.8%). The prevalence of *S. lacrymans* and *C. puteana* in buildings in Poland is similar to the European average. The occurrence of indoor polypores group (*Amyloporia sinuosa, Fibroporia vaillantii, Neoantrodia serialis*) in Poland is twice as high as the European average. *Donkioporia expansa*, which is numerous in buildings in Western Europe, is sporadically recorded in Poland (0.1%).


## Introduction

Due to its high strength (load-bearing capacity), insulation, durability and low carbon footprint, wood is an important structural material used in construction. However, if not properly protected, it is subject to degradation by a number of biotic agents. Fungi are one of the main groups contributing to the degradation of wooden buildings.

House-rot fungi are not species specialized in wood degradation exclusively in buildings. They are typical species of saprotrophic fungi inhabiting dead wood in forests or outdoors, and they colonize building materials in buildings due to the creation of conditions conducive to their development. This happens, among others, as a result of errors made at the design stage, during construction or operation of buildings. These species then populate the wood in building structures in accordance with their natural preferences in terms of temperature and humidity, for example fungi decomposing fallen trees and stumps can often be observed in damp and cool basements.

In the northern hemisphere, mainly coniferous wood is used as structural timber. This makes brown decay fungi the main group of fungi causing the most economic damage to European and North American buildings (Shmidt and Huckfeldt 2011). Wood attacked by fungi, as a result of progressive decay, loses its original properties. The mechanical strength of structural timber is then reduced, resulting in serious building failures or disasters.

In the world literature, the term house-rot fungi and dry-rot fungi is used exclusively for wood destroying fungi in buildings. Fungi destroying stored wood and structural timber outdoors constitute a separate group. In Poland, with separate in this respect traditions of classification of fungi destroying structural timber indoors and outdoors dating back to the 1930s. (Skupieński 1937), species destroying structural timber indoors, structural timber outdoors and stored wood are referred to as "house-rot fungi". The first classification of house-rot fungi, published after World War II, was presented by Ważny (1951). It was modified by Ważny for a number of years (1956, 1958, 1963, 1970, 1983). The latest version of this classification (Table 1) was published in 2001 (Ważny 2001). Publications by other authors, which appeared in later years (Krajewski and Witomski 2012, Karyś 2014) did not introduce any changes to the Ważny 2001 classification. Thus, despite the passage of years, the last update of the classification of house fungi according to Ważny is still considered current and valid in Poland. This is due, among other things, to the fact that this classification includes the location of damage caused by the fungus, developed on the basis of reliable field studies.

Table 1
Classification of house-rot fungi (Ważny 2001).

| Name | Occurrence in Poland |
|---|---|
| **Group I - fungi growing after infection also on dry wood, causing strong and rapid decay of wood on large areas** | |
| *Serpula lacrymans* (Wulfen) J. Schröt | almost only in buildings, rarely on lumber yards, more often in mines |
| **Group II - fungi growing on wood with elevated humidity, causing strong and rapid decay of wood on large areas** | |
| *Coniophora puteana* (Schumach.) P. Karst. | in buildings, in mines, less often on lumber yards and on railway sleeper |
| *Fibroporia vaillantii* (DC.) Parmasto | in buildings, in mines, in greenhouse, on lumber yards, on bridge structural timber and on railway sleepers |
| *Tapinella panuoides* (Fr.) E.-J. Gilbert | in buildings (on roof, on ceilings, on roof truss) on lumber yards, on railway sleepers, in mines |
| **Group III - fungi less harmful in buildings, but very harmful in open on structural timber outdoors, characterized by nesting occurrence** | |
| *Neolentinus lepideus* (Fr.) Redhead &Ginns | on poles, on railway sleepers, in buildings (on ceiling beams, on roof truss, on log walls, on timber framed houses/on half-timbering walls) and outdoor utility buildings e.g. barns, sheds, wood depots etc. |
| *Gloeophyllum sepiarium* (Wulfen) P. Karst. | on lumber yards in mills, on poles, on railway sleeper, on wooden bridges, on fence, in buildings (on ceilings, on roof truss, on log walls, on timber framed houses/half-timbering walls, on terraces and balconies |
| *Neoantrodia serialis* (Fr.) Audet | on lumber yardsstore, on railway sleeper, on mines, in building (in ceiling, on roof truss, on rafters, on timber framed houses/half-timbering walls, on log walls and structures) |
| *Daedalea quercina* (L.) Pers. | less often in buildings (kitchen flooring and window sill), on lumber yardsstore, on railway sleepers |
| *Trametes versicolor* (L.) Lloyd | on lumber yardsstore, on poles, in buildings |
| **Group IV - slightly harmful fungi, causing weak surface decay of wood, developing in high humidity** | |
| *Phlebiopsis gigantea* (Fr.) Jülich | on lumber yardsstore, in buildings (on ceiling beams, on roof truss, on wooden walls) |
| *Cylindrobasidium laeve* (Pers.) Chamuris | on lumber yardsstore, in new building (on roof truss, on wooden walls), on boardings, on truss |

Only the most important species are discussed in national monographs on wood-destroying fungi indoors and outdoors. Thus, the list of house-rot fungi in domestic monographs is limited to 8–13 species. In contrast, 6–26 species of house-rot fungi are discussed in foreign monographs (Table 2). A higher number of species discussed in foreign monographs is connected, among others, with more frequent use of hardwood in construction (Andres et al. 2019).

Table 2

List of house-rot fungi from the class *Basidiomycetes* discussed in domestic and foreign monographs (Andres et al. 2019) (● - species described in

| **The species** | **Skupieński 1937** | **Orłoś 1950** | **Ważny 1951** | **Kochman 1951** | **Orłoś 1952** | **Ważny 1956** | **Ważny 1958** | **Ważny 1963** | **Ważny 1970** | **Ważny 1983** | **Kozarski 1992** | **Grzywacz 1997** | **Koz 199** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| *Alutaceodontia alutacea* | ● | | | | | | | | | | | | |
| *Amyloporia sinuosa* | ● | | | | | | | | | | ● | ● | ● |
| *Amyloporia xantha* | | | | ● | ● | | | | | | | | |
| *Armillaria mellea* s.l. | ● | | | | | | | | | | | | |
| *Asterostroma cervicolor* | | | | | | | | | | | | | |
| *Asterostroma laxum* | | | | | | | | | | | | | |
| *Ceriporiopsis mucida* | ● | | | | | | | | | | | | |
| *Cinereomyces lindbladii* | | | | | | | | | | | | | |
| *Coniophora arida* | | | | | ● | | | | | | | | |
| *Coniophora fusispora* | | | | | ● | | | | | | | | |
| *Coniophora marmorata* | | | | | | | | | | | | | |
| *Coniophora olivacea* | | | | | | | | | | | | | |
| *Coniophora puteana* | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| *Coprinus sp.* | | | | | | | | | | | | | |
| *Cylindrobasidium laeve* | | | ● | ● | ● | ● | ● | ● | ● | ● | | ● | |
| *Dacrymyces stillatus* | | | | | | | | | | | | | |
| *Daedalea quercina* | ● | ● | | | | ● | ● | | ● | ● | ● | ● | ● |
| *Donkioporia expansa* | | | ● | | | | | | | | | | |
| *Fibroporia vaillantii* | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | | | |
| *Fomitopsis pinicola* | | | | | | | | | | | ● | | ● |
| *Gloeophyllum abietinum* | ● | | | | | | | | | | | | |
| *Gloeophyllum sepiarium* | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| *Gloeophyllum trabeum* | | | | | | | | | | | ● | ● | ● |
| *Laetiporus sulphureus* | | | | | | | | | | | ● | | |
| *Leucogyrophana mollusca* | | | | | | | | | | | | | |
| *Leucogyrophana pinastri* | ● | ● | ● | | | | | | | | | | |
| *Leucogyrophana pulvulenta* | | | | | | | | | | | | | |

| The species | Skupieński 1937 | Orłoś 1950 | Ważny 1951 | Kochman 1951 | Orłoś 1952 | Ważny 1956 | Ważny 1958 | Ważny 1963 | Ważny 1970 | Ważny 1983 | Kozarski 1992 | Grzywacz 1997 | Koz 199 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Meruliporia incrassata* | | | | | ● | | | | | | | | |
| *Neoantrodia serialis* | | | | | | ● | | ● | ● | ● | | ● | |
| *Neolentinus lepideus* | ● | ● | ● | | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| *Perenniporia medulla-panis* | | | | | ● | | | | | | | | |
| *Phellinus ferruginosus* | | | | | | | | | | | | | |
| *Phellinus pini* | | | | | | | | | | | ● | | |
| *Phlebia serialis* | | | ● | | | ● | | | | | | | |
| *Phlebiopsis gigantea* | | | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | |
| *Rhodonia placenta* | | | | | | | | | | | | | |
| *Schizophyllum commune* | | | | | | ● | | | | | | ● | |
| *Serpula himantioides* | | ● | | | | | | | | | | | |
| *Serpula lacrymans* | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| *Serpula tignicola* | ● | ● | ● | | | | | | | | | | |
| *Tapinella panuoides* | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| *Trametes versicolor* | ● | | | | | ● | ● | | ● | ● | ● | ● | |
| *Trechispora nivea* | ● | | | | | | | | | | | | |

However, the species diversity of indoor wood-decay fungi is much higher, as evidenced by numerous articles presenting the results of field studies carried out in Europe. Alfredsen et al. (2005) presented a list of 31 species and genera of indoor decay fungi in southern Norway. Schmidt (2007) presented a list of 74 species and genera of wood-infesting fungi in buildings in Germany. Fraiture (2008) presented a list of 101 species and genera of indoor wood-decay fungi in Belgium. Irbe te al. (2008) presented a list of 23 species of wood infesting fungi in historic buildings in Macedonia. Vampola (2008) presented a list of 40 species of indoor wood-decay fungi in the Czech Republic. Schmidt and Hunckfield 2011 presented a list of 117 species and genera of indoor wood-decay fungi in Germany. Irbe et al. (2012) presented a list of 46 species and genera of fungi destroying the exterior of wooden buildings in Latvia. Haas et al. (2018) presented a list of 40 species of fungi infesting wood in buildings in Styria (Austria).

Modern constructional and material solutions, currently used in newly constructed and old - renovated buildings, should reduce the risk of favorable conditions for the development of house-rot fungi. On the other hand, some conceptual and design solutions, which do not take into account the climatic conditions prevailing in the country, as well as striving for maximum reduction of investment implementation time, combined with the use of old (wet) technologies, promote the occurrence of favorable conditions for the development of indoor fungi. The above-mentioned features of the modern construction industry, which increase the risk of fungal infestation of buildings, have led the authors of this publication to conduct a survey on the biodiversity of indoor wood-decay fungi and fungi of structural timber outdoors. The aim of this work was to review and update the status of biodiversity of indoor wood-decay fungi in Poland and then to compare the results obtained with those of other European studies.

## Materials And Methods

A web-based questionnaire was conducted in late 2019 and early 2020 to update the list of house-rot fungi currently found during mycological and building surveys. A questionnaire was created and made available to respondents through the use of the web. The questionnaire asked respondents about 21 species of fungi, selected on the basis of current publications discussing the occurrence of house-rot fungi in Europe. These species were selected on the basis of their frequency of occurrence in the buildings of Central-Western Europe and on the basis of own observations made during mycological and building surveys in Poland. Before answering the question on the frequency and location of the fungus species, the respondent could read a note containing: the technical name, a synonym of the current Latin name, and a brief description of morphological structures of the fungus. When answering the questionnaire about the frequency of occurrence, the respondent had to choose one of the following answers: very often (more than 50% of observations), often (up to 50% of observations), rarely (up to 25% of observations), occasionally (up to 5% of observations), or not found. Additionally, there was one open question, in which the respondent could provide the species of fungi found, and which were not included in the questionnaire.

After determining the frequency of occurrence of a given species, the respondent had the opportunity to indicate the type of object in which they found morphological structures of the fungus. When answering this question, one or more answers could be chosen from: residential buildings in use, residential buildings not in use, utility buildings not heated, outdoor engineering structures, other (with a place to write in the answer).

The target group of respondents were mycological and mycological-construction experts as well as mycological-construction specialists associated in Polish Association of Building Mycologists (PABM). All members of this group had appropriate, certified specialist knowledge in the field of building mycology, so they represented appropriate population for this study. Information about the survey was posted on the PABM website and social media, which resulted in the participation of mycologists associated in the Polish Mycological Society (PMS).

In this publication the names of fungi are provided according to the systematics updated on a regular basis in Index Fungorum database (indexfungorum.org).

## Results And Discussion

Based on the internet search conducted, the number of building mycologists actively performing expert reports in 2019 was determined to be 100. For the assumed confidence interval ($\alpha = 0.95$), it was calculated that collecting 81 questionnaires from respondents would guarantee a study statistical error of 5%. The study involved 73 respondents, so the statistical error was 6%. All questionnaires were filled out correctly, i.e. there were no logical errors. The results of the questionnaire are presented in Table 3. The table shows the total frequency of fungi occurrence in the inspected objects divided into object categories, in which fungal morphological structures were detected. The fungi were ordered in terms of the total frequency of occurrence in the buildings.

Table 3
Summary frequency of fungi in control sites and locations of fungal morphological structures.

| **Genera and species name** | **decay** | **frequency[%]** | **locations [%]** | | | | |
|---|---|---|---|---|---|---|---|
| | | | **BU** | **UB** | **OB** | **ST** | **OL** |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| *Serpula lacrymans* (Wulfen) J. Schröt | brown | 36.6 | 32.5 | 34.9 | 23.2 | 0.0 | 9.4 |
| *Coniophora puteana* (Schumach.) P. Karst. | brown | 25.1 | 15.8 | 31.5 | 21.1 | 15.8 | 15.8 |
| *Fibroporia vaillantii* (DC.) Parmasto | brown | 22.8 | 30.0 | 30.0 | 27.5 | 12.5 | 0.0 |
| *Phlebiopsis gigantea* (Fr.) Jülich | white | 13.6 | 12.5 | 21.9 | 31.2 | 21.9 | 12.5 |
| *Serpula himantioides* (Fr.) P. Karst. | brown | 10.9 | 15.8 | 31.6 | 21.1 | 15.8 | 15.7 |
| *Amyloporia sinuosa* (Fr.) Rajchenb., Gorjón & Pildain | brown | 10.8 | 24.3 | 32.4 | 21.6 | 13.5 | 8.1 |
| *Gloeophyllum sepiarium* (Wulfen) P. Karst. | brown | 11.1 | 12.5 | 12.5 | 18.8 | 43.7 | 12.5 |
| *Neoantrodia serialis* (Fr.) Audet | brown | 8.2 | 13.8 | 24.1 | 24.1 | 27.6 | 10.3 |
| *Tapinella panuoides* (Fr.) E.-J. Gilbert | brown | 6.9 | 18.2 | 30.3 | 21.2 | 18.2 | 12.1 |
| *Schizophyllum commune* Fr. | white | 6.0 | 8.3 | 0.0 | 0.0 | 50.0 | 41.6 |
| *Cylindrobasidium laeve* (Pers.) Chamuris | white | 5.9 | 22.6 | 25.8 | 25.8 | 12.9 | 12.9 |
| *Gloeophyllum trabeum* (Pers.) Murrill | brown | 5.3 | 9.5 | 19.0 | 23.8 | 33.3 | 14.3 |
| *Gloeophyllum abietinum* (Bull.) P. Karst. | brown | 4.3 | 18.8 | 18.8 | 18.8 | 25.0 | 18.8 |
| *Neolentinus lepideus* (Fr.) Redhead & Ginns | brown | 4.1 | 11.5 | 11.5 | 19.2 | 42.3 | 15.5 |
| *Trametes versicolor* (L.) Lloyd | white | 3.7 | 0.0 | 0.0 | 7.7 | 61.6 | 30.7 |
| *Amyloporia xantha* (Fr.) Bondartsev & Singer | brown | 3.1 | 22.2 | 33.3 | 16.7 | 16.7 | 11.1 |
| *Stereum hirsutum* (Willd.) Pers. | white | 2.7 | 0.0 | 0.0 | 0.0 | 50.0 | 50.0 |
| *Daedalea quercina* (L.) Pers. | brown | 1.9 | 5.0 | 20.0 | 10.0 | 40.0 | 25.0 |
| *Asterostroma cervicolor* (Berk. & M.A. Curtis) Massee | white | 1.0 | | x | | | |
| *Hypholoma fasciculare* (Huds.) P. Kumm. | white | 1.0 | | | | x | |
| *Leucogyrophana pinastri* (Fr.) Ginns & Weresub | brown | 0.6 | 25.0 | 25.0 | 25.0 | 0.0 | 25.0 |
| *Coprinus spp.* | white | 0.6 | x | x | x | | |
| *Peziza spp.* (*Ascomycota*) | - | 0.6 | | x | | | |
| *Rhodonia placenta* (Fr.) Niemelä, K.H. Larss. & Schigel | brown | 0.6 | 14.3 | 28.6 | 28.6 | 14.3 | 14.3 |
| *Laetiporus sulphureus* (Bull.) Murrill | white | 0.3 | | | x | | |
| *Fuscoporia contigua* (Pers.) G. Cunn. | white | 0.3 | | x | | | |
| *Pholiota spp.* | white | 0.3 | | | | x | |
| *Pluteus spp.* | white | 0.3 | | | | x | |
| *Donkioporia expansa* (Desm.) Kotl. & Pouzar | white | 0.2 | 25.0 | 50.0 | 0.0 | 0.0 | 25.0 |
| *Trichaptum fuscoviolaceum* (Ehrenb.) Ryvarden | white | 0.2 | | x | | | x |
| *Hyphodontia ssp.* | white | 0.2 | | x | | x | |
| *Armillaria mellea* (Vahl.) P. Kumm. *s.l.* | white | 0.1 | | | x | | |
| *Chondrostereum purpureum* (Pers.) Pouzar | white | 0.1 | | x | | x | |
| *Coniophora arida* (Fr.) P. Karst. | brown | 0.1 | | | | | x |
| *Daedaleopsis confragosa* (Bolton) J. Schröt. | white | 0.1 | | | | x | |
| *Fomitopsis pinicola* (Sw.) P. Karst. | brown | 0.1 | | x | | | |
| *Fuscoporia contigua* (Pers.) G. Cunn. | brown | 0.1 | | x | | | |
| *Heterobasidion annosum* (Fr.) Bref *s.l.* | white | 0.1 | | | | | x |

BU -buildings used, UB – unused buildings, OB – other buildings (shed, woodshelter, etc.), ST – structural timber outdoor, OL – other location.

| Genera and species name | decay | frequency[%] | locations [%] | | | | |
|---|---|---|---|---|---|---|---|
| | | | BU | UB | OB | ST | OL |
| *Mycena galericulata* (Scop.) Gray | white | 0.1 | | | | x | |
| *Pleurotus spp.* | white | 0.1 | | x | | | |
| *Pseudomerulius aureus* (Fr.) Jülich | brown | 0.1 | | | | x | |
| *Pycnoporus cinnabarinus* (Jacq.) P. Karst. | white | 0.1 | | | | x | |
| *Rhodofomes roseus* (Alb. & Schwein.) Kotl. & Pouzar | brown | 0.1 | | x | | | |
| *Stereum rugosum* Pers. | white | 0.1 | | | | x | |
| *Trametes gibbosa* (Pers.) Fr. | white | 0.1 | | | | x | |
| *Trametes ochracea* (Pers.) Gilb. & Ryvarden | white | 0.1 | | | | x | |
| *Trametes trogii* Berk. | white | 0.1 | | | | x | |
| *Trechispora farinacea* (Pers.) Liberta | white | 0.1 | | x | | | |
| *Volvariella bombycina* (Schaeff.) Singer | white | 0.1 | | x | | x | |

BU -buildings used, UB – unused buildings, OB – other buildings (shed, woodshelter, etc.), ST – structural timber outdoor, OL – other location.

Respondents reported a total of 48 species and genera of wood-decaying *Basidiomycetes*, of which 58.3% caused white decay. The highest species diversity of wood-decaying fungi was found on outdoor structures (33 species). The second location in terms of biodiversity was unused residential buildings (30 species). The lowest biodiversity was found in used residential buildings (21 species). Analogically, results concerning "new" species, i.e. not included in the classification of house-rot fungi according to Ważny (2001) were presented. The greatest number of "new" fungal species was found on structures used outdoors (23 species.). In unused residential buildings 20 "new" species were found, and in used residential buildings and farm buildings 11 "new" species each. In their questionnaires, respondents reported 13 "new" species found in other than the above-mentioned locations. Among all the "new" species, white-rot fungi had a significant share.

The frequency of occurrence of each fungal species was determined by calculating the weighted mean of the answers provided by the respondents. The frequency of occurrence of particular species in the expert reports carried out by the respondents, presented in Table 1, is a relative percentage share in the fungal infestation of the buildings, resulting, among others, from the specialization of some of the respondents (e.g. performing expertises mainly in sacral buildings, only in historic buildings, etc.). Therefore, the sum of column 3 does not constitute 100%.

The fungi *S. lacrymans, C. puteana* were frequently found by the respondents while performing mycological and building expertise of the fungus infested objects (frequency of occurrence ranging from 25.1–50.0%), with *S. lacrymas* being noted most frequently. Both of the aforementioned species are considered the most important house-rot fungi (Ważny 2001, Krajewski and Witomski 2012, Karyś 2014), and therefore are widely discussed in national book publications on this group of fungi. No "new" species, i.e., not included in the classification of house-rot fungi according to Ważny (2001), were found. Among the species rarely occurrring in the controlled objects (5.1–25.0%), the following species described in the national manuals were observed: *F. vaillantii, Ph. gigantea, G. sepiarium, N. serialis, T. panuoides* and *C. laeve*. At the same time, 6 "new" species, not discussed in non-serial publications on house-rot fungi, were recorded in this group, i.e.: *S. himantioides, A. sinuosa, G. trabeum and S. commune*. Among the fungi rarely found on the controlled sites (≥ 5%), the largest number of "new" fungi was found, i.e. 31 species and genera. The most interesting of this group included the following species: *A. cervicolor, A. xantha, D. expansa, L. pinastri, F. contigua*, and *R. roseus*.

Table 1 (columns 4–8) can be used to track which buildings were most frequently infested by each fungal species. In the case of species entered by respondents (fungi outside the list of 21 species included in the questionnaire), Table 1. does not show their percentage occurrence in each category, but only indicates these categories by inserting an "x". The OL (other locations) category, which was completed by respondents, proved to be the most diverse. Respondents mainly entered the following locations: non-sacred historic buildings, churches, structures on forested land, mines, lumber yardsstores, railroad sleepers, and others.

The results of field investigations published in the form of articles generally present a much broader spectrum of wood-decaying fungi in buildings than it is described in monographs. There are relatively few national publications (articles) on the species diversity of house-rot fungi because for over 40 years no data on the occurrence of wood-decaying fungi in buildings were published in Poland. Few publications refer to selected areas of Poland (Ważny and Czajnik 1973, Ważny and Czajnik 1974a,b, Konarski 1974), or focus on a specific category of objects (Ważny and Czajnik 1963a, Ważny et al. 1999, Andres 2011). Only the publication by Ważny and Czajnik (1963b) provides data for the entire country, covering both buildings and outdoor structures. This publication lists 26 fungal species (including 57.1% brown decay fungi and 35.7% white decay fungi). In addition to the species frequently recorded in buildings, rarer species, such as *A. sinuosa, A. xantha, G. abietinum* and *G. trabeum, D. expansa, L. pi-nastri, R. roseus*, and others, also appeared in this publication. The total number of observations of brown decay fungi in buildings was 95.4%, while that of white decay fungi was 35.7%. In order to compare the results of the questionnaire with domestic and foreign publications, the results obtained were compared with the total number of fungi observed by the respondents (Table 4).

Table 4. Prevalence of [%] wood-decaying fungi in buildings (acc to the authors mentioned below).

| Genera and species name | Poland[a] | Germany[b] | Germany[c] | Belgium[d] | Norway[e] | Poland[f] |
|---|---|---|---|---|---|---|
| 1 | 2 | 4 | 6 | 5 | 6 | 7 |
| *Antrodia spp.* | - | 3.6 | 9.4 | 0.7 | 18.4 | - |
| *Amyloporia sinuosa* (Fr.) Rajchenb., Gorjón & Pildain | 9.4 | 1.6 | 1.0 | - | - | 6.4 |
| *Amyloporia xantha* (Fr.) Bondartsev & Singer | 0.5 | 1.5 | 2.0 | 0.4 | - | 1.6 |
| *Antrodia gossypium* (Speg.) Ryvarden | 0.2 | 0.1 | > 0.1 | > 0.1 | - | - |
| *Armillaria mellea* (Vahl.) P. Kumm. *s.l.* | 0.1 | - | - | - | - | 0.1 |
| *Asterostroma spp.* | - | - | - | 4.6 | - | - |
| *Asterostroma cervicolor* (Berk. & M.A. Curtis) Massee | - | 2.4 | 2.4 | 0.4 | 0.2 | 0.7 |
| *Asterostroma laxum* Bres. | - | 0.1 | 0.2 | - | - | - |
| *Coniophora spp.* | - | - | - | 7.8 | - | - |
| *Coniophora arida* (Fr.) P. Karst. | - | 0.3 | 0.2 | 0.4 | - | 0.2 |
| *Coniophora puteana* (Schumach.) P. Karst. | 22.5 | 14.6 | 15.5 | 0.7 | 16.3 | 14.1 |
| *Coprinus spp.* | - | 3.1 | 3.5 | 0.7 | 0.1 | 0.4 |
| *Coriolopsis trogii* (Berk.) Domański | - | - | - | - | - | 0.1 |
| *Cylindrobasidium laeve* (Pers.) Chamuris | 1.6 | 0.3 | 0.2 | - | 0.1 | 3.3 |
| *Daedalea quercina* (L.) Pers. | 0.1 | - | - | - | - | 0.6 |
| *Daedaleopsis confragosa* (Bolton) J. Schröt. | - | - | - | - | - | 0.1 |
| *Donkioporia expansa* (Desm.) Kotl. & Pouzar | 0.1 | 10.0 | 8.8 | 15.5 | - | 0.1 |
| *Fibroporia vaillantii* (DC.) Parmasto | 1.9 | 3.1 | 1.4 | - | - | 13.8 |
| *Fomitopsis pinicola* (Sw.) P. Karst. | 0.1 | 0.1 | - | - | > 0.1 | 0.1 |
| *Fuscoporia contigua* (Pers.) G. Cunn. | - | 1.1 | 0.9 | 2.8 | - | 0.1 |
| *Gloeophyllum spp.* | - | 2.0 | 0.8 | - | - | - |
| *Gloeophyllum abietinum* (Bull.) P. Karst. | - | 1.5 | 1.6 | - | - | 1.9 |
| *Gloeophyllum sepiarium* (Wulfen) P. Karst. | 1.6 | 1.6 | 1.0 | - | 2.9 | 4.4 |
| *Gloeophyllum trabeum* (Pers.) Murrill | - | 0.7 | 1.0 | 0.4 | - | 2.1 |
| *Heterobasidion annosum* (Fr.) Bref *s.l.* | 0.1 | 0.1 | 0.1 | - | - | 0.1 |
| *Hypholoma fasciculare* (Huds.) P. Kumm. | - | - | - | - | - | 0.1 |
| *Hyphodontia ssp.* | - | | | > 0,1 | - | 0.1 |
| *Hyphodontia alutaria* (Burt) J. Erikss. | - | 0.1 | > 0.1 | - | - | - |
| *Hyphodontia breviseta* (P. Karst.) J. Erikss. | - | 0.1 | > 0.1 | - | - | - |
| *Hyphodontia floccosa* (Bourdot & Galzin) J. Erikss. | - | 0.1 | > 0.1 | - | - | - |
| *Hyphodontia nespori* (Bres.) J. Erikss. & Hjortstam | - | 0.1 | > 0.1 | - | - | - |
| *Laetiporus sulphureus* (Bull.) Murrill | 0.1 | - | - | - | - | 0.2 |
| *Leucogyrophana spp.* | - | 0.3 | 0.4 | 0.4 | 0.2 | - |
| *Leucogyrophana mollusca* (Fr.) Pouzar | - | 0.4 | 0.1 | - | 2.0 | - |
| *Leucogyrophana pinastri* (Fr.) Ginns & Weresub | 0.4 | 1.1 | 2.3 | - | > 0.1 | 0.4 |
| *Mycena galericulata* (Scop.) Gray | - | - | - | - | - | 0.1 |
| *Neoantrodia serialis* (Fr.) Audet | 1.1 | 0.3 | 0.2 | - | - | 4.2 |
| *Neolentinus lepideus* (Fr.) Redhead & Ginns | 1.5 | 0.5 | 0.5 | - | 0.1 | 1.3 |
| *Peziza spp.* (*Ascomycota*) | - | - | - | 6.0 | - | 0.3 |
| *Phlebiopsis gigantea* (Fr.) Jülich | 1.5 | - | 0.1 | - | 0.1 | 7.8 |

References: [a]Ważny and Czajnik 1963b, [b]Schmidt 2007, [c]Schmidt and Hunckfield 2011, [d]Fraiture 2008, [e]Alfredsen et al. 2005, [f]survey research 2019–2020.

| Genera and species name | Poland[a] | Germany[b] | Germany[c] | Belgium[d] | Norway[e] | Poland[f] |
|---|---|---|---|---|---|---|
| *Pleurotus sp.* | - | 0.3 | 0.2 | 0.4 | - | 0.1 |
| *Rhodofomes roseus* (Alb. & Schwein.) Kotl. & Pouzar | 0.1 | | 0.3 | 0.3 | 0.1 | 0.1 |
| *Rhodonia placenta* (Fr.) Niemelä, K.H. Larss. &Schigel | - | 1.7 | 0.6 | - | 0.1 | 0.3 |
| *Schizophyllum commune* Fr. | 0.3 | 0.1 | - | 0.4 | - | 0.6 |
| *Serpula himantioides* (Fr.) P. Karst. | 1.0 | 2.0 | 2.6 | - | 0.5 | 5.3 |
| *Serpula lacrymans* (Wulfen) J. Schröt | 52.3 | 25.3 | 24.0 | 41.9 | 16.0 | 24.8 |
| *Stereum hirsutum* (Willd.) Pers. | - | - | - | - | - | 0.1 |
| *Stereum rugosum* Pers. | - | 0.1 | - | - | - | 0.1 |
| *Tapinella panuoides* (Fr.) E.-J. Gilbert | 2.7 | 2.9 | 2.6 | 0.7 | 0.8 | 3.6 |
| *Trametes hirsuta* (Wulfen) Pilát | - | 0.3 | 0.2 | - | - | - |
| *Trametes ochracea* (Pers.) Gilb. & Ryvarden | - | 0.1 | - | - | - | 0.1 |
| *Trametes versicolor* (L.) Lloyd | 0.1 | 0.1 | 0.1 | 0.4 | - | 0.3 |
| *Trechispora farinacea* (Pers.) Liberta | - | 1.1 | 0.4 | 0.7 | - | 0.1 |
| *Trechispora invisitata* (H.J. Jacks.) Liberta | - | 0.1 | > 0.1 | > 0.1 | - | - |
| *Trechispora mollusca* (Pers.) Liberta | - | 0.4 | 0.2 | > 0.1 | - | - |
| *Trechispora spp.* | - | 1.2 | 1.4 | 0.45 | - | - |
| *Trichaptum abietinum* (Pers. ex J.F. Gmel.) Ryvarden | - | 0.1 | - | - | - | - |
| *Trichaptum fuscoviolaceum* (Ehrenb.) Ryvarden | - | - | - | - | - | 0.1 |
| *Volvariella bombycine* (Schaeff.) Singer | - | 0.1 | > 0.1 | 0,2 | - | 0.1 |

References: [a]Ważny and Czajnik 1963b, [b]Schmidt 2007, [c]Schmidt and Hunckfield 2011, [d]Fraiture 2008, [e]Alfredsen et al. 2005, [f]survey research 2019–2020.

The questionnaire results generally correspond to the outcome of studies on indoor fungi conducted in Europe after 2000. Studies conducted in Germany have shown a high biodiversity of indoor wood-decaying fungi. Shmidt (2007) reported a list of 74 species and genera of fungi (including 40.5% brown-rot and 59.5% white-rot fungi), and Schmidt and Huckfeldt (2011) included a list of 117 species and genera of fungi (including 38.9% brown-rot and 61.1% white-rot fungi) responsible for wood decay in buildings. In the publication of Schmidt and Huckfeldt (2011), the total number of observations of brown-rot fungi in buildings was 74.5% and white-rot fungi was 24.8%. Buildings in Germany were most frequently infested by *S. lacrymans* (24-25.3%) and *C. puteana* (14.6-15.3%). Analogous frequency of both species was shown by a questionnaire conducted by the authors of this study. The third most frequent fungus infesting wood in buildings in Germany was *D. expansa* (8.8-10.%), which is very rarely recorded in Poland. On the other hand, in Germany, fungi were present at much lower levels: *F. vaillantii* (1.4-3.1%), *A. sinuosa* (1.0-1.6%) and *N. serialis* (0.3-1.1%).

An equally high biodiversity in infested buildings in Belgium was found by Fraiture (2008). The author listed 101 species and genera of fungi (including 36.8% brown-rot fungi and 63.2% white-rot fungi). Also in France, a low percentage of buildings was found infected by fungi of the genus *Antrodia sp.*, while the incidence of *S. lacrymans* was 41.9%. The cumulative incidence of brown-rot fungi in buildings was 73.5%, while the incidence of white-rot fungi was 21.2%.

A study by Alfredsen et al. (2005) conducted in Norway showed a much lower biodiversity of house-rot fungi. The paper gives a list of 31 species and genera of *Basidiocota* fungi (including 65.6% brown-rot and 34.4% white-rot fungi) infesting wood in buildings. The total number of observations of brown-rot fungi in buildings was 74.9%, and white-rot fungi was 24.5%. The most frequent *Basidiomycetes* causing wood damage in Norwegian buildings were fungi of the genus *Antrodia* (23.7%), and species of *C. puteana* (21.1%) and *S. lacrymans* (20.7%). The proportion of species presented here was related to the number of observations of *Basidomycota* and not to the total number of fungi, as it was done in the cited article. It should be noted that in the publication discussed here the fungi of the genus *Antrodiasp*. include*: A. xanta, A. sinuosa, N. serialis* and *F. vaillantii*, because according to the systematics of that time these species belonged to one genus (*Antrodia*). In Poland, the frequency of wood infestation in buildings by *S. lacrymans* and fungi of the genus *Antrodia* (according to systematics adopted in the article above) was higher than in Norway, whereas the incidence of *C. puteana* in fungus infested buildings was slightly lower.

Gabriel and Švec (2017) in their review paper presented, among others, the frequency of occurrence of the main fungal species in historical buildings of Romania (castles, palaces, citadels, churches of allfaiths, etc.). The buildings were infected, among others, by *S. lacrymans* (32%) and *C. puteana* (60%), *A. vaillantii* (21%), *D. expansa* (21%). The survey conducted showed lower percentage occurrence of fungi in buildings in Poland and lower fungal diversity. It should be noted, however, that the Romanian research concerns historical buildings, which does not necessarily correspond to the general fungal infestation of residential buildings, etc.

Vampala (2008) in a publication on wood-decaying fungi in buildings in the Czech Republic presented a list of selected 40 species of fungi belonging to the *Basidiomycetes* (including 42.1% brown-rot fungi and 57.9% white-rot fungi). Unfortunately, the frequency of their occurrence in decayed buildings was not given in the paper. The diversity of indoor wood-decaying fungi in the Czech Republic is slightly lower than in Poland.

The study of Irbe et al. (2012) focused mainly on biodeterioration of external wooden elements of buildings in Latvia. A total of 46 species and genera of *Basidiomycetes* fungi were found on wooden buildings in the open-air museum (including 31.8% brown-rot fungi and 68.2 white-rot fungi). A total of 19 *Basidiomycetes* genera and species were found on wooden religious buildings (including 26.3% brown-rot fungi and 73.7% white-rot fungi). The most common genera were *Antrodia, Gloeophyllum, Athelia, Hyphoderma, Hyphodontia, Phanerochaete, Postia,* and *Botryobasidium*. It should be noted that according to the systematics adopted in the discussed publication, fungi from the genus *Antrodia sp*. include *A. sinuosa* and *A. xanta*. The percentage share of particular fungi species was not given in the paper. The diversity of wood-decaying fungi in buildings in Latvia is slightly lower than in Poland.

Haas et al. (2018) reported 40 species from 74 different genera of indoor wood-decaying fungi (including 46.8% brown-rot fungi and 53.2% white-rot fungi) in the federal state of Styria (Austria). The total number of observations of indoor brown-rot fungi was 87.8%, and of white-rot fungi - 6.6%. The highest number of damages in buildings was caused by *Serpula spp*. (61.5%), including *S. lacrymans* 61.2% and *S. himantioides* (0.2%). The incidence of fungi of the genus *Antrodia spp*. (according to systematics used in the publication) caused 10.7%, including: *A. sinuosa* (0.2%), *A. xantha* (1.1), *F. vaillantii* (0.8%), *N. serialis* (0.5%). Fungi of the genus *Gloeophyllum* caused damage in 8.2% of buildings, including *G. abietinum* (1.2%), G. *sepiarium* (2.8%), and *G. trabeum* (0.9%). The prevalence of fungi of the genus *Coniophora* was 3.9%, including *C. marmorata* (2.5%) and *C. puteana* (0.2%). *Donkioporia expansa* was responsible for 1.1% of wood damage in buildings. The authors of the publication believe that the high percentage of infestation of buildings by *S. lacrymans* may have its genesis in the large destruction of buildings in this part of Austria during World War II. In Poland, the incidence of *S. lacrymans* in buildings is lower than in Styria (more than 2×), whereas the occurrence of the "indor polypores group" (*A. sinuosa, A. xantha F. vaillantii* and *N. serialis*) is higher (almost 3×). The incidence of *D. expansa* in affected buildings in Poland is significantly lower (10×).

In the countries of southern Europe with subtropical climates, indoor white-rot fungi are much more frequent than in moderate climate countries. Irbe et al. (2008) on the basis of studies conducted in Macedonian cultural heritage (37 monasteries and churches, and one fortress) presented a list of 26 species of wood-decaying *Basidiomycetes* fungi, of which 21 species (80.8%) caused white rot. The most common fungus found was *Lyomyces crustosus*, causing white rot. The prevalence of white rot in buildings was 81.3%. *S. lacrymans* was not found during the inspection of historic buildings; moreover, this fungus was never found in Macedonia. Among the brown-rot fungi, the most abundant was the genus *Antrodia spp*. (including *A. sinuosa*, according to systematics adopted in the article) – 6.2%.

Confronting the results of the questionnaire with national publications (Ważny and Czajnik 1963b), one can state that the species abundance of *Basidiomycetes* fungi destroying wood in buildings has increased significantly. In the publication from the 1960s, a list of 26 species was provided, whereas the respondents of the survey provided a total of 48 types of fungi (43 species and 5 fungi recognized to genus). In addition to the increase in diversity, it can be concluded that the proportions of species causing brown and white wood rot have changed. In the sixties of the twentieth century in Polish buildings the fungi causing brown rot prevailed (95.4%), whereas the results of the survey indicate a decrease in wood damage in buildings caused by these fungi (83.4%). These changes are more evident when we analyze the list of fungi species (without taking into account their frequency of occurrence in buildings). In the list of species presented by Ważny and Czajnik (1963b), 57.1% of fungi found in buildings cause brown rot of wood, whereas the results of the survey indicate that currently brown-rot fungi are only 39.1%. An increasing trend in the number of white-rot species in buildings is observed across Europe (Shmidt 2011).

In Poland there are also changes within the brown-rot fungi. Analyzing the occurrence of individual species we can state that the occurrence of *S. lacrymans* and *C. puteana* has decreased twice, while the share of "indoor polypores group" in infested buildings has increased twice. Such a trend is not observed in other European countries.

## Conclusions

Despite the changes in the method and technology of construction and renovation of buildings, the most important species of house-rot fungi (*S. lacrymans, C. puteana, F. vaillantii*) are still most frequently found in the fungus infested buildings. Among the species of fungi that frequently affect building structures and are included in the mycological and building expert reports performed, the respondents did not find species outside the classification of house-rot fungi according to Ważny (2001). The "new" species of fungi were found in the infested objects usually rarely (*A. sinuosa, G. trabeum, S. himantioides, S. commune*) or sporadically (*A. cervicolor, A. xantha, D. expansa, F. contigua L. pinastri, R. roseus* and others). The frequency of occurrence of these species does not exceed 9.9%.

From the economic point of view, the most important wood-decaying fungi in buildings in Europe and North America are still the brown-rot fungi of coniferous wood. The increase in the diversity of wood-decaying fungi in buildings is mainly due to the increase in white-rot fungi species. Despite the increase in the number of white-rot fungi species in buildings, the frequency of their occurrence is not high. Consequently, they cause little economic loss in buildings in moderate and boreal climate zones. This is due in part to the fact that some white rot species generally prefer hardwoods, which are less often used as construction timbers.

The diversity of wood-inhabiting fungi in forest ecosystems is determined by local factors, including the amount and diversity of dead wood and microclimate (Krah et al. 2018). The analogical situation is in buildings. Increasing the diversity of construction wood species used increases the biodiversity of wood-decaying species in buildings. The microclimate of rooms is also important, as fungi colonize wood according to their thermal and moisture preferences (Shmidt 2006). This aspect, however, depends mainly on improper use of rooms, faults and construction failures, and errors made in the construction of buildings (Krajewski, Andres 2012).

The increase in the proportion of fungi previously not found in buildings carries the risk of their incorrect diagnosis, and thus the issuance of recommendations inadequate to the actual state of risk in the building. Underestimation of the threat (e.g. designation of *L. pinastri* as *S. lacrymans* ), or implementation of fungus control procedures in buildings other than those provided for dry-rot may result in rapid re-infestation of the building by resurgent S.

*lacrymans mycelium*. On the other hand, overestimation of fungal infestation (e.g. designation of *A. cervicolor* as *C. puteana*) will result in unjustified financial outlays for the fumigation of the building.

## Declarations

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## References

1. Alfredsen G, Solheim H, Jenssen KM (2005) Evaluation of decay fungi in Norwegian buildings. IRG/WP/10562 The Int. Res. Group on Wood Prot., Bangalore.
2. Andres B (2011) *Basidiomycetes* growing on the sleepers reused in small garden architecture. Ann. of Wars. Univ. of Life Sci. - SGGW. For. and Wood Technol. 73:91-93.
3. Andres B, Krajewski KJ, Betlej I (2019) Różnorodność gatunkowa grzybów *Basidiomycota* powodujących biodeteriorację drewna w budynkach (The species diversity of *Basidiomycota* causing biodeterioration of wood in buildings). In: Skowroński, W. (ed) Ochrona budynków przed wilgocią, korozją biologiczną i ogniem (Protection of buildings against moisture, biological corrosion and fire, t. 15) Publ. House of the Wroc. Univ. of Technol., Wroclaw, pp 29-39.
4. Fraiture A (2008) Introduction à la mycologie domestique. Les champignons qui croissent dans les maisons. Revue du Cercle de Mycologie de Bruxelles 8:25-56.
5. Gabriel J, Švec K, (2017) Occurrence of indoor wood decay basidiomycetes in Europe. Fungal Biol. Rev. 31(4): 212-217 https://doi.org/10.1016/j.fbr.2017.05.002
6. Grzywacz A (1997) Gatunkowa różnorodność biologiczna grzybów rozkładających drewno. (Species biodiversity of wood-decaying fungi). In: Ochrona obiektów budowlanych przed korozją biologiczną i ogniem (Protection of buildings against biological corrosion and fire). PSMB Publ. House, Wrocław, pp. 69-78.
7. Haas D, Mayrhofer H, Habib J. Galler H, Reinthaler FF, Fuxjäger ML, Buzina W (2018) Distribution of building-associated wood-destroying fungi in the federal state of Styria, Austria. Eur. J. Wood Prod. 77, pp. 527–537 https://doi.org/10.1007/s00107-019-01407-w
8. Index Fungorum database, http://www.indexfungorum.org/ (15.05.2021)
9. Irbe I, Karadelev M, Andersone I, Andersons B (2008) Biodeterioration of cultural monuments in the Republic of Macedonia. IRG/WP 08-10640. The Int. Res. Group on Wood Prot., Istanbul.
10. Irbe I, Karadelev M, Andersone I, Andersons B (2012) Biodeterioration of external wooden structures of the Latvian cultural heritage. J. of Cultural Heritage 13S:S79–S84 https://doi.org/10.1016/j.culher.2012.01.016
11. Karyś J (2014) Mikroorganizmy zdolne do rozwoju w obiektach budowlanych. (Microorganisms capable of development in building facilities). In: Karyś, J (ed) Ochrona przed wilgocią i korozją biologiczną w budownictwie. (Protection against moisture and biological corrosion in construction.) MEDIUM Publ. House, Warsaw, pp. 35-63.
12. Kochman J (1951) Grzyby domowe. (House-rot fungi) PWRiL, Warszawa 1951.
13. Konarski B (1974) Występowanie grzybów i owadów niszczących drewno w budynkach Warszawy. (The occurrence of fungi and insects that destroy wood in buildings in Warsaw). In: Materials of the VII Symposium of Wood Protection, Scientific J. of the Wars. Univ. of Life Sci. - SGGW – For. 20, pp. 71-79.
14. Kozarski P (1992) Konserwacja domu. (House maintenance). PKZ-Omnipress, Wrocław.

15. Kozarski P (1997) Konserwacja domu. (House maintenance). PSMB Publ. House, Wrocław.
16. Krah FS, Seibold S, Brandl R, Baldrian P, Müller J, Bässler C (2018) Independent effects of host and environment on the diversity of wood-inhabiting fungi. J. Ecol 106:1428–1442 https://doi.org/10.1111/1365-2745.12939
17. Krajewski A, Witomski P (2012) Biologiczna korozja drewna materialnych dóbr kultury. Przewodnik konserwatora. (Biological corrosion of wood of material cultural assets - Conservator's guide). SGGW Publ. House, Warsaw.
18. Krajewski KJ, Andres B (2012) Warunki sprzyjające pojawianiu się różnorodnych gatunków grzybów domowych na konstrukcjach drewnianych. (Conditions favorable to infestation of wooden construction by various wood-destroying fungi). In: Karyś J., Krajewski K. J., (eds) Ochrona budynków przed wilgocią i korozją biologiczną, t. 8 (Protection of buildings against moisture, biological corrosion and fire, t. 8) Wrocław, PSMB Publ. House, s: 27-35.
19. Orłoś H (1950) Grzyby szkodliwe w budynkach i na składach drewna. (Harmful fungi in buildings and lumber yardsstore.) IBL Publ. House, Warszawa 1950.
20. Orłoś H (1952) Fitopatologia leśna. PWRiL, 1952, Warszawa.
21. Ridout B (2019) Timber decay in building and its treatment. Historic England, Swindon.
22. Schmidt O (2007) Indoor wood-decay basidiomycetes: damage, causal fungi, physiology, identification and characterization, prevention and control. Mycol. Progr. 6(4):261-279 https://doi.org/10.1007/s11557-007-0534-0
23. Schmidt O, Hunckfield T (2011) Characteristics and identification of indoor wood-decaying basidiomycetes In: Adana OCG, Samsona RA (eds) Fundamentals of mold growth in indoor environments and strategies for healthy living. Wageningen Academic Publishers, The Netherlands, pp. 117-182. https://doi.org/10.3920/978-90-8686-722-6_6
24. Skupieński FX (1937) Czynniki mikrobiologiczne niszczące drewno użytkowe. In: Skupieński FX (ed) Grzyby domowe i inne szkodniki budulca oraz metody i środki walki. (Microbiological factors destroying usable wood. (House-rot fungi and other building pests and methods and means of control.) PTH, Warszawa, pp. 49-102.
25. Ważny J (1951) Grzyby domowe. Krótki przewodnik do rozpoznawania grzybów w budynkach (House-rot fungi. Guide to recognizing destroying fungi in buildings). Prace Instytutu Techniki Budowlanej nr 98, Państwowe Wydawnictwa Techniczne, Warszawa 1951.
26. Ważny J (1956) Grzyby domowe. (Dry-rot fungi.) In: Czajnik M, Lehnart M, Lerczyński S, Ważny J (eds) Impregnacja i odgrzybianie w budownictwie. (Impregnation and control in buildings). Budownictwo i Architektura Publ. House, Warszawa 1956, s. 54-96.
27. Ważny J (1958) Grzyby domowe. (Dry-rot fungi.) In: Czajnik M, Lehnart M, Lerczyński S, Ważny J (eds) Impregnacja i odgrzybianie w budownictwie (Impregnation and control in buildings). Arkady Publ. House, Warszawa, pp. 40-85.
28. Ważny J (1963) Oznaczanie grzybów domowych. Przewodnik. (Identification of wood-destroying fungi in buildings. Guide). Arkady Publ. House, Warszawa.
29. Ważny J (1970) Grzyby domowe (Dry-rot fungi). In: Czajnik M, Lehnart M, Lerczyński S, Ważny J (eds) Impregnacja i odgrzybianie w budownictwie (Impregnation and control in buildings). Arkady Publ. House, Warszawa, pp. 38-76.
30. Ważny J (1983) Grzyby domowe (Dry-rot fungi). In: Ochrona budowli przed korozją biologiczną. Poradnik. (Protection of buildings against biological corrosion. Guidebook). Komitet Trwałości Budowli Publ. House, Wrocław, pp. 13-24.
31. Ważny J (2001) Mikroorganizmy rozwijające się w budynkach. (Microorganisms growing in buildings), In: Ważny J, Karyś J, (eds.) Ochrona budynków przed korozją biologiczną (Protection of buildings against biological corrosion). Arkady Publishing House, Warsaw, pp. 52-90.
32. Ważny J, Czajnik M (1963a) Występowanie grzybów niszczących drewno w tunelu doświadczalnym metro w Warszawie. (The occurrence of wood-destroying fungi in the experimental tunnel of the metro in Warsaw). Fol. For. Polonica 5, ser. B:79-94.
33. Ważny J, Czajnik M (1963b) Występowanie grzybów niszczących drewno w budynkach na terenie Polski. The occurrence of wood-destroying fungi in buildings in Poland. Fol. For. Polonica 5, ser. B, 5-18.
34. Ważny J, Czajnik M (1973) Występowanie grzybów i owadów niszczących drewno w budynkach woj. olsztyńskiego. (The occurrence of fungi and insects that destroy wood in buildings in the voivodeship Olsztyn). Zesz. Naukowe Akad. Rol. w Warsz. -Leśn. (Scientific J. of the Agric. Univ. of Wars.– For.) 19:123-133.
35. Ważny J, Czajnik M (1974a) Występowanie grzybów i owadów niszczących drewno w budynkach na terenie województwa rzeszowskiego. (The occurrence of wood-destroying fungi and insects in buildings in the Rzeszów voivodeship). Rocznik Nauk Rolniczych (Yearb. of Agric. Sci.) 4, ser. E:213-222.
36. Ważny J, Czajnik M (1974b) Występowanie grzybów i owadów niszczących drewno w budynkach południowo-zachodniej Polski. (The occurrence of fungi and insects that destroy wood in buildings in south-western Poland). Zeszyty Naukowe Akademii Rolniczej w Warszawie-Leśnictwo (Scientific J. of the Agric. Univ. of Wars.-For.) 20, 81-90.
37. Ważny J, Oleksiewicz M, Prądzyński J (1999) Drewniany most pod Wyszogrodem. (Wooden bridge near Wyszogród). Przemysł Drzewny (Przemysł Drzewny. Research&Development) 50(9):21-24.
38. Vampola, P (2008) Dřevokazné houby v budovách (Wood-destroying fungi in buildings). Mykologické listy 104, 21-25.
39. Zyska B (1999) Zagrożenia biologiczne w budynku. (Biological hazards in a building). Arkady Publ. House, Warszawa.