Asian Journal of Advanced Research and Reports

15(5): 1-8, 2021; Article no.AJARR.71071
ISSN: 2582-3248

COVID-19 Desertion – Investigating Mold Potentials before Office Re-Entry

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJARR/2021/v15i530393
Editor(s):
(1) Dr. Juan Manuel Vargas-Canales, the University of Guanajuato, Mexico.
(2) Dr. Fagbadebo Omololu Michael, Durban University of Technology, South Africa.
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Reviewers:
(1) Patel Gayatriben Bhagavandas, Kadi University, India.
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(3) Andrea Santo, Italy.
Complete Peer review History: https://www.sdiarticle4.com/review-history/71071

Original Research Article

Received 29 May 2021
Accepted 28 July 2021
Published 29 July 2021

ABSTRACT

Background: While workers and organisations heeded lockdown enforcements and abandoned offices in response to COVID-19 pandemic, the potential for mold growth thrived in unoccupied offices. An investigative enquiry to assess the potential and risk of exposure to mold is a sine-qua-non to safe re-entry to offices.

Materials and Method: An analytical study conducted through walk through survey involving visual inspection, measurement of physico-chemical parameters (Temperature, Relative Humidity, Air Velocity and Particulate Matters PM2.5); collection and analysis of suspected swab and bulk samples.

Results: Results showed copious amount of moisture evidenced by an averagely high relative humidity of 94%, low ambient temperature of 16% and poor ventilation evinced by an air velocity of 0.4 metre per second. Analysis of samples Mucor species revealed (*Mucor mucedo*, *Mucor himalis, Mucor racemosus*); Aspergillus species (*Aspergillus flavus, Aspergillus fumigatus and Aspergillus terrus*); Cladosporium species (*Cladosporium cladosproides* and *Cladosporium sphaerosperum*).

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Conclusion: Poor ventilation, deposits of debris, increased moisture and dysfunctional ventilation system as found in abandoned offices for Mold growth. Post lockdown re-entry to offices should be preceded by Mold risk assessment among other measures to rule out the presence of Mold growth. Preparations for re-entry should include deep cleaning with anti Mold agents, optimization of ventilation system using anti Mold and High Efficiency Particulate Absorbing (HEPA) filters, dehumidifiers and safe remediation of suspected mold growth using suitable personal protective equipment.

Keywords: Mold; re-entry; relative humidity; ventilation.

1. BACKGROUND

The global outbreak and subsequent spread of Coronavirus Disease (COVID-19) from Wuhan, China to every continent led to a global pandemic with massive impact on different spheres of life and global economy including occupational settings [1,2]. COVID-19 is caused by a highly infective and novel species of coronavirus called Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) [1,2]. It inflicted severe impacts on organisations and workers including but not limited to exacerbation of ailments, deaths, loss of employment, mental health issues, loneliness, limitation of workers' freedom, fear of uncertainty, insolvency of organisations and businesses, and more. Among several response strategies, workplace vacation was the most common and apparently effective strategy applied over a year due to enforced lockdowns. Due to the increasing adherence to preventive measures, lockdowns and roll-out of vaccines; there has been an eventual reduction in the transmission of virus, decreasing mortality and morbidity rate in some countries. Thus, governments and industry players have launched a gradual return and phased re-entry to workplaces especially previously abandoned offices. Potential health risks exist in re-entry to deserted offices with exposure to airborne contaminants from mold growths, especially in areas within rain belt and flood prone region like in the costal regions of Sub-Saharan Africa.

The United States Environmental Protection Agency described mold as a natural organism of the fungi class that lives in our environment playing an important role in the decomposition of lifeless organic matters such as leaves and trees [3]. It is a microscopic filamentous organism with spores used for asexual reproduction which is usually identified with powdery features in their colonies [4]. Since molds can naturally occur in our environment, it is obvious that it flourishes in favourable conditions for its grow. The absence of any or all the parameters hinders the growth of mold and any control measure that should be applied to prevent the growth should aim to monitor each and all the parameters. Different studies have identified relevant parameters for mold growth to include moisture, poor ventilation, source of nourishment, humidity and optimum temperature. Spotti et al. reported that relative humidity, air and the length at which the mold spore is exposed to these conditions determines the growth and the length of mold life [5]. Eva et al. reaffirmed the parameters above and stated that water is a requirement for influencing mold growth [6]. Moisture is an indispensable requirement for mold reproduction. Moisture can be released in residential buildings through leaky pipes, windows, cracked walls, environmental building and water tanks. The International Energy Agency declared that 80% relative humidity is required for mold growth [7], however, the American National Standards Institute (ANSI) and American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASRAE) noted that the relative humidity standard for mold growth ranges from 60% to 80% [8]. Apart from humidity, nourishment is another basic requirement for the completion of metabolic processes of every cell [8]. Another important parameter that influences mold growth is temperature. The growth of mold on buildings has drawn the attention of all concerned stakeholders and has led to increased litigations targeted at both property owners, builders, and operators of real estate [9]. This is due to the health impacts and damaging effects of mold on the buildings. In order to reduce and eliminate mold from residential buildings, severe health and environmental investigations are needed especially in industrial buildings including offices. Previous studies have revealed that the optimal interior temperature for offices is ranging from 40^0 to 100^0 F associated with moisture and organic material content to be able to sustain the growth of mold [10]. While this sounds plausible in deserted buildings as found during the re-entry after COVID-19 desertion, it will require an assessment to confirm its existence. America's

Housing Technology and Information Resource (AHTIR) asserted that the absence of any of the above conditions will lead to the dormancy of the mold in residential building making it free of the damaging effects on the building [10]. In this turn, there is a need to assure healthy office environment through health and environmental risk assessment strategies involving identification and ridding infective mold which might potentially impact the health of workers.

The main objective of this study was to investigate the potential for mold growth and its presence in offices before re-entry of workers in an industrial estate in Sub-Sahara Africa. More specifically, it aimed to determine the presence, location and extent of fungal growth and extent of proliferation in the offices. The results of this study could serve to establish a risk mitigation strategy for re-entry of workers in deserted office buildings.

2. MATERIALS AND METHODS

2.1 Study Design

An analytical study accomplished through a walk-through survey, visual inspection of offices, interview of workers working from home, physicochemical evaluation of office environment, review of past office inspections and bulk material sampling and analysis of suspected mold stains [4,8,9,10,11].

2.2 Study Area

Study was carried out in a large governmental office complex in the coastal region of Sub-Sahara Africa. Office complex consists of 35 Open-Plan Offices, 24 Low Partition Offices and 15 Cubicle Offices. All offices are located on 3 floors designed to accommodate three thousand (3000) office workers. It is domiciled between latitudes 4^0 46’ 38.71” N and longitude 7^0 00’ 48.24’’E.

2.2.1 Visual mold inspection

Visual inspection of offices through a walk-through survey was undertaken. A site walkthrough was conducted to visually identify any further health hazards, and gain insight into recognising the potential exposure scenarios to mold occurrence and health effects [11]. Materials used include pen-torch, basic building plan of the complex, documentation materials, magnifying glass, camera source and a buddy knowledgeable in the infrastructure. Areas inspected include external and internal aspects of the building with external inspection involving the plumbing architecture for breakages, water pool, cracks with water ingress, sources of aerosolised mold, basement and failed structure. Internal aspects of the offices inspected includes surfaces of tables, floor, wall, furniture, around windows, under sink, storage, roof and attics.

2.2.2 Physicochemical evaluation

Environmental measurement of physico - chemical parameters which includes ambient temperature, Relative Humidity (RH) and Particulate Matters (PM2.5) using the 3M Environmental Monitor Series 7 [4,8,9].

2.3 Surface Swab and Bulk Material Sampling and analysis

Four (4) wall scrapings (bulk) and four (4) swab samples were collected and cultured in the laboratory using nutrient agar. Isolation, identification and speciation of mold species were conducted through macroscopic and microscopic technique [4].

3. RESULTS

3.1 Laboratory Analysis of Samples

Analysis of scrapings and surface swab revealed the presence of three genus and eight species of fungi in the investigated sites. Samples were isolated and identified through macroscopic and microscopic methods on different selective and differential media with the greater percentage being Aspergillus followed by Mucor and finally Cladosporium. Macroscopic examination showed a mixture of creamy white filaments which darkens with time; brownish circular cells with smooth edges; greenish rough edges with elevated margin, velvety in texture flattened and fluffy; creamy white colonies with smooth surface.

Microscopic examination showed broad hyphae non-septate, long sporangiophore terminating in columella containing sporangia; non-septate hyphae with unbranched conidiophores and swollen vesicles, round conidia singly and some in chains; conidiophores of different length that is spiny and rough with vesicle entirely covered; conidiophores branched and septate and conidia attached directly to the conidiophores with no vesicle; non-septate hyphae with unbranched conidiophores and swollen vesicles, round conidia singly and some in chains. Mucor species isolated include *Mucor mucedo, Mucor himalis, Mucor racemosus*. Aspergillus species include *Aspergillus flavus, Aspergillus fumigatus and Aspergillus terrus.* Cladosporium isolated include *Cladosporium cladosproides and Cladosporium sphaerosperum*.

3.2 Physicochemical Evaluation

Measurements revealed an average indoor relative humidity of 95% and outdoor 96%. The average ambient temperature was 16 ^{0}C and average air velocity 0.4 m/s^2. These values are outside the limits of normal comfort parameters recommended by ASHRAE (American Society of Heating, Refrigerating and Air Conditioning Engineers).

3.3 Visual Inspection

Visual observations made across the offices revealed brownish patches of suspected mold-like growth; evidence of previously wetted carpet; multiple areas of moisture staining on carpets and floor; wet and moist tile, moisture condensation on floor tiles and hard surfaces; brownish staining on the wall; moisture around some window seal; some patches of wet areas on the wall; rising damp at the ground floor; moisture under some carpets; dust build-up in some Heating Ventilation and Air Conditioning (HVAC) duct but no obvious leakages in the plumbing network.

Light brown mold like growth on interiors of some doors; patches of discolouration on roof decking; green slimy growth observed on walls; condensation type air conditioners used in some offices; wall paint flaking; extensive wall paint flaking and discoloration in some offices and rising damp at basement of the office complex.

4. DISCUSSION

An average Relative Humidity (RH) of 95% and 96% indoor and outdoor respectively, provides a needed ingredient for usually existing mold spores to grow into a full-blown mold organism as against ANSI/ASHRAE preferred range of RH is 30% to 60% [8]. Various studies have revealed moisture sufficiency, organic matter, poor ventilation and nutrients as essential ingredients for the metabolic processes involved in the growth of mold both in indoor and outdoor conditions [8]. The potential for these conditions in abandoned or unoccupied offices such as evaluated is significant. Increased RH lead to obvious wetting of the walls in buildings, causing bulging of plasters and blistering of paint [12]. Robbins (2000) noted that multiple spores from mold growths releases different mycotoxins which can produce a great number of species that impact the environment and occupants [13]. Mycotoxin is a secondary metabolite that causes toxic effects in human. Mold growth and mold exposure have negative health implications on humans [14]. According to World Health Organisation (2009) and Robbins (2000) findings and opined that diseases such as asthma, allergic feelings, respiratory diseases, nervous and immune disorders are the related health impacts of mold. Suriani et al. (2015) reported that exposure to airborne mold spore in a moist environment leads to different respiratory disturbances such as coughing, nasal congestion, and wheezing [12]. Other symptoms associated with severe cases include hypersensitivity pneumonitis ailments in vulnerable persons [15]. Mold growth subsequently contaminates the air thereby reduces the role of oxygen in human health through poor air quality. This is because it releases mycotoxins, pathogenic spores, and substances capable of causing allergy leading to respiratory irritations and other health challenges [16]. Other studies have shown that mold could be responsible for about 70-100 cases of weakness and fatigue among patients that are highly exposed to mold. Other health challenges associated with mold includes disorders such as anxiety, depression, irritability, and loss of memory [17].

Cladosporium (C.) species (spp) was isolated and identified in the sample under investigation. Aihara et al. (2001) asserted that this is the most common indoor and outdoor air mold that can easily be found on textile, foodstuffs, soil, plastics, and plants [18]. Adams et al. (1997) demonstrated that there are 218 species belonging to Cladosporium generic name which was classified into 3 complexes namely the *Cladosporium herbarum*, *Cladosporium sphaerospermum*, and *Cladosporium cladosporioides*. While *C. sphaerospermum* and *C. cladosporioides* and all their related molds can be found on foodstuffs, household utensils, and indoor air. *C. cladosporioides* is also found on fresh vegetables, rice, table eggs among others [19-21]. According to Rafał et al. (2012) *Cladosporium spp*. are one of the most common mold causing fungi species globally and can be

Picture	Finding
	Patches of mold-like growth on the wall and around windows.
	Moisture damaged sections on the wall and roof with browning staining and discolouration
	Wall paint damaged by moisture showing mold-like patches
	Stained wall with brownish patches

Picture	Finding
	Water damaged wall with rising damp

Fig. 1. Visual observation of suspected mold growth

regarded as cosmopolitan organisms [22]. The results of this research show that mold spores are plant pathogen which can cause diseases to both plants and humans, therefore, has significant economic importance while some sub-species of the mold have widespread importance. Studies have revealed that, though there are molds that can endure higher temperature, Cladosporium spp., does not consider temperature conditions like other molds [22]. They can be on perishable products in buildings, restaurant cooler gaskets, and storage systems. In other areas mold species can be found but are not limited to windows and ceramic tiles. Aspergillus (A.) species(spp) was isolated and identified in examined samples. *Aspergillus* species are famous to produce wide range of mycotoxins such as Ochratoxins and Steringmatocystin which has different carcinogenic and immunosuppressive factors in human body. Aspergillus species is common and exist as the most effective mold specie, contributing in different ways to the ecosystem and human economic life through its biotechnological potentials. They produce organic acids and important extracellular enzymes in addition to secondary metabolites used in biotechnology. It also serves as a pathogen to both plants and animals. Mucor (M) species (spp) was also isolated and found in the analysed samples. This is composed of saprotrophs found in dungs and an endophyte which serves a plant parasite [24]. Its economic importance ranges from food production, to Biotechnology. They noted that Mucor is commonly found in soil samples and capable of infecting humans with disease known as mucormycosis. Mucor circinelloides is the most clinically isolated of all Mucor specie [24]. The species identified in this study possesses the capacity to produce mycotoxins that could negatively inflict harm on humans especially the unsuspecting workers in offices post prolonged period of abandonment. This could contribute to the sick-building burden where occupants might would present with respiratory illnesses among others.

Strength and Weaknesses – The strength of this studies lies in the complementary analysis of samples in addition to visual observation. The limitation however lies in the non-availability of sophisticated equipment and few study samples examined. Further Work - Further work would be required to identify airborne levels of mold spores before re-entry.

5. CONCLUSION

This study has shown that mold occurrence and spread constitute a significant risk in unoccupied offices with high humidity, poor housekeeping and poor ventilation. These conditions provide favourable conditions for mold growth as evinced by the results. Post lockdown re-entry to offices should be preceded by mold risk assessment among other measures to rule out the presence of mold growth. Preparations for re-entry should include deep cleaning with anti mold agents, optimization of ventilation system, use of anti-mold and High Efficiency Particulate Absorbing (HEPA) filters in the air purification systems of the offices, dehumidifiers and safe remediation of suspected mold growth using suitable personal protective equipment.

ETHICAL APPROVAL

The authors declare that due diligence, compliance with high ethical standards were observed in the execution of this research. As per international standard or university standard written ethical approval has been collected and preserved by the author(s).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle4.com/review-history/71071