Biodeterioration of Building Timbers in the High Water Activity Built Environment of Nigerian

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Abstract: - Moulds have been reported to destroy large volume of timber s used in buildings annually. As a result, several timber components within the built environment greatly decline and fail to fulfill their basic requirements. This research focuses on the isolation and evaluation of the prevalence and effects of timber deteriorating moulds in the Rain forest and Swampy rain forest Regions of Nigeria which the authors considered a high water activity region based on its aw level of around 0.7. To accomplish this, decayed timber samples were aseptically collected on timber components on buildings from 6 different locations in the regions. The samples were serially diluted and inoculated onto sabouraud dextrose agar medium in petri dishes in the laboratory. The petri dishes were incubated for 72 hours at 30 oC. Mould were identified and isolated through visual and microscopic observations. The most commonly encountered moulds were evaluated and analysed. It was observed that, prevalence of moulds on buildings used for non residential was higher . There was no significant difference between the prevalence on the components inside the building and outside the building. Ceiba pentandra exhibited highest degradation while Masonia altissima resisted most Aspergillus, Mucor, Rhizopus, and Gliocladium were among the timber deteriorating organisms in the regions. The deteriorations of Ceiba pentandra, Afzelia africana, Lophira alata, Anogessus leocarpus and Gossweilerodendron balsamiferum species of timber under Aspergillus attack were also projected.

Key-words: Mould, Timber in building, Biodeterioration, High-water-activity, Microclimate

1 INTRODUCTION

Buildings are designed to serve specific functions desired by users [11]. However, as soon as they are put to use, they start to deteriorate, losing important functional qualities. Such deteriorations do occur as a result of normal wear and tear, weather, chemicals or biological agencies. Whichever, can lead to serious effects on the entire capabilities of buildings. The principal causal factor of deterioration of timber is the biological agency whose action is referred to as biodeterioration [15].

Biodeterioration is any undesirable change in the properties of material of economic importance brought about by the activities of living organisms [1]. For biodeterioration to take place, suitable temperature, Relative Humidity (RH), Water Activity (aw), pH, and a substrate – a substance (timber) that serves as food must be in place. Pérez, et al [14] reported that each substrate possesses special properties that attract moulds just like what flowers do to insects. Hence, prevalence of moulds inhabiting one piece of timber differs from one another and even though not all are capable of utilising the timbers substrate [15]. Erickson et al [3] specified extents of timber biodeteriorations to cover mere surface growth, blue stain and outright decay of cell wall structure. Biodeterioration in timber usually occur when the RH value is greater than 95%, temperature between -5°C to 50°C [16]; and aw ranging between 0.5 – 0.94[9].
A combination of the favourable conditions for biodeterioration is obtainable in the rain forest and swampy rain forest regions of Nigeria where adequate humidity, aw and temperature required for the growth of deteriorating moulds are guaranteed. The Rain forest belt has an average annual rainfall of 1300–2000 mm; 27°C, and RH of 80% [5] while the swampy rain forest has average rainfall of 3175 mm, temperature of 30°C with a RH over of 90% coupled with a wet season of over 10 months [2]. These regions can continuously ensure adequate supply of these factors to sustain substantial degree of deterioration almost throughout the year. The values of pH and aw – the measure of energy status of water in individual timber are depended on specific local conditions of timbers in the buildings. The aw in this region is considered high not only because of the availability of the two major factors; RH and temperature that are directly relate to it but the ability of the region to support the growth of a wide range moulds. A w is a determinant factor for available of water for moulds to grow, since they exploit energised water not still water to survive and flourish; without which deterioration is considered impossible. Lebow and Highley [4, 8] states even if a timber contains high moisture content it would not make it liable to deterioration as far as the energy level is not sufficiently high for moulds to remove it to support growth.

By definition, aw is the ratio of vapour pressures under normal working conditions [9]; aw = vapour pressure of water over a substance (p) divided by vapour pressure of pure water (po). Hence, aw = p/po. And aw x 100 = RH (%); this is, the RH in equilibrium with a piece of timber, being a hygroscopic material. As long as the condition is conducive, biodeterioration will remain continuous and progressive as long as the condition is conducive until timber substrate is exhausted. Therefore, if timber buildings and components operated within these zones are to fulfill their objectives as expected, there would be need to know how they deteriorate and loss potentials that affect the owners, occupants, society and the built environment.

2 MATERIALS AND METHODS

2.1 Sampling and Sample Collections
The study population was subdivided into six subregions along geographical boundaries [5], 2000) of U, V, W, X, Y, and Z. Buildings within each subregion were selected for the study based on local conditions. Bulk samples of ten grammes were aseptically collected on timber components in the buildings that showed visible signs of deteriorations and documented. In addition, samples of sound and fresh timbers, and designation of buildings were also recorded.

2.2 Cultivation and Evaluations of Moulds
Sabourad Dextrose Agar (SDA) was used as the culture media and was prepared according to manufacturer’s specification: glucose 40.0g, peptone 10.0g, streptomycin 0.01%, agar 15.0g, and distilled water 1000ml. This was poured into 20ml petri dishes and sterilized at 121°C for 15 minutes and then allowed to solidify. A stock of one gramme of decayed sample collected from buildings used for residential and non residential purposes was dissolved in 10 millilitre of peptone water. These were thoroughly shaken to dislodge the mould spores that may be present. From this, dilutions of 0.5 millimetres of the second and fourth series were inoculated on to the petri dishes already labeled. The inoculums were then spread over the entire surface using sterile glass rod spreaders. The plates were incubated at 30°C for 72 hours [10], after which developed colonies were identified and isolated and then counted.

2.3 Identifications and Classification of Moulds
Visual observations and light microscopes observations were used to identify the moulds. The isolates were stained with methyl cotton blue and viewed at 40 times magnification. During the observations under the microscope, attention was paid to characteristic growth and presence and forms of conidia, septa, conidiophore, appendage, hyphae, texture, catenation, and colour features [10]. The observed features were recorded and compared with existing standards. The moulds were finally identified by comparing the growth morphology characteristics and the observe features with dichotomous keys and picture keys from text books [1] and online sources [7,13].

2.4 Determining Degradability of Timbers by the Moulds
To determine the biodegradability of the timbers commonly used in construction of buildings in the region and identify the saprophytic moulds, known weights of sterile timber samples were inoculated with the moulds in a minimal medium and incubated for 72 hours at 30°C [17]. In this
experiment, the only source of nutrients available to the moulds was the timber substrate and temperature were controlled and maintained throughout the period of the study. Percentage growths as a result of utilization of the timbers were recorded and graded as; 0% = nil, 1-24% = scanty, 25-49% = moderate, 50 – 100% = profuse.

3 RESULTS AND DISCUSSIONS

3.1 Evidences of Presence of Moulds on Timbers in Buildings situated in the Regions

Table 1 represents the prevalence of moulds identified on the timber components in the buildings in six subregions. The species of Aspergillus and Alternaria were most dominant in each subregions.

Table 1: Presence of Moulds in Decayed Timber Samples from the Buildings

| Moulds              | Rain Forest Region | Swampy Rain Forest |
|---------------------|--------------------|--------------------|
|                     | Colony forming Unit per gramme (CFU/G) |                     |
|                     | U      | V          | W          | X      | Y          | Z          |
| Acremonium          | 1.800x10^5 | 1.000x10^4 | 2.000x10^4 | -      | -          | 4.800x10^7 |
| Alternaria          | 1.900x10^5 | 3.300x10^5 | 2.200x10^5 | 5.700x10^5 | -          | 1.380x10^8 |
| Aspergillus         | 1.290x10^6 | 4.700x10^6 | 3.040x10^6 | 2.010x10^6 | 8.970x10^6 | 2.340x10^6 |
| Cladosporium        | 5.000x10^4 | -          | -          | -      | -          | -          |
| Geotrichium         | 2.400x10^6 | 5.800x10^5 | -          | 1.600x10^6 | 2.400x10^6 | -          |
| Gliocladium         | 1.600x10^6 | 5.000x10^4 | 1.700x10^3 | -      | -          | 4.000x10^4 |
| Mucor               | 2.800x10^5 | 1.200x10^4 | -          | 1.300x10^3 | 8.000x10^4 | 3.100x10^5 |
| Mycelia sterilata   | 3.000x10^4 | -          | 1.900x10^3 | -      | 2.600x10^4 | 1.000x10^4 |
| Paecilomyces        | 9.000x10^6 | 8.000x10^6 | 8.000x10^6 | -      | -          | -          |
| Penicillium         | 7.000x10^4 | 1.700x10^5 | -          | 5.000x10^3 | 7.000x10^3 | 3.000x10^5 |
| Rhizopus            | 3.000x10^4 | 3.000x10^4 | 2.700x10^4 | 6.100x10^3 | -          | 8.000x10^4 |
| Saccharomyces       | -      | 4.000x10^3 | 4.400x10^5 | 1.600x10^5 | 3.000x10^4 | 4.000x10^4 |
| Streptomyces        | -      | -          | 1.200x10^3 | 2.300x10^5 | 2.200x10^5 | 5.000x10^4 |
| Synecphalastrum     | -      | 1.000x10^2 | -          | 6.000x10^4 | 1.800x10^5 | 3.000x10^4 |
| Trichoderma         | -      | 4.000x10^5 | 4.900x10^5 | -      | -          | -          |
| Trichothecium       | -      | 7.000x10^6 | 6.000x10^6 | 7.000x10^4 | -          | 4.000x10^4 |
| Unidentified        | 2.000x10^4 | 1.100x10^5 | 3.100x10^4 | 8.000x10^4 | 4.200x10^5 | 5.800x10^4 |

Other studies isolated similar organisms in damaged building. Viitanen et al [18] isolated Alternaria alternata, Aspergillus species, Cladosporium cladosporioides, Paecilomyces variotii, Penicillium species and Trichoderma viride in American homes and also Kumar and Verma [6] in India.

3.1.1 Prevalence of Moulds on Residential and Non Residential Buildings
Fig. 1: Prevalence of Moulds on timbers in Residential and Non Residential

Fig. 1 shows the prevalence moulds on timber components from buildings used for residential and non residential buildings purposes. In comparison, buildings revers is the case in W and Y subregions.

3.1.2 Prevalence of Moulds on indoor and Outdoor Environment

Fig. 2: Prevalence of Moulds on Components located indoor and outdoor

The prevalence of moulds inhabiting timber components at the indoor and outdoor environment of the buildings are presented in Fig. 2. There is no much difference between the prevalence.

3.1.3 Prevalence of Moulds on Decayed Timber Samples
An investigation into prevalence of the moulds on fresh timber samples commonly used in construction of buildings in the region shown in Fig. 3 suggests higher prevalence of Terminalia ivorensis, Daniellia ogea, Cordia millennii, Terminalia superba, and Pentadesma butyracea compared to Mitragyna stipulosa, Anogeissus leocarpus and Masonia altissima species which are significantly low.

### 3.2 Effects of Moulds on Timbers in the Region

#### 3.2.1 Biodeterioration of the Timbers

![Mould Degradation on common Timbers Used in the Region](image-url)
Fig. 4 depicts the ease at which the various timbers deteriorate under the attack of the moulds spp. The natural resistivities of the timbers used in the regions to the attacks of the moulds in Table 1 are presented in this Fig. *Terminalia superb*, *Anogeissus leocarpus* and *Mitragyna stipulosa* demonstrated high levels of resistance. Other species that high susceptibilities were *Ceiba pentandra*, *Gossweilerodendron balsamiferum*, *Syzygium guineense* and *Triplochiton nigericum*. Masonia altissimia showed less signs of deteriorations. In the study by Usher and Ocloo [17] compared the resistivity of West African timbers to combined effects of microorganisms and termites. These values are close to what was obtained by Mshelgaru and Olonitola [12].

### 3.2.2 Comparison of abilities to breakdown the Timbers

![Histogram of Mould Attack Intensity](image)

Fig. 5: Intensity of Mould Attack on Timbers

The intensity of deteriorations of some of the moulds to deteriorate timbers in the region is presented in Fig. 5 portraying viabilities of attacks. Thiboldeaux [16] reported that *Aspergillus* and *Alternaria* can utilize wide varieties of timbers because of their ability to produce a large number of enzymes.

### 3.2.3 Estimating Aspergillus Degradation on Selected Timbers Samples over time
Fig. 6 presents the forecasted deterioration of five commonly used timbers: *Ceiba pentandra*, *Afzelia africana*, *Lophira alata*, *Anogessus leocarpus* and *Gossweilerodendron balsamiferum* that responded more to biodeteriorations (Fig. 4) under the attack of *Aspergillus* for the period of 24 months. 62% lost was forecasted for this period in *Lophira alata*. The laboratory results of Erickson et al [3] on different spp of timbers and fungi confirmed 1% loss in weight led to 6% to >50% losses in toughness and at 10% weight losses more than 50% of strength was lost.

The regression equation forecasting weight loss in *Lophira alata* is expressed thus, \( y_1 = 0.244x^{1.391} \). Where \( y_1 \) = percentage mass loss and \( x \) is the durations of the attack in months. The value of the coefficient of determinant \( R_1^2 = 0.875\% \). This shows how much the model represents the data used and is computed as \( \frac{SS_R}{SS_T} \). Where \( SS_R = \sum_{i=1}^{n} (\hat{y}_i - \bar{y})^2 \) being the regression sum of squares and; \( SS_T = \sum_{i=1}^{n} (y_i - \bar{y})^2 \), representing the total sum of squares of the response variable \( y \) or the corrected sum of squares of \( y \). The following values represent the regression equation for series 1, 2, 4, and 5 respectively. \( Y1 = 0.244x^{1.391} \), \( R_1^2 = 0.875\% \); \( Y2 = 0.196x^{1.656} \), \( R_2^2 = 0.999\% \); \( Y3 = 0.106x^{2.068} \), \( R_3^2 = 0.993\% \); \( Y4 = 0.159x^{1.612} \), \( R_4^2 = 0.896\% \); and \( Y5 = 0.108x^{2.035} \), \( R_5^2 = 0.990\% \).

### 3.3 Consequences of Biodeteriorations on Performance of the Buildings

Biodeterioration of timbers in building is accompanied by emissions of CO₂, mycotoxin, dust particles, Volatile Organic Compounds; and can directly lead to destruction of aesthetics, strength and other vital properties. It also enhancement of nutritional values of timber for further insect attacks [18], cause sick building syndrome, building related illnesses, and increase running costs. The effects are directly borne by occupants, owner, society, built environment and the global environment.

### 4 CONCLUSION

Buildings with timber components in the high water activity built environment of Nigeria have high prevalence of moulds on them. The wide varieties of the moulds isolated were able to deteriorate the timbers commonly used for construction of buildings. Biodeterioration is a degradation that can make buildings loss their performance capabilities.

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