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EFFECT OF MICROBES AND ATMOSPHERIC PARAMETERS ON WOOD PRODUCTS UTILIZATION IN UYO, AKWA IBOM STATE, NIGERIA

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ABSTRACT

This study evaluated microbial deteriorating agents and atmospheric parameters that influence strength of woods commonly sold in Uyo timber markets and their impact on the wood utilization .Using the pour plate technique, analytical procedures and the Young Modulus formula, microbial biodeterioration agents, atmospheric parameters and tensile strength of woods exposed to in-door and out-door atmospheric conditions in Uyo, Akwa Ibom State were investigated respectively.Result revealed that microorganisms were commonly deposited on Triplochiton sclerozylon (Obeche), Gmelina arborea Linn (Gmelina)and Milicia excelsa(Iroko) wood samples exposed in suspended atmospheric conditions. The densities of the microbial biodeterioration agents colonizing the woods, varied with wood type and exposure conditions. Wood samples exposed in indoor atmospheric condition had higher densities of fungal deteriogens and those exposed outdoor were colonized more by bacteria. Statistical analysis at 95 % confidence limit revealed weak or insignificant relations (P > 0.5) between atmospheric determinants and microbial loads. This implies that the Atmospheric temperature and relative Humidity (RH) had little or no influence on the microbial activities of woods in suspended atmospheric conditions. The temperature range for indoor exposure was between 30.4 -35.0, relative humidity ranged from 70.0- 80.0 while in the outdoor exposure the temperature fluctuated between 31.8- 40.3 and relative humidity of 50.0-79.0. Even though the environmental conditions fluctuated and did not favour the growth of biodegradation organisms; the atmospheric conditions might change anytime to favour the wood biodegrading organisms. It is therefore recommended that proper treatment with wood preservatives should be employed to enhance the usage life and quality of woods used in suspended platforms.

Keywords: Atmospheric, deterioration, environment, wood

INTRODUCTION

Timbers are susceptible to rapid deterioration by a variety of organisms. The wood in living trees and also in used products would start to decay and decompose with the attack of organisms which is termed as the biodegradation of wood but technically described as bio-deterioration of wood because of the associated economic loss. Among the biological agents of wood decay are; insects such as the larvae and pupae of wood boring beetles or wasps which attack weakened living trees (Mohebby, 2003). Others include termites, carpenter ants and marine borers, ((Mohebby 2003). Fungi mainly the filamentous fungi, moulds spore production and the associated discoloration is often confined to the surface and can be washed or planed off. However, some moulds are known to cause respiratory problems in sensitive individuals (Heseltine *et al.*, 2009). Staining fungi have brown, blue or black coloured mycelium giving the wood a characteristic black, brown or blue appearance. These fungi, while unsightly, generally cause very little damage. However extensive wood damages are usually noticed on woods colonized by the soft rot fungi, wood rotting Basidiomycetes, white rot fungi and brown rot fungi. Bacteria are also known to cause damage in wood with high moisture content, either fresh from the tree, water sprinkled for long term storage prior to sawing or submerged in lakes or wet soil (zabel *et al.*, 1992).

Bio-deterioration is dependent upon many factors including temperature, microbial population, degree of acclimatization, accessibility of nutrient, cellular transport properties and chemical portioning of growth medium. The cell structure itself and properties of wood has great influence on resisting or enhancing the biodegradation (Blanchette 2000). The minimum, maximum and optimum temperature required for growth varies with different decay fungi. Mohebby (2003)reported that wood decay fungi require wood Moisture content in excess fiber saturation point to propagate, that fungal growth below fiber saturation point (absence of lumen water) is greatly retarded and that below 20 % wood moisture content their development is completely inhabited. Decay fungi require the free water (lumen water) whereas sap stain can occur even with bonded water (Morris 2000).

Wood deterioration is supposedly one of the major challenges of the world economy. Although the rate of deterioration of woods stored or piled for sales are widely studied and well known, the agent responsible for decay of woods in suspended or common roofing conditions have not been extensively studied nor its effect on the strength of wood over time investigated. This study was designed to evaluate effect of microbes and atmospheric parameters on wood products utilizations in Uyo, AkwaIbom State, Nigeria"

MATERIALS AND METHODS

Sample collection and preparation

The hardwood samples namely; *Triplochiton sclerozylon* (Obeche), *Gmelina arborea Linn* (Gmelina) and *Milicia excelsa* (Iroko) were obtained from commercial piles at the Uyo Timber Market in Akwa-Ibom State which lies on the latitude 5° 03' 4.57" N and longitude 7° 56' 0.60" E . Planks of the selected woods were carefully and separately sawn into sizes of 1.25 cm and 15cm width and the pieces transferred into sterile polythene bags. The samples were then transported to the experimental sites at the University of Uyo Permanent Site.

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Determination of Microbial and Atmospheric Parameters

After every two weeks of exposure, representative samples of each of the exposed wood samples were removed from the line, sized into pellets using sterilized knife and then crushed into powdery form using sterile laboratory mortar and pestle then 2g of the milled sample was suspended in 18 ml of sterile distilled water.

A ten-fold serial dilution of the supernatant solution derived from each milled sample of the exposed wood sample was carried out by transferring 1ml of the milled sample suspension into test tubes containing 9ml of sterile distilled water arranged serially in the order 10^{-1} – 10^{-10}. The dilutions of 10^{-3} and 10^{-4} were subjectively chosen for the enumeration and isolation of heterotrophic bacteria and fungi

The density of heterotrophic bacteria associated with the deterioration of the wood samples were enumerated and isolated using the pour plate technique and Nutrient agar (NA) as the analytical media. 1ml of the suspension from the chosen dilution were aseptically transferred to a sterile petri dish then sterile molten NA allowed to cool to about 45^{o}C was added to the plates, swirl and allowed to set. The plates were incubated at room temperature for 24hrs. After incubation, the emerging colonies were counted and expressed as colony forming unit per gram (CFU/g) of wood sample analyzed.

Total heterotrophic fungi associated with the deterioration of the wood samples were enumerated and isolated using the spread plate technique and Sabouruad dextrose agar (SDA) as the analytical media. As in heterotrophic bacterial analysis above, the desired dilution levels (10^{-3} and 10^{-4}) of the inoculums were carefully and aseptically inoculated on SDA plates. The SDA plates after inoculation were incubated at room temperature for 96hrs. After incubation, the emerging colonies were counted and expressed as colony forming unit per gram (CFU/g) of wood sample analyzed. The bacterial and fungal isolates were characterized and identified using standard methods of microscopic and biochemical characterization (Cheesbrough, 2006; schemes of Samson et al., 1981 and, Pitt and Hocking (1985)

The changes in relative humidity and temperature levels of the outdoor and indoor atmospheric environments where the hardwood samples were exposed were also determined bi-weekly using Multipurpose Hygro, Baro and Thermo (Hygro 20-100%, Thermo 10-50^{o}C) while the moisture content was determined by weighing each of the

wood samples using precision analytical weighing balance the weight was taken as W_1. The weighed sample was then introduced into a thermostatic oven at 100 degrees Celsius for one hour, allowed to cool and weighed again and the weight is recorded as W_2.This process was repeated until a constant weight was achieved. After which the moisture content of the wood samples was calculated using the formula below;

$$\frac{W1-W2}{W1} \, x \, 100 \ldots\ldots\ldots [1]$$

Data Analysis

The relationships between the microbial loads and the atmospheric parameters (relative humidity and temperature) of the environments where the woods were exposed as well as the wood moisture content and microbial loads were statistically analyzed at P = 0.05 using Karl Pearson's correlation(Zar *et al.*,1984).

RESULTS

Microbial Loads of the Exposed Wood Samples

The microbial loads of the exposed wood samples varied with the type wood and exposure conditions. The research data have shown that wood samples exposed indoor had harbored proportionately more numbers of fungal deteriogens than those exposed outdoor, and those exposed outdoor are readily colonized more by bacteria deteriogens. The results also showed that the duration of exposure influences the microbial loads on exposed woods. For example, the; *Triplochiton sclerozylon* wood samples exposed in indoor atmosphere harbored the highest fungal load of $4.5x10^5$on the 12 week of exposure while the highest bacteria load of 5.3 $x10^5$ was obtained on the 16 week of exposure (Table 1 and 2).

Table 1: Microbial loads of woods exposed in the indoor atmosphere

Wood Sample	Duration In Weeks									
	0	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**
Triplochiton sclerozylon	$1.70x10^5$	$2.35x10^5$	$2.55x10^5$	$4.3x10^5$	$4.2x10^5$	$1.6x10^5$	$5.1x10^5$	$3.25x10^5$	$5.3\ x10^5$	$4.8x10^5$
Gmelina arborea Linn	$1.75x10^5$	$2.0x10^5$	$2.4x10^5$	$3.6x10^5$	$4.9x10^5$	$1.4x10^5$	$2.4\ x10^5$	$4.95x10^5$	$5.9x10^5$	$3.8x10^5$
Milicia excelsa	-	-	$1.4x10^5$	$2.45x10^5$	$3.6x10^5$	$1.25x10^5$	$3.6x10^5$	$4.8x10^5$	$1.7x10^5$	$1.2x10^5$

Bacteria loads

Fungi loads

Wood Sample	Duration In Weeks									
	0	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**
Triplochiton sclerozylon	$1.05x10^5$	$1.8x10^5$	$2.95x10^5$	$1.4x10^5$	$1.2x10^5$	$1.0x10^5$	$4.5x10^5$	$2.9x10^5$	$3.0x10^5$	$1.25x10^5$
Gmelina arborea Linn	$1.15x10^5$	$1.2x10^5$	$2.0x10^5$	$2.1x10^5$	$2.5x10^5$	$1.2x10^5$	$1.15x10^5$	$1.5x10^5$	$1.8x10^5$	$2.15x10^5$
Milicia excelsa	–	$1.0x10^5$	$1.32x10^5$	$1.45x10^5$	$1.5x10^5$	$1.4x10^5$	$1.25x10^5$	$1.3x10^5$	$1.4x10^5$	$1.2x10^5$

Table 2: Microbial loads of Woods Exposed in the Outdoor Atmosphere

Bacterial loads

Wood Sample	Duration In Weeks									
	0	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**
Triplochiton sclerozylon	$1.05x10^5$	$2.95x10^5$	$1.75x10^5$	$4.05x10^5$	$6.0x10^5$	$2.6x10^5$	$1.4x10^5$	$4.05x10^5$	$4.0x10^5$	$3.4x10^5$
Gmelina arborea Linn	$1.15x10^5$	$3.1x10^5$	$2.85x10^5$	$3.5x10^5$	$5.6x10^5$	$3.5x10^5$	$5.25x10^5$	$2.65x10^5$	$3.5x10^5$	$2.75x10^5$-
Milicia excelsa	-	$1.25x10^5$	$1.95x10^5$	$2.35x10^5$	$3.6x10^5$	$1.01x10^5$	$1.16x10^5$	$2.0x10^5$	$2.1x10^5$	$3.2x10^5$

Fungal loads

Wood Sample	Duration In Weeks									
	0	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**
Triplochiton sclerozylon	$1.7x10^5$	$3.15x10^5$	$2.4x10^5$	$3.1x10^5$	$3.8x10^5$	$1.75x10^5$	$2.7\ x10^5$	$3.8x10^5$	$3.2\ x10^5$	$2.3x10^5$
Gmelina arborea Linn	$1.75x10^5$	$3.05X10^5$	$3.7x10^5$	$3.9x10^5$	$1.75x10^5$	$2.05x10^5$	$1.85x10^5$	$2.7x10^5$	$2.5x10^5$	$2.2x10^5$
Milicia excelsa	-	$1.7x10^5$	$3.15x10^5$	$2.4x10^5$	$3.1x10^5$	$2.8x10^5$	$1.75x10^5$	$2.7\ x10^5$	$2.8x10^5$	$3.2x\ 10^5$

The changes in relative humidity and temperature rates of the indoor and outdoor atmospheric environment where the wood samples were exposed are presented in Table 3 and the moisture content of the wood samples is presented in Table 4 .The results revealed average ranges in temperature of 30.4-40.3^{o}C, relative humidity of 50.0 - 80.0% and wood moisture of 4.9-19.0%. Higher relative humidity levels were recorded in the indoor than the outdoor atmospheres.

Table 3 Changes in Temperature and Relative humidity of indoor and outdoor conditions where the woods were exposed

Indoor

Atmospheric Parameters	Duration in Weeks									
	0	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**
Temperature (◦c)		30.4	30.8	34.6	32.9	35.0	35.3	30.4	34.0	32.0
Outdoor Relative humidity (%)		80.0	82.5	70.0	79.5	73.5	70.5	78.0	70.0	72.0

Outdoor

Atmospheric Parameters	Duration in Weeks									
	0	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**
Temperature(◦c)		31.9	32.8	36.6	33.7	40.3	36.7	31.8	35.5	33.0
Relative humidity (%)		75.0	79.0	64.0	74.0	50.0	65.5	71.0	64.0	66.0

Table 4: Changes in the moisture content of the woods exposed in the indoor and outdoor conditions

Indoor

WoodSample	Duration in Weeks									
	0	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**
Triplochiton sclerozylon	13.0	13.0	12.1	11.4	11.0	5.7	12.6	12.7	16.8	9.6
Gmelina arborea Linn	11.7	12.2	14.4	21.2	19.0	7.4	16.2	13.0	16.2	13.3
Milicia excelsa	11.1	11.4	11.6	12.1	16.4	5.3	12.3	12.9	11.8	7.9

Outdoor

Wood Sample	Duration in Weeks									
	0	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**
Triplochiton sclerozylon	13.0	11.4	10.0	12.0	13.3	4.9	11.7	14.5	13.3	12.4
Gmelina arborea Linn	11.7	12.2	12.6	14.4	11.4	5.8	12.6	13.7	12.8	11.7
Milicia excelsa	11.1	10.3	12.0	10.1	13.0	5.1	10.8	11.7	13.2	7.8

Relations between Microbial Loads and Atmospheric Parameters in Different Wood Samples

The relationships between the microbial loads and the atmospheric parameters (relative humidity and temperature) of the environments where the woods were exposed as well as the wood moisture content and microbial loads were statistically analyzed at P = 0.05. The results of analysis are summarized Tables 5 -7, the results showed a generally weak relationship between RH and microbial activities. Except for *Milicia excelsa* wood exposed indoor, where negative but insignificant (P > 0.05) relationships were established for fungi (r = -0.28) and bacteria (r = -0.36), other pairs of relation analyzed for the three woods revealed positive but insignificant (Table 5). Relations between moisture content and microbial loads of all the test woods were positive and insignificant (Table 6).Similar results were recorded between temperature and microbial loads of woods except for the bacterial loads of *Triplochiton sclerozylon* and *Milicia excelsa* exposed outdoor which had r - values of -0.23 and -0.44 respectively (Table 7).

Table 5: Relations between microbial activities on wood and relative humidity of the atmosphere

S/No.	Pair of Variables	r at P = 0.05	Remark
1	RH and fungal loads of *Gmelina arborea Linn* exposed in outdoor atmosphere	0.338	Positive but insignificant
2	RH and bacterial loads of exposed in outdoor atmosphere *Gmelina arborea Linn*	0.090	Positive but insignificant
3	RH and fungal loads of *Triplochiton sclerozylon* exposed in outdoor atmosphere	0.576	Positive and significant
4	RH and bacterial loads of *Triplochiton sclerozylon* exposed in outdoor atmosphere	0.031	Positive but insignificant
5	RH and fungal loads of *Milicia excelsa* exposed in outdoor atmosphere	0.424	Positive but insignificant
6	RH and bacterial loads of *Milicia excelsa* wood exposed in outdoor atmosphere	0.370	Positive but insignificant
7	RH and fungal loads of *Gmelina arborea Linn* exposed in indoor atmosphere.	0.402	Positive but insignificant
8	RH and bacterial loads of *Gmelina arborea Linn* exposed in indoor atmosphere	0.347	Positive but insignificant
9	RH and fungal loads of *Triplochiton sclerozylon* exposed in the indoor atmosphere.	0.373	Positive but insignificant
10	RH and bacterial loads of *Triplochiton sclerozylon* exposed in indoor atmosphere.	0.399	Positive but insignificant
11	RH and fungal load of *Milicia excelsa* exposed in indoor atmosphere	-0.288	Negative and insignificant
12	RH and bacterial loads of *Milicia excelsa* exposed in indoor atmosphere	-0.360	Negative and insignificant

Key: *RH-relative humidity*

Table 6: Relations between microbial activities on wood and atmospheric moisture

S/No.	Pair of Variables	r at P = 0.05	Remark
1	Moisture level and fungal loads of *Gmelina arborea Linn* exposed in outdoor atmosphere	0.301	Positive but insignificant
2		0.021	Positive but insignificant
3	Moisture level and bacterial loads of *Gmelina arborea Linn* exposed in outdoor atmosphere	0.596	Positive but insignificant
4	Moisture level and bacterial loads of *Triplochiton sclerozylon* e exposed outdoor atmosphere	0.0210	Positive but insignificant
5	Moisture level and fungal loads of *Milicia excelsa* exposed in outdoor atmosphere	-0.522	Negative and significant
6	Moisture level and bacterial loads of *Milicia excelsa* exposed in outdoor atmosphere	0.601	Positive and significant
7	Moisture level and fungal loads of *Gmelina arborea Linn* exposed in indoor atmosphere	0.681	Positive and significant
8	Moisture level and bacterial loads of *Gmelina arborea Linn* exposed in indoor atmosphere	0.175	Positive but insignificant
9	Moisture level and fungal loads of *Triplochiton sclerozylon* exposed in indoor atmosphere	0.032	Positive but insignificant
10	Moisture level and bacterial loads of *Triplochiton sclerozylon* exposed in indoor atmosphere	0.404	Positive but insignificant
11	Moisture level and fungal loads of *Milicia excelsa* exposed in indoor atmosphere	0.028	Positive but insignificant
12	Moisture level and bacterial loads of *Milicia excelsa* exposed in indoor atmosphere	0.075	Positive but insignificant

Table: 7 Relations between microbial activities on wood and atmospheric temperature

S/No.	Pair of Variables	r at P = 0.05	Remark
1	Temperature and fungal loads of *Gmelina arborea Linn* exposed in outdoor atmosphere	0.322	Positive but insignificant
2	Temperature and bacterial loads of *Gmelina arborea Linn* exposed in outdoor atmosphere	0.843	Positive but insignificant
3	Temperature and fungal loads of *Triplochiton sclerozylon* exposed in outdoor atmosphere	-0.604	Negative but significant
4	Temperature and bacterial loads of *Triplochiton sclerozylon* exposed in outdoor atmosphere	-0.228	Negative and insignificant
5	Temperature and fungal loads of *Milicia excelsa* exposed in outdoor atmosphere	0.268	Positive nut insignificant
6	Temperature and bacterial loads of *Milicia excelsa* exposed in outdoor atmosphere	-0.436	Negative and insignificant
7	Temperature and fungal loads of *Gmelina arborea Linn* wood exposed in indoor atmosphere	0.405	Positive but insignificant
8	Temperature and bacterial loads of *Gmelina arborea Linn* exposed in indoor atmosphere	0.327	Positive but insignificant
9	Temperature and fungal loads of *Triplochiton sclerozylon* exposed in indoor atmosphere	0.375	Positive but insignificant
10	Temperature and bacterial loads of *Triplochiton sclerozylon* exposed in indoor atmosphere	0.533	Positive and significant
11	Temperature and fungal loads of *Milicia excelsa* exposed in indoor atmosphere	0.535	Positive and significant
12	Temperature and bacterial loads of *Milicia excelsa* exposed in indoor atmosphere	-0.0756	Negative and insignificant

DISCUSSION

The load (density)of the potential biodeteriogens did not follow a definite pattern but fluctuated over time by prevailing atmospheric conditions, this supports the fact that growth and decay depends on the kind of wood and the environmental conditions (Blanchette, 2000).

Appropriate environmental conditions such as temperature, moisture and oxygen favour the growth of basidiomycetes which are known to be majorly responsible for 'white rots' and 'brown rots' in wood pulp. Nevertheless under high moisture conditions the wood is degraded by ascomycetous fungi. In this study, the temperature and relative humidity of the atmosphere in which the woods were exposed were not stable but rather fluctuated over time and had may have affected the wood moisture. The wood moisture levels were generally below 20%, a level in which many bacteria may find difficult to survive and proliferate (Morris 2000). It is common knowledge that microorganisms cannot replicate while suspended in the air due to limiting environmental factors such as dehydration, UV radiation and temperature which are often lethal. These conditions are responsible for the relatively low number of vegetative (diverse) forms found

on the suspended woods, whereas resistant dormant structures such as the spores of bacteria and fungi are more numerous (Petri *et al.*, 2011). Therefore, the occurrence and activities of the white and brown rots fungi may also have been retarded due to the low moisture content of the exposed woods. The prevalent conditions in which the woods were exposed were "harsh" though the samples were colonized by some hyphomycetous fungi and bacteria. Their actual ability to degrade would be determined by their ability to produce the necessary enzymes.

The results revealed ranges in temperature of 30.4-40.3^{o}C, relative humidity of 50.0 - 80.0% and wood moisture of 4.9-19.0%. Higher relative humidity levels were recorded in the indoor than the outdoor atmospheres. This temperature range falls within the optimum required temperature for mesophiles. According to Morris (2000), wood rotting fungi have varying temperature optima but commonly lie between 20^{o}C and 30^{o}C. A few wood deteriogens grow fasters at 34 -36^{o}C and these are typically the species that are dominant on exterior wood products exposed to sunlight. Most wood bio-deteriogens are stopped by temperature higher than 46^{o}C but they may not be killed until the temperature reaches 60^{o}C as with many biological systems, a ten degree drop in temperature result in a halving of the growth rate. Water on the other hand is a key limiting factor in decay of woods in structures and in temperate climates, moisture control is key to the durability of wood systems. While some molds can colonize wood at moisture content between 15 – 20% little or no sporulation will occur (Morris, 2000). Statistical analysis of the relationships between the microbial loads and atmospheric parameters (relative humidity and temperature) as well as wood moisture levels revealed no definite pattern. The relations were weak and positive in most cases and negative in few cases depending on the type of wood and exposure conditions. It implies that at conditions in which the woods were exposed. The atmospheric temperature and relative humidity had little or no promoting influence on the activities of the microbial colonizers.

CONCLUSION AND RECOMMENDATION

The results of this study have revealed that woods kept off soil would last longer when used in roofing purposes. This has shown that wood exposed in suspended atmospheric conditions is a poor substratum for microbial growth, and subsequent degradation. The conditions in which the woods were exposed, the atmospheric temperature and relative humidity had little or no influence on the activities of microbial colonizers. The environmental conditions fluctuated and did not favour the growth of biodegradation organisms. It is therefore recommended that proper treatment of wood with preservatives should be employed to enhance the usage life and quality of woods used in suspended platforms.

REFERENCES

Blanchette, R. A. (2000). A Review of Microbial Deterioration Found in Archaeological Wood from Different Environments. *International Bio-Deterioration and Biodegradation* 46,189-204.

Cheesebrough, M. (2006). *District Laboratory Practice in Tropical Countries.* Part 2 Cambridge Low Price Edition

Gaur, R., Darmwal N. S. and Pandey, P. K. (2005). The Production of Alkaline Protease by Bacillus sp. N-40 Isolated from Soil. *Biochemistry*, 40, 3569 – 3575.

Heseltine, E and Rosen, E. D. (2009). WHO Guidelines for Indoor Air Quality: *Dampness and Mould* (PDF). 93. February 1, 2015.

Mohebby, B. (2003). Biological Attack of Acetylated Wood, Unpublished Ph. D Thesis Submitted to Georg-August University, Goettingen, Germany.

Morris P.I. (2000). Understanding Biodeterioration of Wood in Structure. Report to the Forintek Canada Corp. Vancouver B.C, p.23. Z

Petri, S., Gleb, A., Juha, Hand Timo, K. (2011). Biological Control of Wood Decay Against Fungal Infection. *Journal of Environmental Management*, 92(7): 1681 – 1689.

Pitt, J. I and Hocking, A. D. (1985). Fungi and Food Spoilage Academic Press. New York, pp. 30.

Ruden, H, Thorfen, E., Fisher, P. and Mihm, M. (1978). Airborne Microorganism: Their Occurrence, Distribution and Dependence on Environmental Factors Especially on

Organic Compound of Air Pollution., *pageop, Birk Hauser, Basel.*

Samson, R. A and Pitt, J. I. (1985). *Advances in Penicillum and Aspergillus Systematics*, London: Plenum Press, pp.455 – 460.

Vainio-Kaila T., Kyyhkynen A., Viitanieni P., Siitonen A. (2010). Pine heartwood and glass surfaces: Easy Method to Test the Fate of Bacterial Contamination. *European Journal Wood Production*, 69: 391-395.

Zabel, R. A, and Morell, J. J. (1992). *Wood Microbiology: Decay and its Prevention.* San Diego, C A: Academic Press, Orlando, p.476.

Zar, J. H, Bruns, T., Lee S, Taylor, J. W. (1990). *Amplification and Direct sequencing of Fungal Ribosomal RNA Genes for Phylogenetics. PCR Protocols: A Guide to Methods and Applications.* Academic Press, 315 – 322.