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Study of Fungi associated with the biodeterioration of Painted Outdoor Wall Surfaces

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ABSTRACT

Paint is a liquid or semi solid synthetic chemical solution used for the protective and decorative finishing of surfaces. Its components make it susceptible to microbial attack. The economic losses as a result of biodeterioration of outdoor wall surfaces especially those of buildings by fungi can be expensive as these deteriorated exterior surfaces have to be refurbished regularly. This study aimed at determining the fungi involved in the deterioration of painted outdoor walls. Outdoor paint samples for three different types of paint – emulsion, textured paint and oil paint – were collected from various buildings that showed signs of microbial attack. The fungi were isolated using Potato Dextrose Agar. Counts were determined using the dilution plating technique. Fungal identification was done using macroscopic and microscopic methods. The implicated fungi belonged to nine genera – *Aspergillus*, *Penicillium, Fusarium, Alternaria, Curvularia, Mucor, Saccharomyces, Rhizopus* and *Cladosporium*. Emulsion paints were found to be more susceptible to microbial attack having the a greater diversity of isolates and the highest total fungal counts while oil paints were considered least prone to microbial deterioration as the samples had the lowest total fungal counts and diversity. Emulsion paint showed mean total fungal counts of 5.1×10^4 – 6.2×10^4 while textured paint and oil paint had mean values ranging between 2.0×10^4 and 4.1×10^4 and 1.5×10^4 and 3.65×10^4 respectively. The highest frequency of occurrence of fungi across all the paint types was in the order, *Aspergillus* > *Mucor* > *Penicillium* > *Rhizopus*. The other isolates had frequencies below 50%.

Keywords: Biodeterioration; Emulsion; Fungi; Oil Paint; Painted wall; textured paint.

1. INTRODUCTION

There are several descriptions for paint but it is agreed that it is a synthetic chemical solution commonly applied to surfaces in layers forming a coloured solid coating and providing texture. It tends to have a consistency between liquid and a semi-solid paste [1-3]. It is essentially a "solution of pigments in water, oil or organic solvent." [4: 155]. It is used as a protective and decorative finish to prevent materials such as cement infrastructure, wood, metal, furniture and utensils from environmental weathering [5-6].

Paints are broadly classified as being water-based or solvent-based. Emulsion and textured paints (commonly known by the brand name Texcote®) are water-based with emulsion paint having a higher water content. Oil paint is solvent-based [7]. Paints are made of a variety of chemicals mainly binders, solvents, pigments and certain organics [8]. The various organic components of paint, and in some cases the synthetic components as well, including the additives, thickeners, emulsifiers, glues and binders present a good source of carbon for most microorganisms [9, 1, 10-11].

The deterioration of a layer of paint causes its components to be mineralized which impacts on its durability and functionality. This will normally manifest as cracking, blistering, detachment from the coated surface and discolouration [12, 8, 13]. Though various organisms are involved in the deterioration of paint films, fungi and algae are the main defacing agents of applied paints on surfaces with fungi being dominant over algae based on abundance and diversity

[4, 12, 11]. The role of bacteria in the breakdown of applied paints is relatively limited; they tend to play a stronger role in in-can contamination and biodeterioration [2]. Fungal deterioration of external or outdoor paint films is a bigger problem in the tropics probably as a result of the suitable weather conditions [14].

Biodeterioration of paint films results in economic loss as the affected surfaces have to be refurbished as often as the deterioration occurs. It further results in the release of toxic degradation products into the environment [3, 9]. The environmental health implications cannot be over-emphasised. The toxic substances released can be detrimental to human health. Fungal spores have been known to trigger allergic or hypersensitivity reactions including Rhinitis or Asthma. The "sick building syndrome" has been associated with microbial deterioration of paint especially as regards somewhat enclosed spaces. This situation is not helped by the fact that the fungi groups responsible can be quite resilient [15, 3]. Considering the above, it is important to understand the specific fungi involved in the biodeterioration of paints in order to better appreciate the problem and devise effective management techniques and solutions.

2. MATERIALS AND METHODS

2.1 Sample Collection

Outdoor paint samples were collected from various buildings along the East-West road, Port Harcourt, Nigeria. Three sets of each type of paint – textured paint, Emulsion and Oil paint were collected. The samples were collected from outdoor walls that showed signs of microbial attack including discoloration, flaking, peeling or loss of texture. The samples were scrapped into sterile pouches using a scalpel. Samples were collected at weekly intervals over a three-week period.

2.2 Isolation of Fungi and Determination of Total Fungi

A known weight (1g) of the paint sample was added to 9ml sterile normal saline. From this 1ml was obtained for serial dilution and subsequent cultivation. Dilutions 10^{-3}, 10^{-4} and 10^{-5} were aseptically plated in triplicate on to Potato Dextrose Agar (PDA) using the spread plate technique. In order to prevent bacterial growth, 100mg/L of chloramphenicol was added. Incubation was at 37^{o}C for 2 – 5 days. Discrete colonies were sub-cultured on to fresh agar and colonies obtained transferred to PDA slants for preservation and further study.

The same dilutions used for isolation were used to determine the total fungi count. Counts were done on Day 5. Control plates consisted of agar plates with no inoculum.

2.3 Characterisation and Identification of Isolates

Identification of the fungal isolates was done via morphological characterisation – colonial and microscopic [16], [17], [18]. Microscopic examination was done using lactophenol blue stain.

3. RESULTS AND DISCUSSION

This study established that there were twelve (12) isolates altogether from nine (9) different genera. *Aspergillus*, *Penicillium, Fusarium, Alternaria, Curvularia, Mucor, Saccharomyces, Rhizopus* and *Cladosporium* were found to be involved in the biodeterioration of the different types of painted outdoor wall surfaces; *Saccharomyces* sp. being the only yeast genus isolated. The fungi isolated from the different paint samples can be seen in Table 1. *Aspergillus flavus, Aspergillus fumigatus, Aspergillus niger, Mucor sp., Penicillium chrysogenum, Penicillium expansum* and *Rhizopus* were implicated in the biodeterioration of all the paint types. Most of the genera isolated from the water-based emulsion and textured paints were also found in the solvent-based oil paint. *Fusarium* however, was unique to textured paints. No yeasts were isolated from the oil paint samples. *Cladosporium* and *Curvularia* were only found in the water-based paints (emulsion and textured paints) not the oil paint. The *Aspergillus* species implicated were *Aspergillus flavus, Aspergillus niger* and *Aspergillus fumigatus*. For *Penicillium*, the species found were *Penicillium chrysogenum* and *Penicillium expansum*. These findings tally with those of recent studies involving biodeteriorated paint films [19], [20], [8], [21]. In addition to the fungal groups found in this study, *Acremonium* and *Cephalosporium* have also been isolated from biodeteriorated wall paint scrapes [19], [20]. Other reports however include more pathogenic groups such as *Trichoderma, Syncephalastrum, Stachybotrys, Epidermophyton, Helminthosporium* and *Trichophyton* [1], [22], [4]. These are absent in this study. Okpokwasili and Ituen [4] also recorded that *Aureobasidium* and *Geotrichum* among the molds and *Saccharomyces, Kluyveromyces, Rhodotorula, Pichia, Candida* and *Zygosaccharomyces* among the yeasts played a role in the biodeterioration of paint films. In another study, *Tripospermum, Epicoccum, Monascus* and *Nigrospora* were isolated alongside *Cladosporium, Alternaria*, *Curvularia*, and *Aureobasidium* [22].

Emulsion paint had both the highest fungal counts and the highest number of fungal isolates while oil paint had the least in both cases (Fig. 1 and 2). Emulsion paint scrapes had mean total fungal counts of 5.1×10^4 – 6.2×10^4, textured paint, 2.0×10^4 – 4.1×10^4 and oil paint had mean values of 1.5×10^4 – 3.65×10^4. Observations (Fig. 2) revealed that across the individual samples, emulsion paint had 19 isolates across eight genera whereas textured paint had 16 isolates across seven genera and Oil paint, 12 isolates across five genera.

Table 1: Fungal Isolates from the Different Paint Types

Paint Type	Fungi isolated
Emulsion Paint	*Aspergillus flavus* *Aspergillus niger* *Aspergillus fumigatus* *Saccharomyces* sp. *Mucor sp.* *Penicillium chrysogenum* *Penicillium expansum* *Cladosporium* sp. *Curvularia* sp. *Rhizopus* sp. *Alternaria* sp.
Textured Paint	*Aspergillus niger* *Aspergillus flavus* *Aspergillus fumigatus* *Saccharomyces sp.* *Mucor* sp. *Rhizopus* sp. *Penicillium chrysogenum Penicillium expansum* *Fusarium* sp. *Cladosporium* sp.
Oil Paint	*Aspergillus flavus* *Aspergillus fumigatus* *Aspergillus niger* *Mucor sp.* *Penicillium chrysogenum* *Penicillium expansum* *Rhizopus* sp. *Alternaria* sp.

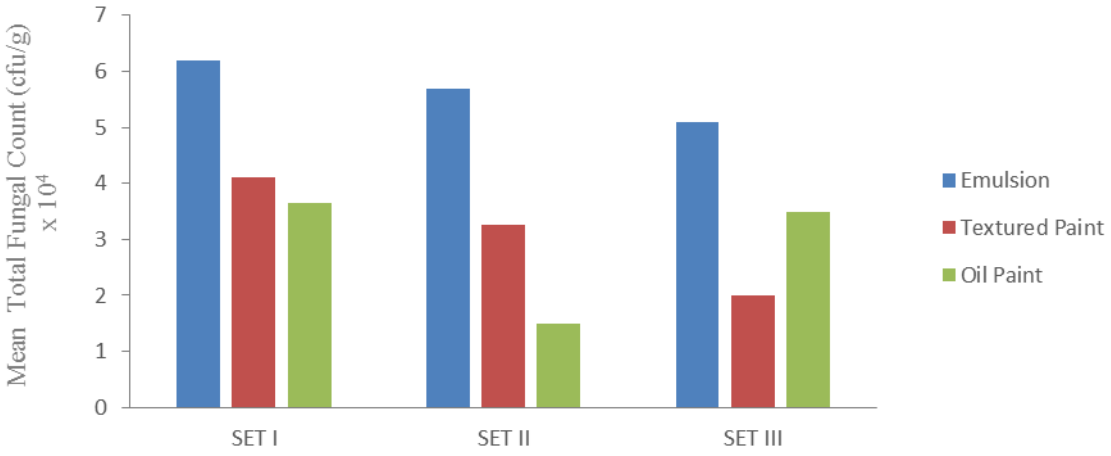

Figure 1. Variation in mean fungal counts across the paint samples

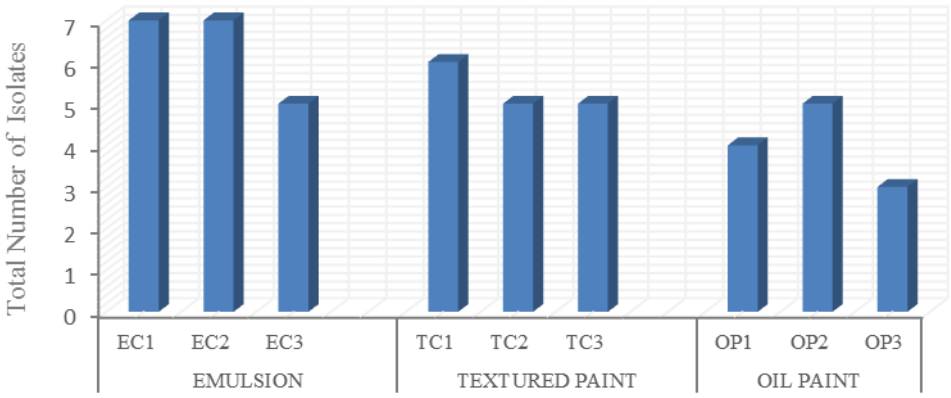

Figure 2. Number of Fungal Isolates Obtained from Each Sample

The greater diversity and counts seen in emulsion paint compared to textured paint and oil paint is attributable to its water content. Emulsion and textured paints have a water content of between 25% and 50% with emulsion having the higher water content. Oil paint on the other hand, has negligible to no water and is consequently the least prone to fungal degradation [23]. It is only natural that microorganisms would find it more convenient to utilise the substrate with the higher water content hence the greater diversity and fungal counts in emulsion compared to the other types of paint. The results revealed that emulsion paint had counts twice that of oil paint. A similar observation was made in another study and credited to the tendency for emulsion paints to retain moisture when applied to a surface and the fact that emulsion paints contain talc which has been found to be an excellent source of nutrients for microorganisms [8]. With textured paint, the total fungal count values were only slightly higher than those found in oil paint which is unexpected considering not only its water content but also that its finish provides a greater surface area for fungal attachment. Total fungal counts of 1.0 x 10^1 – 5.5 x 10^3 cfu/ml were observed on freshly painted wall surfaces monitored for a 10-month period [2]. The painted walls in this study had been exposed for much longer than 10months and so showed higher fungal counts.

Aspergillus was found to have the highest frequency of occurrence across all the samples and the greatest distribution of 31 – 38% within each paint types compared to other isolates (figs. 3 and 4). It was closely followed by *Mucor*, *Penicillium* and *Rhizopus* in both frequency of occurrence and distribution within the different types of paint. The rest of the isolates had frequency values below 50%. The lowest frequencies observed belonged to *Alternaria* and *Fusarium*. The distribution of the fungal isolates in the biodeterioration of the different types of paints is outlined in Fig. 5 to 7.

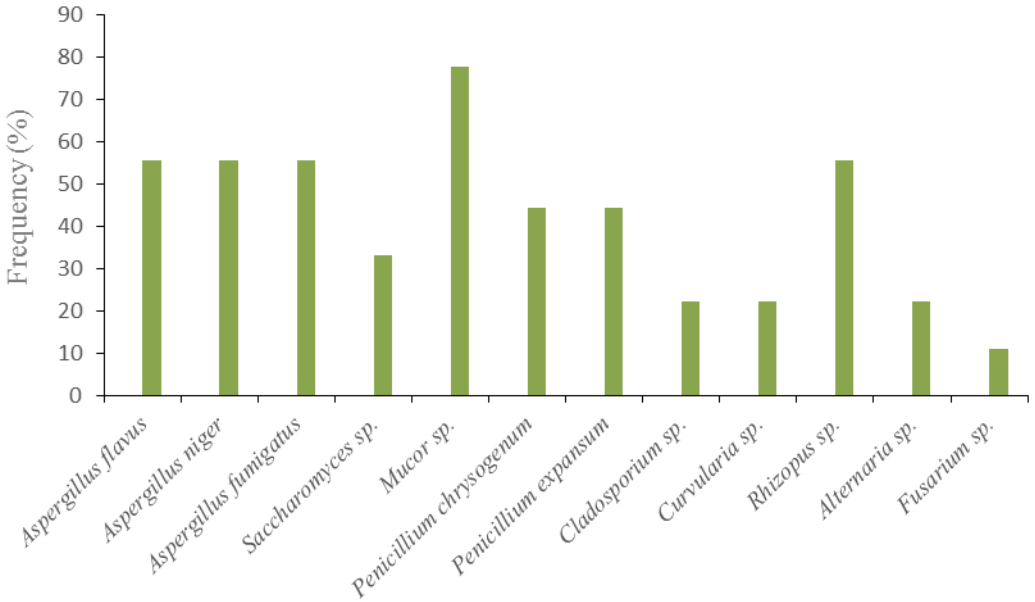

Figure 3. Frequency of occurrence of each isolate across all the types of paint

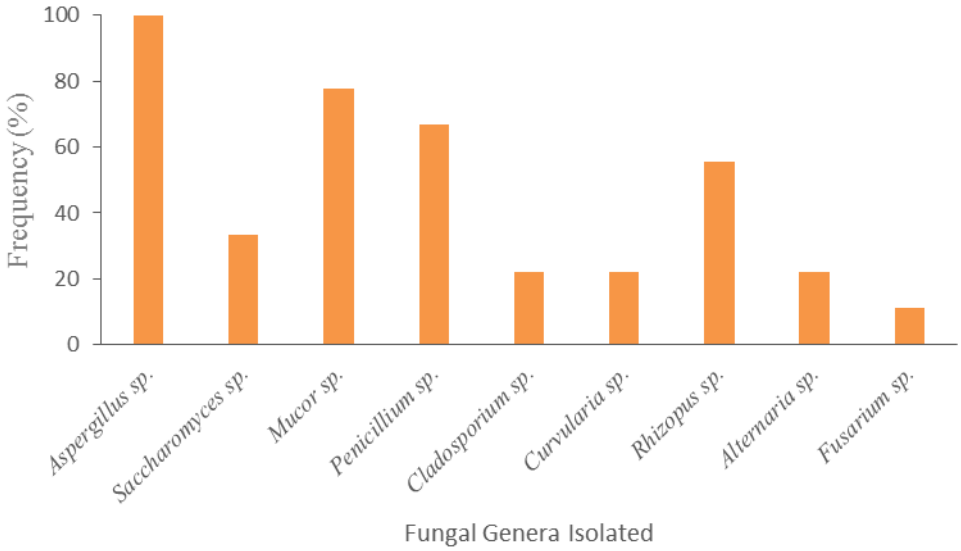

Figure 4. Frequency of occurrence of each genus across all the paint samples

These results are corroborated by the observations of Uzma and Rahlia [19] and Adeleye and Adeleye [24] who recognised that *Aspergillus* sp. predominated in the microbial breakdown of painted wall surfaces. A similar research work likewise, stated that *Aspergillus*, *Penicillium*, *Fusarium* and *Rhizopus* were the major microbial deteriogens of painted surfaces [25]. An investigation into microorganisms involved in bio-fouling of paint films observed that *Aspergillus*, *Alternaria* and *Penicillium* had the same frequency of occurrence but *Fusarium* and *Syncephalastrum* played the strongest role in biodeterioration of the painted surfaces [4]. The same study reported that *Cladosporium* had the lowest frequency of occurrence while *Saccharomyces* had the highest frequency amongst the yeasts. These findings correspond to some extent with the low frequency of *Curvularia*, *Cladosporium* and *Fusarium* observed in this study. Shirakawa *et al.* [21] in contrast found that *Cladosporium* dominated in newly painted buildings.

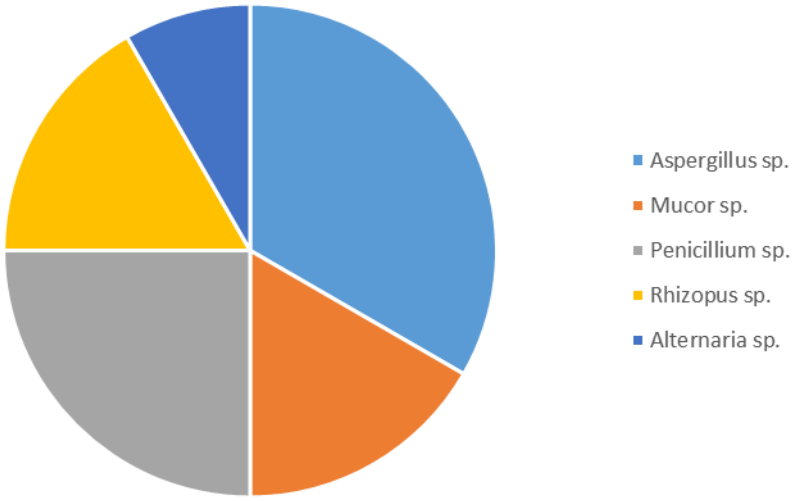

Figure 5. Distribution of Fungi Implicated in the Biodeterioration of Outdoor Oil Paint

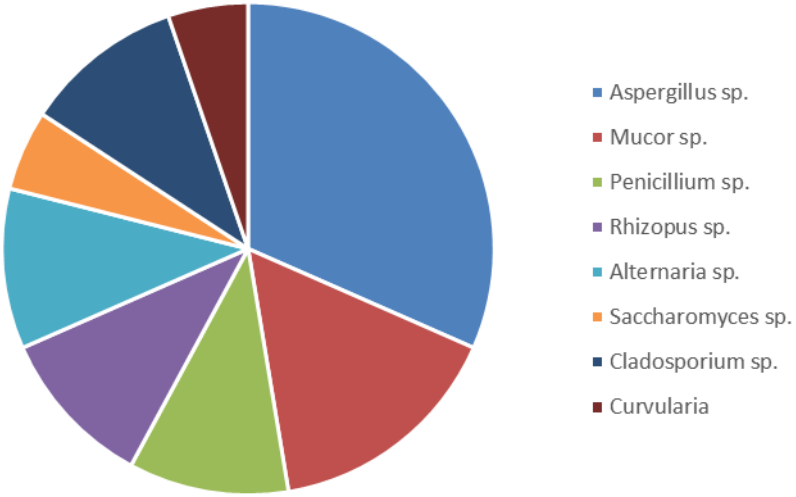

Figure 6. Distribution of Fungi Implicated in the Biodeterioration of Outdoor Emulsion Paint

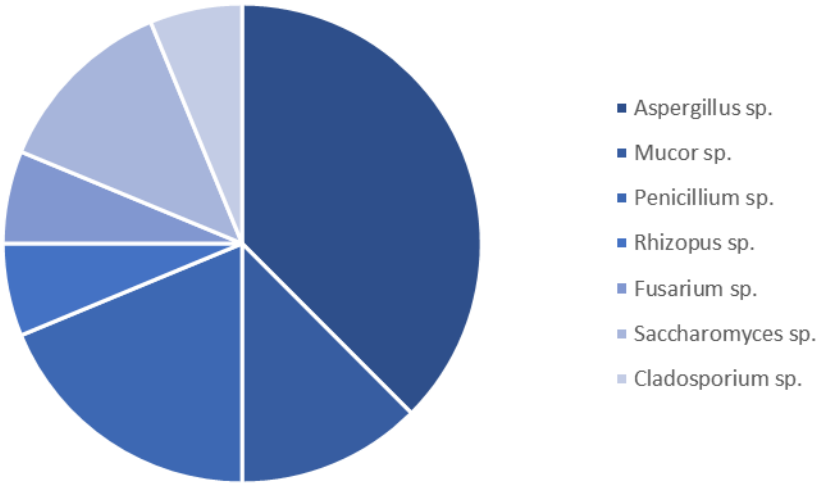

Figure 7. Distribution of Fungi Implicated in the Biodeterioration of Outdoor Textured Paint

It is important to note that environmental factors including relative humidity, dampness and rainfall pattern play an important role in the biodeterioration of these surfaces alongside microorganisms. It has been found that sometimes these paints could be contaminated in-can prior to application which informs the inclusion of biocides during paint formulation [14]. It is recommended that paints be moisture repellent and contain antimicrobials in order to combat the problem of biodeterioration [19]. [20]. For paint films that have already been impacted, it might be best to strip the paint layer and replace with moisture proof paint containing environmentally friendly biocides.

4. CONCLUSION

Fungi not only affect the aesthetics of painted surfaces but also cause direct breakdown of the pigments through their metabolic activities. *Aspergillus, Mucor, Rhizopus* and *Penicillium* play key roles here. Water-based paints are more susceptible than solvent based paints to deterioration by fungi and thus stronger precautions should be taken in their formulation and manufacture.

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