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NIGERIAN COASTAL TIMBER BUILDINGS: EVALUATING THE PREVALENCE OF BIODETERIORATING MICROORGANISMS FOR SUSTAINABILITY

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ABSTRACT

Microorganisms were found to undermine sustainability of timbers. This research focuses on identification and evaluation of prevalence of microorganisms deteriorating timber buildings along Nigerian coastline. The assessment proceeded by collection of samples on timber buildings along the coastline. Serial dilutions were produced and inoculated onto agars. Nutrient Agar dishes were incubated for 24 hours at 35^{o}C while Sabouroud Dextrose Agar dishes were incubated for 72 hours at 30^{o}C. Biochemical tests were used to identify bacteria and visual observations were used on fungi. Commonly encountered microorganisms were analyzed. Concentrations of bacteria were higher than fungi in both residential and non-residential buildings and on internal and external fabrics. Buildings further away from sea did not significantly differ from those closer even though some timbers were more susceptible to biodeteriorations than others. The nature and prevalence of microorganisms suggested that sustainability of the timber buildings were detrimental.

Keywords: Microorganisms, sustainability, and coastline

INTRODUCTION

The concept of sustainable building incorporates and integrates variety of strategies during material selection, operation and maintenance of buildings (Eco Business Links, 2008). Sustainable building is expected to benefit owner and users by means of reduction in costs of maintenance through out the lifetime, conserve energy, and improve health and productivity

(Eco Business Link, 2008). Timber is a natural material that can be made to contribute to sustainable development in a number of ways. However, Morris (1998) reported that timbers used in construction of buildings were found to be more prone to harboring microorganisms than other construction materials chiefly because of the nature of their cells. Hence, through such conditions the benefits of the sustainable manner of timber are outweighed when left at the mercy of these microorganisms. Majority of the microorganisms inhabiting timbers in significant prevalence do so for reasons of deteriorating them (Richardson, 1995) but some few others are there for other reasons. The effects of microorganisms have rendered timber structures less sustainable. An annual loss of billions of US dollars was reported by the Environmental and Energy Study Institute (2006), and It was reported that more than 5% of all the construction timbers in United State were used to replace timbers that have decayed in service due to microorganism attacks (Prescott et al; 2005). The deteriorations of timber buildings due microorganisms are more when exposed to weather conditions conducive to the microorganisms (The Forest and Wood Products Research and Development Corporation, 2001) and the littoral states of the coast of Atlantic Ocean has a coastline of 853 kilometers (Nigerian Maritime Administration and Safety Agency, 2009).

The high rain fall, humidity, thick vegetational forest and the nature of combinations of fresh water swamps and salt water swamp give the Nigerian coastline it peculiar weather conditions under which the timber buildings under study are serving. This region experiences a maximum of up to 3175 mm rainfalls and a minimum of about 102 mm (Bradford and Kent, 1994). The continuous rain fall maintains unbroken clouds that lowers the temperature of the day dropping the mean annual temperature to 27^{o}C but the relative humidity remains high all through the year except for a month or two when it averages as low as 80% in some areas further away from the coastline.

Such consequences of microorganisms that is, aptly been termed “slow fire", undermines sustainability of the built environments (Smulski, 1996). It is reported that buildings are responsible for significant impacts on the environment account for about half the UK's emissions of carbon dioxide- the main 'greenhouse' gas. Buildings can also release contaminants into the atmosphere or ground and water that can negatively influence the essential elements of the factors of sustainability, resulting in Sick Building Syndrome (SBS), building related illnesses, early degradation of buildings (Akhtar *et al*; 1997), as well as make buildings uneconomical to manage, reduced reuse of removed components (Lamothe, 2008) and less durable to reach their expected design ages.

MATERIALS AND METHODS

Sampling and Sample Collections

The study population was divided into three zones along vegetational and political boundaries of Lagos, Delta and Rivers, all along the coastline, guided by proximity to the sea. The settlements within each zone were selected based on local conditions and perceived mode in which species of timber or types were used among the housing stocks available. Bulk samples of ten grams were aseptically collected on timber components that showed visible signs of deteriorations as identified by a microbiologist. In addition to that, information on age and designations of buildings were also gathered.

Cultivation of Microorganisms

Nutrient agar (NA) and Sabouraud Dextrose Agar (SDA) were used as the culture media. The media were prepared according to specification and sterilized at 121^{o}C for 15 minutes. A stock of one gram of each sample in 10 milliliter of peptone water was prepared. These were shaken thoroughly in order to dislodge the cells into the peptone water. Then, a dilution of 0.5 millimeters of the second and fourth serial (dilution factors of 10^{-2} and 10^{-4}) were inoculated on to the petri dishes labeled NA and SDA. The inoculums were evenly spread over the entire surface using a sterile glass rod spreader. The NA plates were incubated at 37^{o}C for 24 hours while the SDA plates were incubated at 30^{o}C for 72 hours. Colonies were identified, isolated and counted using magnifying electronic counter.

Identifications and Classification of Microorganisms

Fungi

Visual observations and observations through light microscopes were the main techniques used to identify the fungi. The microscopic observations paid attentions to characteristic growth and the presence and forms of conidia, septa, conidiophore, appendage, hyphae, texture, catenation, and color features.

Bacteria

Characteristic colonies grown on NA were obtained by pin inoculators and colonies were made suspended in a drop of clean water in grease-free glass slide and spread evenly, stained by means of crystal violet, fixed with Lugols iodine and decolorized with 95% ethanol. Slides were counterstained with diluted carbol fuchsin solution dried and observed under oil immersion. The bacterial isolates were first classified according to how they responded to gram stains before been prepared for biochemical assessments.

Isolate inoculants were stabbed into TSI medium and incubated at 35^{o}c for 24 hours. The TSI test examinations the possibility of the organisms to ferment the three sugars. The reactions were either one or two or three of the sugars were fermented. In some few instances reactions evolved gasses and hydrogen sulphate. The ability of the organisms to produce catalase enzymes were also tested by dropping isolates on one millimeter of a 3% hydrogen peroxide solution and rapid evolvement of bubbles of gas resulting from breakdown of the hydrogen peroxide into oxygen and water by the catalase enzyme was a sign for positive reaction. In the coagulase investigation, human plasma diluted with normal saline was used. Signs coagulation of the solution was proved positive whereas Positive and negative controls were also set to serve as guides. To distinguish whether organisms were aerobic or anaerobic, the carbohydrate fermentation experiment was carried out on glucose and sucrose where productions of acids in course of reactions were interpreted as either oxidative or fermentative, depending on whether the reaction took place on the surface or below the surface of the medium.

Investigations on gram-positive organisms for motility were conducted via observation of broth of cultured organisms under oil immersion, where vigorous movements in random directions signified positive motility. In indole assessment, the red color in Kovac's and alcohol layer solution indicated positive reactions while negative reactions retained normal yellow color. The ability of organisms to utilize citrate was tested using Simmon's citrate medium where conversion of the green color of the medium to blue indicated positive utilization. Biochemical experiments of Methyl Red and Voges Proskauer using methyl red reagent and 1ml of 40% potassium hydroxide and 3ml of a 5% solution of K-naphthol in absolute ethanol respectively were performed. Reactions of bright red color signified positive Methyl Red test while development of pink color and becoming crimson signified Voges Proskauer test positive.

Statistical Analysis

The data were analyzed using T-test at 95% confidence interval in order to ascertain if significant difference existed between prevalence of microorganisms on a timber species and another, or one part of building or a component and another. To determine whether the microorganisms captured were by chance or were influenced by certain inherent factors, an analysis of variance (F-test) was also carried out at 95% confidence interval.

RESULTS

Mean Prevalence of Commonly Encountered Microorganisms

Table 1: Mean Prevalence of Bacteria

Species	Delta	Lagos	Rivers
	Colony Forming Units (CFU /G)		
Serratia species	-	-	5.500×10^{5}
Serratia liquefacians	1.400×10^{5}	4.260×10^{6}	-
Enterobacter hafniae	2.450×10^{6}	-	9.800×10^{5}
Micrococcus	8.240×10^{6}	1.797×10^{7}	1.734×10^{7}
Staphylococcus aureus	1.700×10^{5}	3.900×10^{5}	3.650×10^{6}
Enterobacter species	1.100×10^{5}	-	-
Klebsiela species	1.800×10^{5}	5.000×10^{4}	5.100×10^{5}
Bacillus species	6.210×10^{6}	1.270×10^{6}	1.621×10^{7}
Enterobacter agglomerons	2.090×10^{6}	6.530×10^{6}	2.790×10^{6}

Tables 1 show the prevalence of microorganisms on buildings situated in different locations in the coastline regions.

Table 2: Mean Prevalence of Fungi

Fungal genera	Mean Colony Forming Units (CFU/G)
Acremonium	1.60×10^5
Alternaria	6.50×10^5
Aspergillus	4.44×10^6
Geotrichium	1.33×10^5
Gliocladium	7.00×10^4
Mucor	1.73×10^5
Mycelia sterilia	9.00×10^4
Penicillium	5.07×10^5
Rhizopus	2.30×10^5
Saccharomyces	7.67×10^4
Streptomyces	1.67×10^5
Syncephalastrum	9.00×10^4
Trichoderma	2.33×10^4
Trichothecium	1.33×10^4
Unidentified	4.47×10^5
Yeast	2.20×10^5

In Table 2, the average prevalence of different fungal genera in the coastline region.

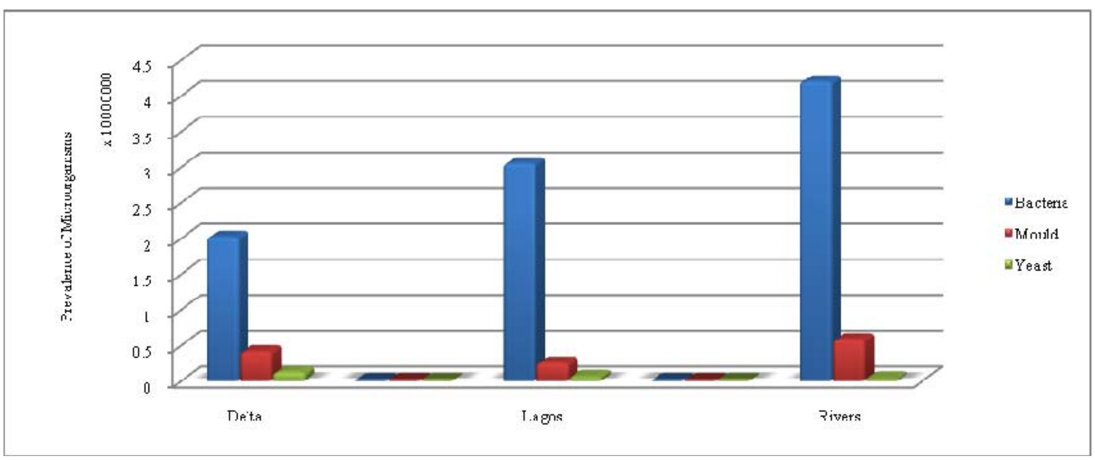

Figure 1: Prevalence of Microorganisms on Buildings in the Three Study Regions

Figure 1 shows the prevalence of bacteria, mould and yeast on the buildings in the Lagos, Delta and Rivers sub regions.

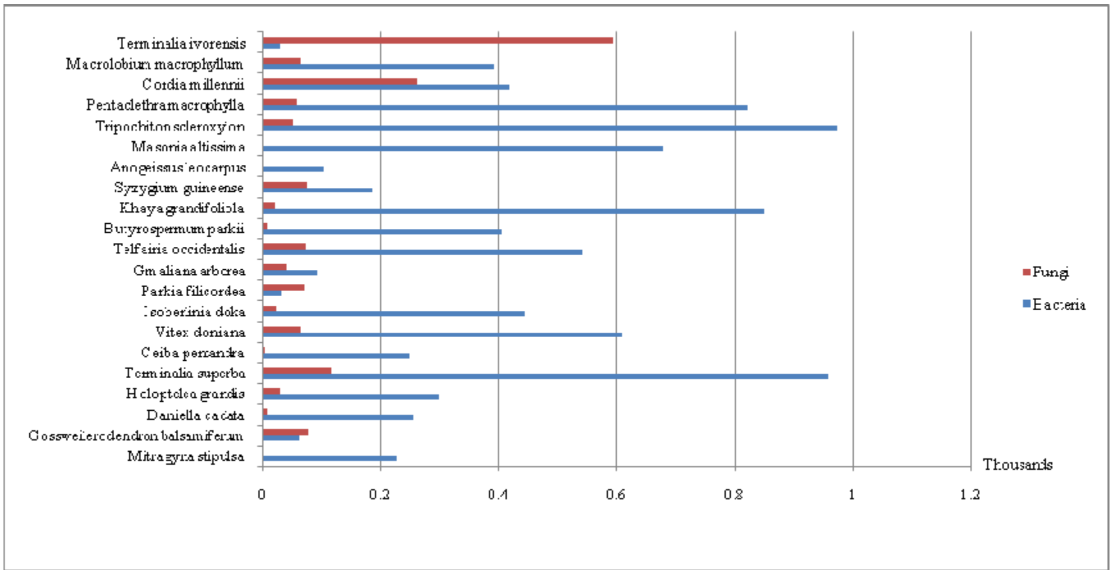

Figure 2: Prevalence of Microorganisms on Some Deteriorated Local Timbers

Figure 2 presents prevalence of fungi and bacteria on some common building timbers. The timbers represented by their scientific names are presented on the x-axis.

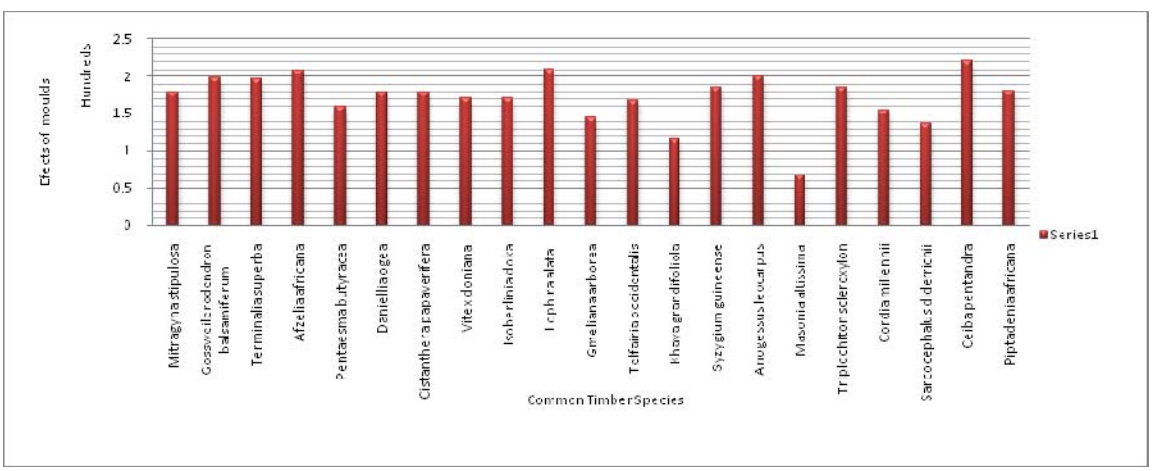

Figure 3: Mould Degradation of Some Selected Timber Species

The resistivity to microbial degradation of common timber samples was tested. Figure 3 shows the value for some selected timber species identified by their scientific names.

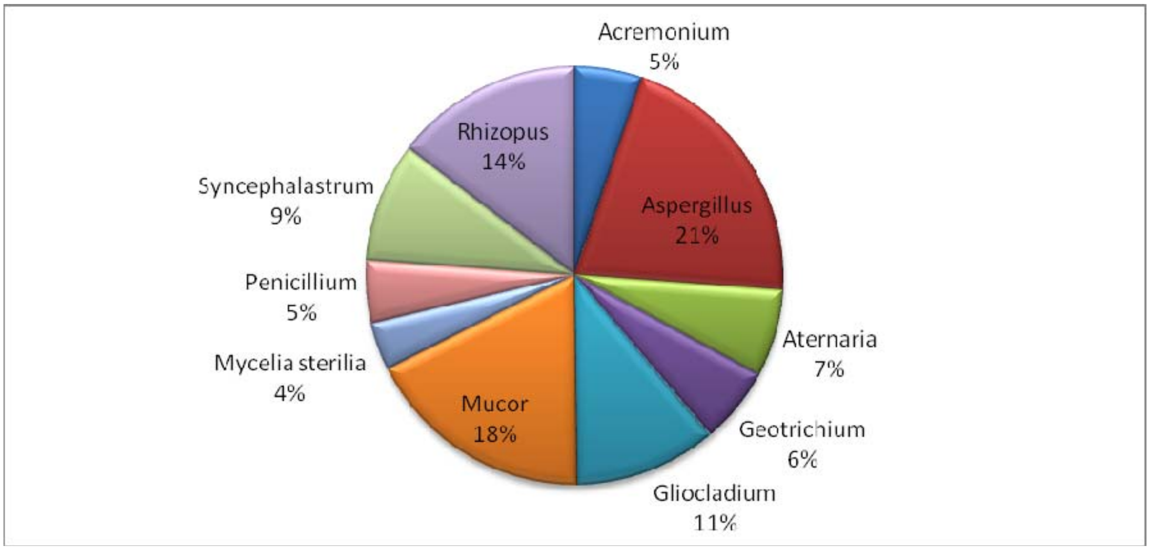

Figure 4: Contributions of Some Selected Moulds to Deteriorations of Timbers

Figure 4 shows the percentage contributions of some moulds on some selected timber samples that are commonly used in construction of buildings.

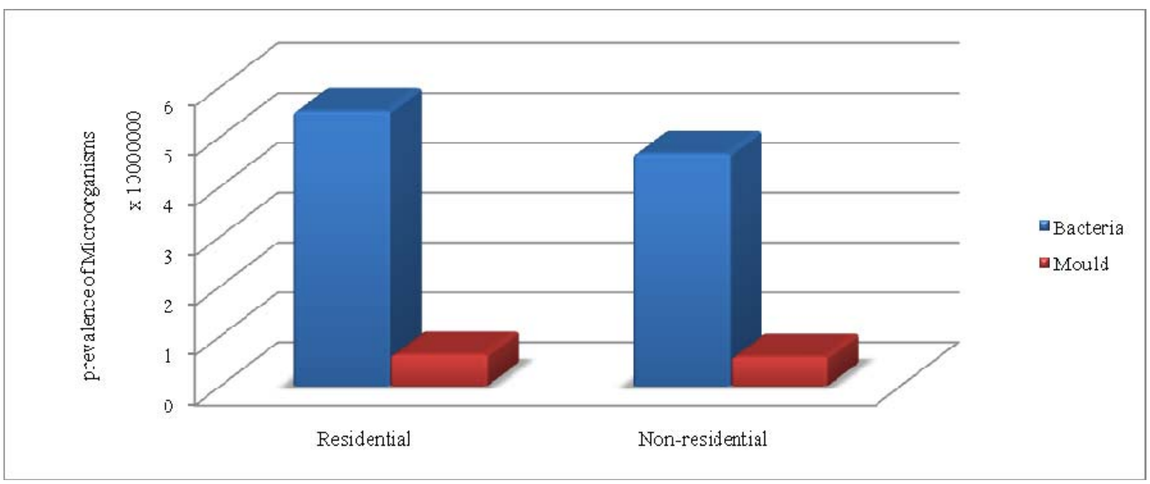

Figure 5: Prevalence of Microorganisms on Residential and Non-Residential Buildings in the Coastline Region

Figure 5 demonstrates the prevalence of microorganism on deteriorated timber components from the residential and non-residential building in the coastline.

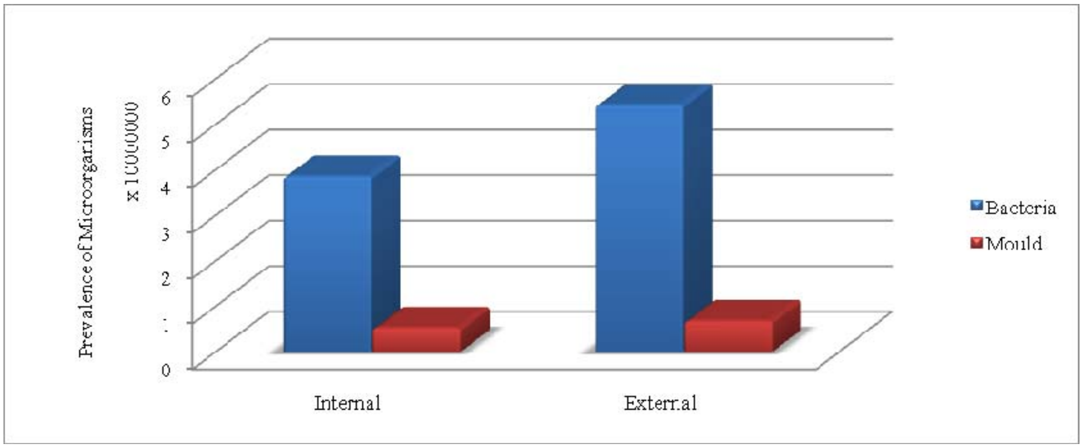

Figure 6: Prevalence of Microorganisms on Internal and External Parts of Buildings in the Coastline Region

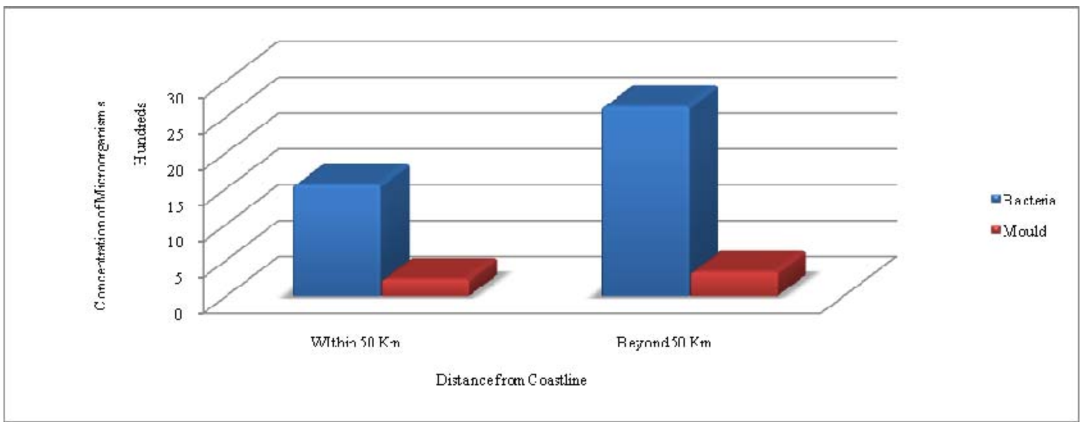

Figure 7: Prevalence of Microorganisms on Building within 50 Kilometers and Greater than 50 Kilometers from the Coastline

DISCUSSIONS

The timber species, '*Triplochiton sculeroxylon*', '*Distemononthus benthamianus*', '*Khaya grandifoliola*', and '*Pentaclethra macrophyila*' habour more microorganisms (Figure 1) and the degree of concentrations on buildings depict contaminations. High prevalence can be linked (Figures 3 and 4) to deteriorations of the timbers. The most contaminants among the fungi are *Aspergillus* species (4.44 x10^6) and the least dominant are Trichothecium (1.33 x 10^4). Moulds are also identified as the major degradants of timbers, main cause of illnesses and sick building syndrome (Hodgson *et al*; 1986; Prescott et al; 2005). Their presence cause serious threats to sustainable environments (Sustainableworld, 2008), because the number of diseases fungi can cause, and the hosts they infect exceed those of bacteria, protozoa and viruses put together. The highest contaminations among bacteria species are *Baccilus* and *Micrococcus* while Enterobacter specie had the least contaminations. Prescott et al (2005] reported that bacteria affect building components via biocorrosion, smell, and health problems, especially at relative humidity greater than 97% and temperature between -5 to 60^{o}C (Erickson *et al*; 2005).

Lebow and Highley (2008) observed that exposed timbers deteriorate more rapidly in warm, wet climates than in cold and or dry climates. This position explains the high distributions and contaminations obtained in this study. Hyvarinen (2002) reported a concentration of 4.500 x 10^5 cfu per meter cube in some other building materials in Finland. The prevalence obtained in this study, varied from one location to another due factors such as microclimates which are generated by natural and artificial infrastructures, soil type, and vegetations that also differ from one area to another within the coastline.

To determine which species of timbers can withstand combined attacks of different species of microorganisms better, selected species were exposed to similar laboratory conditions. '*Masonia altissima'* and '*Khaya Grandifoliola'* species showed higher resistance whereas '*Ceiba pentandra'*, '*Lophira alata'* and '*Afzelia africana'* resisted least (Figure 3). Timber buildings serve under the combined actions of many species of mould, in which each is having certain effects. The extent of damage depends on the species and type of timber being attacked. The contribution to destruction of each genus presented on figure 4 suggests that Aspergillus is responsible for 23% of the total harm to sustainability due to decays of the timbers in building. *Mucor, Rhizopus, Gliocladium* and *Cladospoium* contribute 11% followed by *Mycelia sterilia*, *Penicillium*, *Acremonium*, *Altternaria* and *Chrysolinia* with less than 6% each.

Bacteria contaminated residential buildings more than non-residential buildings and the contaminations of moulds are equal on residential and no residential buildings (Figure 5). The contaminations at the external parts of the buildings are higher than the internal parts (Figure 6). The likely reasons may be that that the internal and the external environments were exposed to the same conditions human activities.

The contaminations on buildings located at a distance further away from the coastline are more than those close to the coastline (Figure 7) but fungal species contaminate buildings further away from the coastline more. The probable reasons being that building closer to the coastline could be too salty for some species to inhabit and certainly, less salty for marine borers to be present.

There is significant difference (0,254) in the prevalence of microorganisms on the timber samples collected indoors and outdoors parts of the building and the analysis of variance indicated that the prevalence and number of microorganisms among the internal and external parts of the buildings are entirely due to the influences of inherent factors and not by chance. There is significant statistical difference of 0.37 in the prevalence of microorganisms. An analysis of variance indicated values greater than the critical value of 1.34 that suggested that some of the microorganisms were captured by chance.

CONCLUSSIONS

The timbers in buildings in the Nigerian coastline are highly dominated by various species of microorganisms. Timber species that showed high levels of susceptibilities to deteriorations due to the microorganisms are *Ceiba* pentandra, *Gosswellerodendron balsamiferum*, *Syzygium guineense*, *Triplochiton nigericum Terminalia superb*, *Anogeissus leocarpus*, and *Mitragyna stipulosa* whereas, '*Masonia altissima'* and '*Khaya Grandifoliola'* showed higher resistance to the biodeteriorations. The most prevalent and degrading among the fungi were species of *Aspergillus, Alternaria* and *Penicilium and* amongst bacteria species were *Micrococcus, Bacillus, Staphylococcus, Klebseila* and *Enterobacter agglomerons.* The fungi species were reported to be saprophytic and can produce VOCs and mycotoxins (Akhtar *et al;* 1997; Doctor Fungus, 2008). The weather is conducive for biodeteriorations of these timbers species and this hampers the sustainability of the region.

The microorganisms influence the sustainability of the coastline by impacting on the environments through emissions of VOCs and toxins, indoor and outdoor air pollutions, waste and emissions of greenhouse gasses. These subsequently impact on health and safety-comfort, well being, environmental and community health, public and occupants' health; maintenance and operating cost- durability, economy of running cost and energy conservation; aesthetics and social prestige- harmony between buildings and the natural environments, and beauty; functionality and adequate use of buildings; employee productivity and reuse and recyclability.

The effects of the biodeteriorations can be mitigated through selections of timber species base on individual natural resistivity to biodeterioration considering locations and positions of use in buildings to avoid contact with water or high relative humidity. Achieving this will not only enhance social and economic sustainability but also promote use of timber as a local building material.

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