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Relationship Between Fungal Contamination of Indoor Air and Health Problems of Some Residents in Jos

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1. Introduction

The problem of indoor air quality has in recent times attracted more concern than was the case several decades ago. Morey, (1999) presented some probable reasons why this is so. Construction materials have markedly changed from stones, wood and other 'natural' products to synthetic, pressed wood and amorphous cellulose products, some of which may be less resistant to microorganisms than the earlier ones. The indoor environment is invariably the closest to humans in terms of daily interaction, as a large proportion of man's time is spent indoors, especially in the modern cities and urban societies. There are indications however, that in many parts of the world, our homes, schools and offices are heavily contaminated with airborne molds and other biological contaminants. Biological contaminants of the indoor air include fungi, bacteria, viruses, pollen etc.; and many species of fungi are able to grow wherever there is moisture and an organic substrate. Building materials such as ceiling tiles, wood, paint, carpet rugs, etc., present very good environment for growth of fungi (Robin et al, 2007; Morey, 1999; Heseltine and Rosen, 2009). Water accumulation and moist dirty surfaces also encourage growth of fungi within a building, and contribute to human health problems. Fungi are very successful organisms capable of survival in diverse environments. This is possible because of their physiological versatility and genetic plasticity. Their spores are produced in large quantities and easily spread over a wide area. These spores can remain dormant for a long period of time during unfavorable conditions. Fungal spores and products of their metabolism are able to trigger allergic reactions which include hyper-sensitivity pneumonitis, allergic rhinitis and some types of asthma. Infections such as influenza, respiratory fungal infections, mycotoxicoses, and eye irritation by fungal volatile substances, among others, are health risks and challenges to susceptible individuals. Children, the elderly and immuno-compromised persons are at greater risks (Simoni et al, 2003).

1.1 Medically important fungi

Molds are part of the kingdom Fungi. Fungi are a diverse group of organisms within a wide range of species that include mushrooms, bracket fungi, molds and yeasts. Fungi, are eukaryotic, heterotrophic organisms which may be filamentous, i.e. multicellular (molds) or single celled (yeasts). They are found everywhere around the human environment and more than 1, 500,000 species of molds exist in the world (Hawksworth, 1991; Cannon & Hawksworth, 1995; Hawksworth, 1999). Fungi are not photosynthetic and hence obtain nutrients by absorption. Molds are composed of linear chains of cells (hyphae) that branch and intertwine to form the fungus body called mycelium. All fungal cell walls contain (1-3)-beta-D-glucan, chitin and mannan (Hawksworth, 1998). They exist as saprobes, mutualists or parasites in their relationships with other organisms. They reproduce by forming sexual or asexual spores which are in most instances, their dispersal propagules. Fungi grow very easily in damp and wet conditions; especially on materials and products containing moisture and an organic substrate. When these conditions are met, molds will grow and reproduce by forming spores that are released into the air. Molds are very adaptable and can grow even on damp inorganic materials such as glass, metal, concrete or painted surfaces if a microscopic layer of organic nutrients is available. Such nutrients can be found on household dust and soil particles (Robins and Morell, 2007). Fungi are capable of extracting their food from the organic materials they grow on and the ability to reproduce by way of minute spores makes them ubiquitous (DeHoog et al., 2007). Fungi are a part of nature's recycling system and play an important role in breaking down materials such as plants, leaves, wood and other natural matter (Robins and Morell, 2007). Because various genera grow and reproduce at different substrate water concentrations and temperatures, molds occur in a wide range of habitats. Microbial growth may result in greater numbers of spores, cell fragments, allergens, mycotoxins, endotoxins, β-glucans and volatile organic compounds in indoor air (Nielson, 2003). Persistent dampness and microbial growth on interior surfaces and in building structures should be avoided or minimized, as they may lead to adverse health effects. When mold growth is observed remediation should be given top priority (Zaslow, 1993; Douwes, 2009).

1.2 Fungi and the Indoor environment

Fungi grow on any material that provides a carbon source and adequate moisture. Fungi can grow on building and other materials, including: ceiling tiles; wood products; paint; wallpaper; carpeting; some furnishings; books/papers; the paper on gypsum wallboard (drywall); clothes; and other fabrics (Robins and Morrell, 2007). Mildew most often appears on natural fibers, such as cotton, linen, silk, and wool. It can actually rot the fabric. Mold can also grow on moist, dirty surfaces such as concrete, fiberglass insulation, and ceramic tiles (North Carolina Cooperative Extension Services 2009; Robins and Morell, 2007). Fungal growth in building materials is more dependent on the moisture content of the substrate than on atmospheric relative humidity. The minimum moisture content of building materials allowing fungal growth is near 76 %. Wood, wood composites (plywood, chipboard), and materials with a high starch content are capable of supporting fungal growth, at the lowest substrate moisture content. Plasterboard reinforced with cardboard and paper fibers, or inorganic materials coated with paint or treated with additives that offer an easily-degradable carbon source, are excellent substrates for fungal growth when substrate moisture content reaches 85-90 % (Pasanen et al, 1992; Dubey et al, 2011).

1.2.1 Common fungal contaminants and factors responsible for indoor contamination

Several fungi have been isolated from the indoor environment in various parts of the world and there seems to be relatedness in the types found from different places. Common air-borne fungi in indoor environments include: *Alternaria sp, Aspergillus glaucus group, Aspergillus versicolor, Aspergillus fumigatus, A sydowii, Penicilium aurantiogriseum, Penicillium chrysogenum*, *Stachybotrys chartarum, Chaetomium globosum, Cladosporium cladosporoides, Ulocladium, Aspergillus nidulans,* and *Alternaria alternata*. Others are *Mortierella sp., Trichoderma sp.Penicilium lividum, P. arenicola, P. verrucosum P. citrinum, P. bilai, P. cyaneum, P. granulatum, P. sublateritium, Cladosporium sphaerospermum, C. herbarum, Fusarium sp. Trichoderma sp. Memnoniella sp. Epicoccum nigrum, Scopulariopsis fusca and Chrysosporium queenslandicum*. There seems to be some variation in the abundance of fungi at different seasons of the year (Shelton et al., 2002; Mirabelli et al, 2006; Sautour, 2009) while others occurred irrespective of the season (Horner et al, 2004). *Cladosporium species* are abundant in the summer, but *Penicillium* concentrations are higher in the wetter months (Verhoeff, 1993; Flannigan, 1997; Dubey et al, 2011).

Mold types and concentrations indoors are primarily a function of outdoor fungi (Shelton et al., 2002). They presented an exhaustive study of the mycoflora of outdoor and indoor atmospheres in all USA regions. More than 12,000 samplings were carried out, both in outdoor and indoor atmospheres in more than 1,700 buildings. The moisture content of the substrate (related to indoor humidity level) has also been considered. Higher concentrations of outdoor molds and other fungi occur where trees, shrubs and landscape irrigation occur close to exterior building walls (McNeel and Krautzer, 1996). Humidity is the most important factor determining fungal growth in indoor environments (Got et al, 2003). Atmospheric relative humidity influences directly the release of conidia from conidiophores, and concomitantly, the concentration of spores in the atmosphere. The pattern may differ for different types of fungi. Pasanen et al., 1991, showed that spore release by *Cladosporium* was favored by low humidity unlike in *Penicilium* where the reverse was the case. These differences influence the seasonal patterns of outdoor fungi.

In general, the types and concentrations of molds that affect indoor air quality are similar to those found in outdoor air and molds may occur in homes without dampness problems (Gots et al, 2003; Horner et al, 2004; O'connor et al, 2004; Codina et al, 2008). However, background mold numbers may shift whenever water accumulates in buildings. Damage caused by floods, plumbing leaks, poor understanding of moisture dynamics and careless building design and construction lead to structures that are more susceptible to water intrusion. Also, lack of good maintenance practices in some buildings can lead to moisture buildups that, when left alone, can result in microbial contamination and higher levels of bioaerosols (BCBS, 2007; Stetzenbach et al, 2004). Dampness has usually been associated with moldiness indoor and its attendant ill health conditions (Dales et al, 1997; O'connor et al, 2004; BC Non-profit Housing Association,2007; Vocaturo et al, 2008). Damp buildings often have a moldy smell or obvious mold growth; some molds are human pathogens (Kuhn et al, 2003). Fungal colonization of buildings is especially common in low income communities in developing countries, where buildings are situated indiscriminately without consideration for environmental sanitation, urban planning and building regulations (Ahiamba et al, 2008; Ayanbimpe et al, 2010). Among factors responsible for indoor air contamination in developing countries are poor locations of refuse dumps, standing water

bodies, water damaged materials and absence of proper urban planning. According to Heseltine &Rosen, (2009) indicators of dampness and microbial growth include the presence of condensation on surfaces or in structures, visible mould, perceived mould odour and a history of water damage, leakage or penetration. Thorough inspection and, if necessary, appropriate measurements can be used to confirm indoor moisture and microbial growth. Similarly, contaminated air handling systems can become breeding grounds for molds and mildews and also distribute spores all over the home. Excessive humidity and high water content of building materials, lack of thermal insulations and incorrect behaviours of residents may also contribute (Ahiamba et al, 2008).

1.3 Indoor molds and health

A healthy indoor environment is a necessity for every human being. A number of studies have examined the health risks related to the presence of fungi indoors and shown positive associations between fungal levels and health outcomes. Evidences abound on the problems of dampness which consequently contribute to mold colonization of the indoor environment (European Environment and Health Information System, 2007). To control diseases caused by fungi the primary avenues of their introduction into the indoor environment should be attended to and knowledge of these avenues is required. Identifying conditions which contribute to fungal presence in the indoor environment and correction of such is a necessary step to preventing ill-health and resultant losses. Various suggestions have been made to this effect (Buck, 2002).

Some reports have highlighted the importance of housing conditions as determinants of mental and physical health and the importance of housing as a medium for promoting universal health efforts (BC Non-profit Housing Association, 2007; Shenasa et al, 2007; BCBS, 2007; Canadian Center for Occupational Health and Safety, 2008). Surveys of indoor environments have shown that symptoms of ill-health associated with air-borne fungi and their products are higher in households with molds and mildews and that are characterized by moist or damp surfaces, damp walls, wet surfaces, damaged materials, standing water and refuse dumps (Shelton et al, 2002; O'connor et al, 2004; Ahiamba et all, 2008; Ayanbimpe et al, 2010;). Pathogenic infections may be elicited by some molds which are primarily found in soil or on vegetation but are carried into homes by human foot wears or animals. When spores of some air-borne fungi are inhaled by immunocompromised persons, they may develop disease processes, for example Aspergillosis, and histoplasmosis. Respiratory illnesses are the major reported problems among persons living in homes colonized by molds (Dales et al., 1991). Persons at greater risk of effects of indoor air fungal colonization are the young, elderly, immunocompromised individuals, persons undergoing intensive surgical procedures like transplant patients and those on immunosuppressive therapy (Simoni et al, 2003; Ritz et al, 2009;). Fungal components implicated in pathogenesis include spores; β-1,3-D-glucan; Hydrophobins; Volatile organic compounds (VOCs) and Dihdroxynaphthalene (DHN) Melanin.

1.4 Symptoms of ill health associated with poor indoor air quality

There are suggestions that even very low levels of some common air pollutants can gradually cause health problems. Such condition have been reported to include; allergic

reactions in which mild and occasional, to severe and chronic symptoms caused by most species of fungi may develop in susceptible individuals who may present with hay fever, runny nose, breathing problems, and sinusitis (Bryant, 2002; Moloughney, 2004, Wu et al, 2007; Kuhn and Ghannoum,, 2004; Mirabelli et al, 2006). Some people could develop skin diseases and skin rashes as an allergic reaction to toxic mold. (Gots et al, 2003; http://www.cleanwaterpartners.org/mold/black-mold.html). Most people can recognize and react to the moldy smell negatively with symptoms like headaches, vomiting, nausea, blocked noses, and asthma. Volatile products of indoor molds have also been suggested to cause toxic illnesses or mycotoxicoses (Abbott, 2002; Straus and Wilson, 2006). Mycotoxins can be inhaled by people through the air, ingested through food, and can also come in contact with skin, resulting in many illnesses. Different molds produce different mycotoxins, which also depends on what kind of material the toxic mold is growing on. Among the illnesses caused by mycotoxins are gastrointestinal, respiratory, and reproductive disorders (O'connor et al, 2004; Mirabelli et al, 2006). Also reported are eye irritations, poor taste sensations, sore throat and tiredness (U.S. Environmental Protection Agency, 2003; Worksafe Bulletin, 1999). Even severe neurologic conditions such as depression have been linked to indoor mold colonization (Shenassa et al, 2007). Under certain metabolic conditions, many fungi produce mycotoxins, natural organic compounds that initiate a toxic response in vertebrates. Molds that are important potential producers of toxins indoors are certain species of *Fusarium*, *Penicillium*, and *Aspergillus*. In water-damaged buildings *Stachybotrys chartarum* and *Aspergillus versicolor* may also produce toxic metabolites. A large body of information is available on the human and animal health effects from ingestion of certain mycotoxins (Sorenson, 1989; Smith and Henderson, 1991), Two classes of mycotoxins have been isolated from house dust samples: aflatoxins from some strains of *Aspergillus flavus* and trichothecenes from some species and strains of *Fusarium, Cephalosporium, Stachybotrys* and *Trichoderma* (Kuhn and Ghanoum, 2004). The fungus cell wall component, (1-3)-beta-D-glucan, a medically significant glucose polymer that has immunosuppressive, mitogenic (i.e. causing mitosis or cell transformation) and inflammatory properties. This mold cell wall component also appears to act synergistically with bacterial endotoxins to produce airway inflammation following inhalation exposure in guinea pigs.

1.5 Environmental pollution and regulations

The problem of environmental pollution is enormous and various attempts have been made to establish facilities for its control and regulation in various parts of the world. In Nigeria, the Federal Military Government set up the Federal Environmental Protection Agency (FEPA) Act 1988, established under Decree 58 of 30 December 1988 with statutory responsibility for overall protection of the environment and setting and enforcing ambient and emission standards for air, water and noise pollution (Federal Government of Nigeria (FGN), 1988). The Environmental Impact Assessment (EIA) Act 1992 reaffirmed the powers of the FEPA and defined the minimum requirements for an EIA (Environmental Policy, 1999). The democratic government created a Ministry of Environment in 1999, thus bringing agencies such as the FEPA and the Environmental Health Unit of the Ministry of Health under one administrative system. Further effort to ensure the maintenance of a healthy environment was made by instituting the National Environmental Standards and Regulations Enforcement Agency (NESREA) charged with the responsibility for protection, and development of the Nigerian environment (Federal Republic of Nigeria, 2007). Among

numerous initiatives advanced to attain the United Nations Millennium Development Goal is the relationship between the physical environment and human health, and this is a top priority of the WHO. Here the need to ensure that people, especially children, live in environments with clean air was emphasized. The WHO recognized healthy indoor air as a basic right because people spend a large part of their time each day indoors; in homes, offices, schools, health care facilities, or other private or public buildings, therefore quality of the air they breathe in those buildings is an important determinant of their health and well-being (World Health Organization, 2009). Regulations by relevant authorities to control the environmental air pollution have focused on industrial emissions and chemical contaminants but less on microbiological contaminants, especially of the indoor air.

1.6 Relationship between indoor air fungi and health of residents

Indoor air pollution, such as from dampness and mould, chemicals and other biological agents, is a major cause of morbidity and mortality worldwide (Environmental Protection Agency, 2010). Biological pollutants, volatile organic compounds and indoor molds have been associated with symptoms such as rhinitis, wheezing, conjunctiva irritation, skin rashes, tightness in the chest, difficulty in breathing, runny nose, fever, muscle aches, headaches, diarrhea, nausea and nose bleeding. Aggravation of respiratory symptoms has been linked to increased concentration of airborne particles (McNeel and Kreutzer, 1996; Wong et al, 1999; Petrescul, et al, 2011). Interventions to reduce the colonization of indoor environment by contaminants which may serve as triggers to respiratory illnesses, especially asthma in various places yielded positive results. Follow-up from one of such interventions (Morgan et al. 2004), showed that the subjects experienced fewer symptom days for 2 years, and there were significant reductions in dust mite and cockroach allergens, also for 2 years. Another study showed the rate of doctor-diagnosed asthma was higher (25%) in children residing in deteriorated public housing compared with only 8% in those in other houses. A similar observation was made by Howell et al. (2005), on the self-reported health status of some individuals. Petrescu1 et al., (2011) related increase in chronic respiratory symptoms to increased concentrations of particles in the air. Shenasa et al, (2009) reported a strong association between depression and indoor mold. In their study, 9% of the respondents reported 3 or 4 depressive symptoms and older women and unemployed persons were more prone depressive symptoms. This was irrespective of dampness of the indoor environment.

1.7 Health effects of mycotoxins and volatile organic compounds

Molds produce acute health effects through toxin-induced inflammation, allergy, or infection. Some reports have associated overgrowths of trichothecene-producing fungi with human health effects such as cold and flu-like symptoms, sore throats, headache and general malaise (Croft et al., 1986; Johanning et al., 1993; Pasanen et al., 1996). Molds also produce a large number of volatile organic compounds (VOCs) which are responsible for the musty odors produced by growing molds. These VOCs have not concretely been associated with disease, although ethanol, the most common VOC, synergizes many fungal toxins. When fungal spores are inhaled, they may reach the lung alveoli and induce an inflammatory reaction, creating toxic pneumonitis. Severe toxic pneumonitis can cause fever, flu-like symptoms and fatigue (organic toxic dust syndrome). Hypersensitivity pneumonitis, a particular form of granulomatous lung disease, is a syndrome caused by inhalation of large concentrations of dust containing organic material including fungal spores.

Mycotoxicosis may also be acquired through exposure to toxins produced by some fungi as a result of their secondary metabolism, elaborated through various metabolic pathways (Wang et al, 2002). Mycotoxins have been detected from crude building materials and include Acetyl-T-2 toxin; Aflatoxin A; DON, HT-2 toxin; OchratoxinA; citrinine; Nivalenol, indoor environments (Nielson 2003). These mycotoxins may target various organs of the human body such as the liver, lungs, kidney, nervous system, immune system and the endocrine system. The severity of the mycotoxicoses depends on the target organ, nutritional and health status of the individual, type of toxin, and the synergistic effect of the mycotoxins with other chemicals or mycotoxins in the target organ.

1.8 The general challenge of indoor air quality

Indoor air pollution has been identified as one of the biggest health threats facing Americans in recent times (US Environmental Protection Agency, 2003). This may be even more in the developing countries but are underreported because of the near absence of research into this aspect. Knowledge of indoor air quality, its health significance and the factors that cause poor quality is key to enabling action by relevant stakeholders, including building owners, developers, users and occupants (Heseltine &Rosen, 2009). Maintaining a clean indoor air involves every one of the above. It is clear that elucidating the actual state of indoor air and its relationship to health of residents is an important step that would enable proper action, by regulation and policy to be taken by appropriate authorities. The building users on their part would also play a role in this very important issue. There are very few reported investigations in the study area on the health effects of indoor air fungi on the residents and because of this, little or no data is available.

2. Materials and methods

This household survey and examination of health data of residents of houses with indoor air fungal contamination was carried out to establish the association between microbial contaminations of indoor air and the health of residents. Some aspect of this was highlighted in a previous report by us (Ayanbimpe et al, 2010), thus the present study is a follow up on subjects previously identified in order to establish a relationship, if any, between the indoor air fungal colonization and the health of residents. The criteria considered for determination of a relationship between ill-health symptoms in residents and indoor air were as follows:

1. The presence of fungus growth indoor and isolation of fungi from indoor air of the residence.
2. Dampness of the indoor environment and presence of other parameters considered as risk factors (see Table 3).
3. The experience of symptoms among residents while in the specific indoor environment.
4. The reduction of symptoms following mold remediation.

2.1 Description of the study area

The Jos metropolis is the capital city of Plateau State of Nigeria located at 1900m above sea level in the North Central part of the country. The Jos Plateau is bounded approximately by latitudes 8° 0′55′′N and 10° 0′′N, and longitude 8 ^{0}′S 22′′ E and 9 ^{0}′ 30′′E. Tin mining which

began around 1904 was a major occupation of people of this area. This activity has led to creation of ponds; gullies and water logged ditches (some of which are used as dumping sites by residents) around residential areas that may contribute to dampness. The rock materials are used extensively for various forms of building construction in and around Jos (Solomon, et al 2002). The study area is characterized by several unplanned settlements, with haphazardly located buildings.

2.2 Evaluation of indoor air quality in the study area

A previous study had highlighted the poor indoor air quality of the study area (Ayanbimpe et al, 2010). The following fungi were isolated: *Aspergillus versicolor, Eurotium sp, Stachybotrys chartarum, Chaetomium globosum, Stachybotrys alternans, Aspergillus versicolor, Alternaria alternata, Aspergillus fumigatus, Xylohypha bantianum, Rhizopus sp, Stemphylium sp, Penicillium sp, Sepedonium sp* and *Phoma sp*. (see Table 1). More than 75% of the population in that report had complaints of respiratory symptoms; frequent headache, eye irritation, skin rash etc. (see Table 2). 17 households out of the 150 had molds growing in one or more parts of the house. The relationship between poor housing conditions and indoor air contamination was also established.

2.3 Investigation of factors in the study area

Using structured questionnaires and one on one interviews the conditions of the buildings considered as risk factors were determined. This was done by obtaining responses for the following questions:

a. How old is the building?
b. What type of accommodation is it?
c. How many rooms are there in the house?
d. How many persons live in a room?
e. Did you experience flooding at any time or are there leaking areas in the house?
f. How many households share the building?
g. Do you have moist walls and moldy spots/areas within the house?

The following problems were identified as risk factors for the different households in the study area:

- Flooding
- Bad house roofs.
- Fungal growth on asbestos ceiling sheets
- Non – painted house walls
- Over crowding (families of 5 to 8 persons living in one room)
- Fungal growth on some food stuff stored in –doors.

Residents with health problems related to airborne fungi had been identified and specific symptoms recorded. The present study assumed that the presence of moldy surfaces indoors contributed to the concentration of airborne spores. By a random selection, 8 of the 17 households with indoor mold colonization and high concentration of airborne fungi were visited for follow-up. Each of the 8 households revisited underwent mold clean up and remediation or correction of conditions / factors supposedly responsible for indoor mold colonization.

Fungus	Average number	percent
Chaetomium globosum	64	16.8
Stachybotrys alterans	53	13.9
Aspergillus versicolor	53	13.9
Alternaria alternata	53	13.9
Aspergillus fumigatus	37	13.9
Xylohypha bantianum	29	7.6
Penicilium sp	16	4.2
Rhizopus sp	28	7.8
Stemphylum sp	24	6.3
Sepedonium sp	13	3.4
Phoma sp	10	2.6
Total	380	100

Table 1. Fungi isolated from indoor air in the study area (Adopted from Ayanbimpe et al., 2010)

Symptoms	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	Total
Cough,	7	8	1	0	10	4	0	1	31
Nocturnal cough	2	2	0	0	1	1	0	1	7
Dyspnea	0	1	0	0	8	0	0	0	9
Sore throat	1	12	2	0	8	2	0	0	25
Hoarseness	1	4	2	0	3	0	0	1	26
Rhinitis	7	6	3	0	7	2	0	1	26
Nasal bleeding	1	4	0	0	0	0	0	0	5
Sinusitis	0	0	0	0	1	1	0	0	2
Skin rash	2	4	1	0	3	0	0	1	11
Headaches	3	9	3	0	9	2	0	1	27
Nausea	2	8	0	0	8	0	0	0	18
Diarrhea	4	7	1	0	4	0	0	0	16
Tightness in the chest	2	4	0	0	3	0	0	0	9
Fever	7	8	2	0	4	2	0	0	23
Muscle aches	2	8	1	0	12	1	0	1	25
Eye irritation	4	9	2	0	4	4	0	1	24

Table 2. Symptoms reported among residents of various age groups before mold remediation

2.4 Fungal clean up and remediation

Because of the seriousness of the problem of indoor air contamination, the WHO guideline recommended that remediation of the conditions that lead to adverse exposure should be given priority to prevent an additional contribution to poor health in populations who are already living with an increased burden of disease (WHO Regional Office for Europe, 2006). The various conditions that supposedly contributed to mold colonization were physically assessed and the necessary remediation procedure determined. Methods proposed in standard manuals and guidelines (Kennedy; Buck, 2002; New York City Department of Health and Mental Hygiene; 2008; North Carolina University Cooperative Extension Services, 2007) were followed, with slight modifications, under close expert monitoring. The steps adopted for each house depended on the extent of mold contamination and the part of the building affected. Two of the households completely relocated to new accommodations. The process of remediation essentially involved:

1. Flooded apartment – Only one of the households experienced flooding which affected two of the rooms. Here the rugs were removed, washed with detergent solution and rinsed with water and Sodium hypochlorite disinfectant solution (diluted according to Manufacturer's instructions). These were dried in the sun. The rooms were also washed, disinfected and allowed to dry before re-occupation.
2. Bad Roofs – Leaky roofs were repaired by replacing punctured sheets and boards. This was done by a carpenter.
3. Fungal growth on asbestos and wooden ceiling sheets – These were removed using absorbent cotton pads soaked in disinfectant, held in place by a wooden handle over a disposable plastic collector. The spot was then scrubbed with detergent solution and dabbed dry, after which paint was applied. Adequate protective measures were observed with every procedure. A physical inspection of each household was done to ascertain the absence of moldy areas following remediation.

2.5 Questionnaires to determine link between indoor air fungi and health symptoms

From these households, 47 residents, made up of 20 males and 27 females, ages between 0 and 80 years old, with one or more complaints of respiratory and other symptoms before remediation, were closely monitored after remediation for a period of 3 to 6 months to determine their state of health with respect to the previously observed symptoms. This was done with the aid of structured questionnaires designed to obtain personal information on age, sex, location before and after remediation and other salient features considered in determining the state of health of the residents post remediation. The following questions were asked:

a. What symptom(s) or complaint(s) have you experienced and when did it begin?
b. Do symptoms occur only when you are in the home, or at other places?
c. Do symptoms disappear when you are out of the house?
d. How frequent was the symptom
e. Does any other person in your home experience similar symptoms?
f. What steps did you take to solve the problem?
g. After the repairs and mold clean-up of your home did you notice a difference?

i. Frequency of symptoms
ii. Type of complaint
iii. Moldy odor in the home?

The symptoms included cough, nocturnal cough, dyspnea, sore throat, hoarseness, rhinitis, nasal bleeding, sinusitis, skin rashes, headaches, nausea, diarrhea, tightness in the chest, fever and muscle aches. The questionnaire responses were analyzed to establish the state of health of subjects post remediation. The Pearson correlation test was applied to determine significant association between mold presence or absence in homes and ill health symptoms experienced by residents.

3. Results

Table 3 shows outcome of questionnaire responses with respect to the eight houses revisited. Mold growth, Arthropod infestation and presence of suggestive symptoms were reported in all (100%) of the houses before remediation. All the households inspected, post remediation, had complete absence of moldy spots. There was significant correlation between reduction in frequency of symptoms of some health problems among residents and mold remediation ($r = 0.577$; $P>0.05$). Significant reduction of the following symptoms,

Features of responses	**Yes (%)**	**No (%)**
Location unplanned	72	28
Males	100	0
Females	100	0
Age of building (old)[1]	62.5	37.5
Leaking	50	50
Flooding	12.5	87.5
Dampness indoors	75	25
Mold growth indoor	100	0
Musty odor indoors	55	45
Arthropods infestation	100	0
Suggestive symptoms	100	0

Table 3. Features of Questionnaire responses with respect to the eight residences

cough (83.3%), dyspnea (100%), nasal bleeding (96.9%), skin rash (85.1%), tightness in the chest (83.3%), rhinitis (85.1), muscle aches (92.3%) and eye irritation (92.3%), were observed (Table 4). Reduction in frequency of occurrence of symptoms with respect to age and gender is shown in table 3. 72.3% of individuals experienced significant reduction or total

[1] Building above 25 years old was considered old

disappearance of symptoms of ill-health. More females (77.8%) experienced reduction in frequency of symptoms than males. Among the age groups examined, there was no significant difference in the rate of reduction of symptoms. There was no obvious change in the condition of some residents even six months beyond remediation and clear absence of moldy spots in their homes. Some symptoms ranked very low in reduction and were not significantly affected by mold remediation. These included sinusitis (Percentrank =0), nocturnal cough (Percentrank = 0.066), and fever (Percentrank = 0.133). Headache and nausea reduced appreciably but there was no strong association between mold absence and their reduction. Residents also reported relief from some of the symptoms like sneezing, cough and headaches when they left the home but reoccurred on their return. Exposure to moldy environment was influenced by location of building, dampness of the indoor environment and age of building (Student ttest =0.5; $P<0.05$).

Symptoms of ill-health	Frequency before (days/year)	Frequency after (days/year)	Difference (days/year)	Actual reduction (%)	Percentrank
Cough,	90	15	75	83.3	0.533
Nocturnal cough	60	35	25	41.7	0.066
Dyspnea	33	0	33	100	0.933
Sore throat	90	20	70	77.8	0.333
Hoarseness	66	12	54	81.8	0.466
Rhinitis	87	13	74	85.1	0.666
Nasal bleeding	65	2	63	96.9	0.866
Sinusitis	94	94	0	0	0
Skin rash	67	10	57	85.1	0.666
Headaches	94	40	54	57.4	0.2
Nausea	45	0	45	100	0.933
Diarrhea	52	15	37	71.2	0.266
Tightness in the chest	30	5	25	83.3	0.533
Fever	87	45	42	48.3	0.133
Muscle aches	90	20	70	77.8	0.333
Eye irritation	65	5	60	92.3	0.8

Table 4. Frequency of symptoms of ill-health experienced by residents before and after mold remediation

Age group (Years)	Males		Female		Total	
	N[2]	R[3] (%)	N[1]	R[2] (%)	N[1]	R[2] (%)
0 – 10	4	2(50.0)	3	3(100.0)	7	5(71.4)
11 – 20	6	3(50.0)	14	11(78.6)	20	14(70.0)
21 – 30	2	2(100.0)	1	1(100.0)	3	3(100.0)
31 – 40	0	0	0	0	0	0
41 – 50	4	4(100.0)	8	5(62.5)	12	9(75.0)
51 – 60	4	2(50.0)	0	0	4	2(50.0)
61 – 70	0	0	0	0	0	0
71 – 80	0	0	1	1(100.0)	1	1(100.0)
Total	**20**	**13(65.0)**	**27**	**21(77.8)**	**47**	**34(72.3)**

Table 5. Reduction of symptoms among residents with respect to age and sex

4. Discussion

Indoor air fungi may be responsible for some of the health problems experienced by residents of contaminated homes. There was persistent cough, headache, skin rashes and sneezing in some of the residents before mold cleanup. This did not reoccur after relocation of cleanup of molds. The major factors suggested to contribute to indoor air fungi were observed in a significant percentage of the households. Mold growth was seen in all the houses, at one point of the other with varying abundance and locations. There was significant reduction in frequency of symptoms of some health problems among residents post remediation. This implies that there may be a link between indoor air contamination by fungi and occurrence of such health problems. Jacobs et al., (2007) reported that housing interventions and remediation effected reduction of symptoms of asthma among subjects. Dales et al, (1999) and Shenasa et al, (2007) had, independently, related some ill-health conditions to indoor mold contamination. Some health conditions however barely changed, suggesting that sources other than fungi may be responsible. Symptoms like headaches and fever are also indicators of several other disease entities such as malaria, typhoid and other endemic diseases in the study area. Others such as sinusitis may have assumed a chronic status and hence the little or no reduction recorded. Frequencies of occurrence of symptoms among residents recorded before and after remediation showed remarkable difference between males and females. Shenasa et al, (2007) made a similar observation persons with symptoms of depression. This may reflect the level of exposure to sources of fungi outside the home, and the difference in reaction to triggers of such symptoms in relation to proximity to source of fungi. A similar observation was made by O'connor, (2004) and Mirabell et al, (2006) relating outdoor exposure with asthma in children. Males are more

[2] Number of persons in each group
[3] Number of persons with significant reduction of symptoms

involved in outdoor activities either for relaxation or work. There was no significant difference in the rate of reduction of symptom among the age groups. Of note, however is the only elderly female subject, who suffered prolonged respiratory symptoms (cough and runny nose) prior to remediation, which resolved barely three weeks after remediation. It was clear that the source of the symptoms was indoor mold since the old woman spent most of her days indoors.

Residents are gradually taking interest in the relationship between their residential environment and recurring health problems. Other researchers have suggested that effective communication with building occupants is an important component of all remedial efforts. Awareness of the causes and sources of agent of ill health would enable individuals who believe they have mold-related health problems to seek medical attention.

The health symptoms reduced in frequency after leaky roofs and other risk factors that promote mold growth were attended to. This agrees with the numerous reports which emphasize that the health risks of biological contaminants of indoor air could thus be addressed by considering dampness as the risk indicator. Several widely acknowledged global trends contribute to the conditions associated with increased exposure to dampness and mould (Canadian Center for Occupational Health and Safety, 2009). Conditions that favoured presence of indoor molds was well established in the residences studied and may have contributed to the high occurrence of symptoms. The high relative humidity of the study area is another factor that may encourage growth of fungi. Mshelgaru and Olonitola (2010) in considering the post occupancy contamination of timber buildings in Nigeria, found that fungi were predominant in the rain forest belts which included Plateau State. He found that 64% of the workers on such sites suffered symptoms of the sick building syndrome.

To our understanding, most people in the study area, both in administration and planning positions, as well as residents who are the direct victims of a moldy indoor environment, are still very much ignorant of the enormity of the problem. There is a serious need for more research, enlightenment and implementation of research findings by all stakeholders if a better indoor air quality is to be achieved.

5. Conclusions

Dampness in indoor environment encourages mold colonization and indoor air contamination. Molds and moisture indoor were associated with symptoms of ill health among residents. Some adverse health effects of indoor fungi on residents were established in the study area. The young children and the elderly were particular prone to mold-related symptoms and remediation provided relief. Reduction of symptoms was easily noticeable among these individuals when molds were removed from the home. The need for collaborative efforts to tackling the problem of indoor contamination is further highlighted. All stakeholders should participate in engaging resources at our disposal to prevention and control of contamination of the indoor environment with pathogenic fungi.

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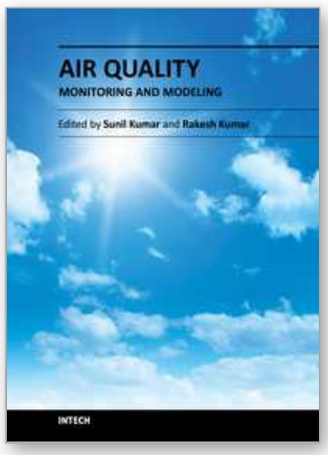
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