CURRENT STUDIES IN COMPARATIVE EDUCATION, SCIENCE AND TECHNOLOGY, VOLUMES 5&6, NUMBERS 1-2, 2019, PP. 109-120

Microbial Diversity Associated with House Dust from Four Different Floor Types in Yenagoa Metropolis, Bayelsa State

Daokoru-Olukole, C. G.
Niger Delta University, Bayelsa State, Nigeria

Olanbiwoninu, A. A.
Ajayi Crowther University, Oyo State, Nigeria

ABSTRACT The microbial diversity associated with house dust from four different floor types (Carpet, Tile, vinyl and Bare floor) was investigated. Dust samples from 24 homes at three different locations (Otioto, Amarata and Swali areas) in Yenagoa, Bayelsa State were collected and investigated using standard microbiological method. From the results obtained, heterotrophic bacterial and fungal counts vary with the floor types and from location to location. The highest bacteria population ($3.75x10^9$cfu/g) was observed in the carpet floor types while the lowest bacteria population ($1.4x10^3$cfu/g) was observed in the tile floor type. The highest bacteria count was recorded at the Swali location, with the highest bacteria diversity of 41.33%, while the lowest bacteria count was recorded at Otioto location. The Bare floor dust samples were also rich in bacteria population density with the highest count of $3.5x10^6$cfu/g and least count of $3.3x10^5$cfu/g at Amarata location. The fungi populations on the floor types were relatively stable in the order of 10^5 cells cfu/g, except for carpet floor type that recorded in 10^6 cells cfu/g. A total of 7 bacteria genera were isolated from the floor types which includes, S*taphylococcus* sp, *Streptococcus* sp, *Bacillus* sp, E. *coli, Azotobacter sp, Serratia sp, and Micrococcus sp.* S*taphylococcus* sp and *Streptococcus sp* were the most dominant genera in all the floor types. *Aspergillus* sp, *Rhizopus* sp, *Mucor* sp, *Penicillum* sp, *Alternaria* sp and *Fusarium* sp were the fungi genera isolated from the floor types. *Aspergillus* sp has the highest density followed by *Rhizopus* sp. The Tile floor types recorded the least generic diversity. There was no significant difference at 95% at the locations. This study revealed the presence of pathogenic microorganisms of public health importance on the different floor types and also creates awareness of microbial populations that accumulates in the homes thorough the choice of floor types made. We therefore conclude that Vinyl and Tile floor types will provide sanitary advantages over the other floor types and should be encouraged in homes, school and health care facilities because it is impervious to water, resist stain and can easily be disinfected.

Keywords: House dust, Floor types, Carpets, Tile, Vinyl, Bare floor

Introduction

Floor covering is a term to generically describe any finish material applied over a floor structure to provide a walking surface, decorative and functional advantages to the interior space. Floor covering include carpet, area rugs, and resilient flooring such as linoleum or vinyl flooring, ceramic tile and terrazzo etc. The choice of floor type is affected by factors such as cost, durability, comfort, beauty effects and cleaning effort. Beside the aesthetic effect provided by floor covering, it cushions falls, and reduces leg and foot fatigue when walking or standing (www. Carpet-rug.com, 2003). In addition to reduction in leg and foot fatigue, floor coverings such as carpet and rugs have been reported to have psychological impact on students, by improving the score of students who access carpeted classroom (Folden and Tanner, 2002). Ceramic tile and terrazzo had been promoted in certain quarters as a better floor covering because they are stylish and fashionable. They are easy to keep clean and wear well especially in high traffic area (Leonas, 2003).

The use of soft floorings in schools, hospitals and other health care facilities has been found to contribute to the presence of microorganisms in the indoor environment. Floor coverings trap dust especially carpets and rugs which tend to act as a reservoir for dust. Dust particles settle on various surfaces in the house and depending on the floor type, dust particles accumulate and hide on the floor coverings.

Household dust is complex and contains biological and non-biological components, which includes, skin cells, animal fur, sand and sediment particles, pet dander, feathers, mold spores, paint particles, fabric fibers, decomposing insects, food debris, soot, lead, arsenic and even DDT (Layton and Beamer, Burge, 1995). A report published in Times magazine by Kluger (2010) stated that "a single home in America can accumulate up to 40 pounds of dust annually, and that 60% of household dust comes from outside through windows, doors, vents, significantly on the soles of our shoes." Soles of shoes can actually retain about 28-49 microns or thousandths of a millimeter dust.

Various types of alignment and illness in children and the elderly have been associated with dust particles. The en route of this illness are usually when the dust particles are inhale or by skin adsorption or broken skin. Crawling babies and toddlers are at a greater risk due to their habit of touching all surfaces and sucking their fingers afterwards. Illness such as allergies, asthma, itchy skin and eyes, coughing, running noses, sinus problems, eczema and bronchia infections are the most common effects of household dust.

Much of the research on household dust has focused on allergens of dust mites, cockroaches and pet dander. A few studies had focused on microorganisms found in carpet. This research work is centered on microbial diversity in four different floor coverings types (carpet, tile, vinyl and bare floor) commonly used in Nigeria.

Carpet and rug are technically used interchangeably across the world. For instance, in America a carpet would mean a floor covering that applies to wall to wall flooring and rugs are area specific or moveable floor covering used as center piece on the floor. While in India both terms are used to denote a floor covering. The carpet floor cover is known in Nigeria as rug i.e the wall to wall carpeting. The vinyl floor cover is known and addressed as carpet in Nigeria. For the purpose of this

study rug floor cover will be referred to as carpet, while the carpet will be referred to as vinyl. Barefloor is a cemented floor without any floor cover on it. And the tile floor cover still remains the ceramic floor as earlier mentioned.

Materials and Methods

Study area

This study was carried out in three different locations in Yenagoa metropolis, Bayelsa state. Yenagoa city lies on the geographical coordinates of 4° 53'28" N, and 6 ° 15'51" E. The climate is tropical.

Sample collection

The study was done in 24 homes at three different locations in Yenagoa metropolis; Otioto, Amarata and Swali areas. Dust samples were collected using vacuum cleaner and stored in sterile bottles. Samplings were done twice in one month. To ensure sufficient variation in the microorganisms associated with house dust in four floor types: Barefloors (BFT), Carpet (CFT), Vinyl (VFT) and Tile (TFT) were investigated. Two samples were collected from living rooms and each sampling was for 3mins for the different homes. The dust samples were sifted, under aseptic conditions; through an 80-mesh sieve to remove large dust particles and were kept at 2-5° C until bacterial and fungal inhabiting the house dust of the four different floor coverings were determined using simple dilution- plate approach. One milliliter of diluted dust sample was transferred under aseptic conditions into each of eight clean and sterilized Petri-dishes (10 cm diameter, each) using a micro pipette.

The visible colonies were counted and calculated per g dry dust particles. Total aerobic heterotrophic bacteria were determined using methods of Prescott *et al* (2005). Bacterial isolates were identified by carrying out series of biochemical tests as stipulated by Holt (1982).

Potatoes dextrose agar media was used as isolation media; chloromycetin (chloramphenicol) (0.05 mg mL-1 medium) was added and served as bacteriostatic agents. The plates were incubated at 28°C for two weeks and the developing colonies of terrestrial fungi were counted and identified. Fungal identification was purely morphologically, depending upon macro- and microscopic characteristics.

Results

The total heterotrophic bacteria count of floor types in the three locations in Yenegoa metropolis are as shown in figure 1. It is observed from the results that heterotrophic bacteria count (TBC) varies with floor types and from location to location. In Otioto location, the bacteria count on carpet varies from ($5.3x10^7$cfu/g) to ($6.5x10^7$cfu/g), in Amarata location from ($6.3x10^7$cfu/g) to ($6.0x10^7$cfu/g) and ($6.3x10^7$cfu/g) to (($7.5x10^9$ cfu/g) in Swali location. For the tile floor types the highest bacteria count ($3.2x10^4$cfu/g) were observed in the Swali location while the lowest count ($1.4x10^3$cfu/g) were observed in Otioto location. On Vinyl floor type the highest bacteria count ($3.3x10^6$cfu/g) were observed in Otioto location while the lowest count ($1.3x10^6$cfu/g) were observed in the both Amarata and Swali locations. For barefloor the highest bacteria count ($6.1x10^6$cfu/g) were observed in Swali location while the lowest count ($6.8x10^4$cfu/g) were observed.

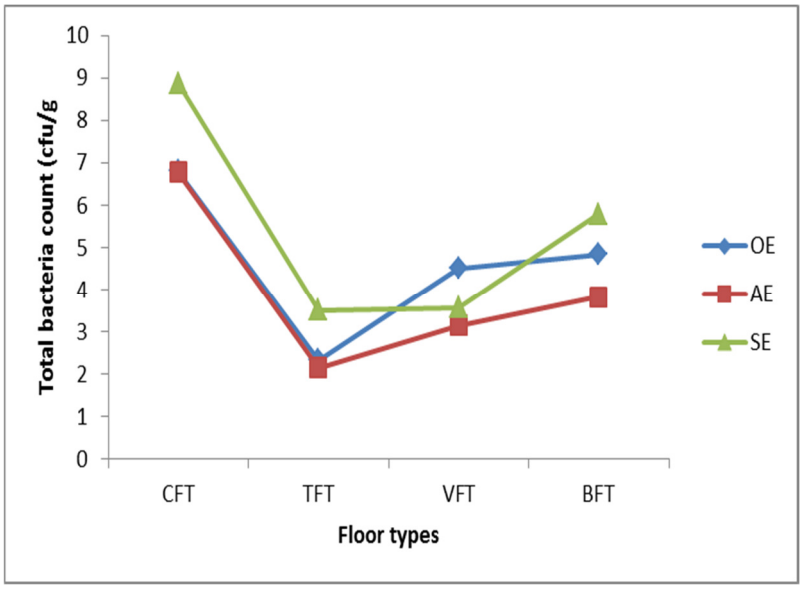

Figure 1. Bacterial Count on floor types
***Key**; OM= Otioto location, AM= Amarata location and SM= Swali location CFT=Carpet, TFT=Tile, VFT= Vnyl, BFT= Barefloor*

The results obtained for bacteria and fungi population of the different floor types are shown in Table 1. The bacterial and fungal load in the house dust varied significantly. Bacterial and fungal populations in the three locations studied also showed variation and diversity. The average number of bacterial present in the house dust was higher than the average number of fungal found in the different floor coverings. Results of analysis of variance showed a significant difference at 95% confidence limit between the floor types.

Table 1. Average microbial load on the floor types (Cfu/g)

Floor Type	Bacteria population (cfu/g)	Fungi Population (cfu/g)
CFT	$3.75x10^{9}$	$3.0x10^{5}$
TFT	$1.67x10^{4}$	$3.12x10^{5}$
VFT	$1.70x10^{6}$	$1.75x10^{5}$
BFT	$3.10x10^{6}$	$1.80x10^{5}$

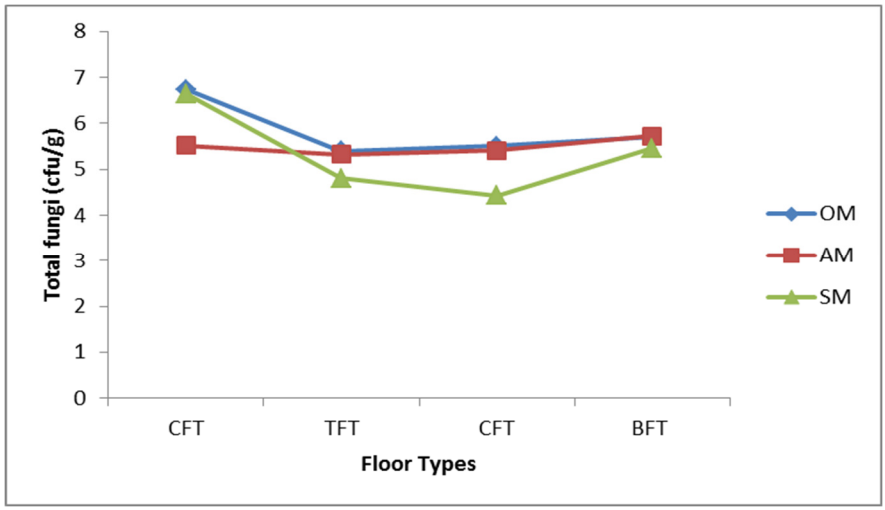

Figure 2 **Total fungi count on floor types**
***Key**; OM= Otioto location, AM= Amarata Location and SM= Swali location*
CFT=Carpet, TFT=Tile, VFT= Vnyl, BFT= Barefloor

Results of analysis of variance showed a significant difference at 95% confidence between the CFT and the other floor types, while there was no significant difference between TFT, VFT and BFT.

In Swali location, bacterial load was consistently high for all the floor types. The highest bacterial count in Otioto was recorded in CFT. Next to the CFT value was the bacterial load value on VFT. Figure 2 showed the total fungal population on floor types and locations sampled. The fungi count on carpet floor type ranged between ($5.5x10^6$ cfu/g) to ($5.9x10^6$ cfu/g) in Otioto location while in Amarata location from ($3.2x10^5$cfu/g) to ($4.9x10^5$cfu/g) and ($4.4x10^6$cfu/g) to (($1.48x10^6$ cfu/g) in Swali location. For the tile floor types the highest fungi count ($3.1x10^5$cfu/g) were observed in the Amarata location while the lowest count ($6.25x10^4$cfu/g) were observed in Swali location. On Vinyl floor type the highest fungi count ($3.4x10^6$cfu/g were observed in Otioto location while the lowest count ($2.4x10^4$cfu/g) were observed in Swali location. For bare floor the highest fungi count ($1.5x10^6$cfu/g) were observed in Swali location while the lowest count ($1.3x10^5$cfu/g) were observed. The fungal load was recorded in VFT and TFT was equally high in the order of 10^5. There was no significant difference between the floor types and locations at 95% confidence level.

Table 2. Bacteria Genera isolated from the four floor types and the Frequency of Occurrences

Organisms	CTF	VFT	TFT	BFT	Total occurrence	% occurrence
Stapyloccocus sp	6	6	4	7	23	31
Streptococcus sp	6	5	3	6	20	26.6
Bacillus sp	7	-	-	5	12	16
E. coli	6	-	-	3	9	12
Micrococcus sp	4			2	6	8
Serratia sp	2			2	4	5.3
Azotobacter sp				1	1	1.1
Total occurrence	31	11	7	26	75	
% occurrence	41.3	14.7	9.3	34.7	100	100

Table 3. Fungal Genera Isolated from the four floor types and the Frequency of Occurrences

Organisms	CTF	VFT	TFT	BFT	Total occurrence	% occurrence
Aspergillus sp	7	6	-	6	19	19.39
Rhizopus sp	6	4	-	6	16	16.32
Mucor sp	-	5	4	6	15	15.31
Penicillin sp	6	-	3	5	14	14.29
Alternaria sp	6	-	-	5	11	11.22
Fusarium sp	7	-	-	3	10	10.20
Candida sp	-	1	2	4	7	7.14
Chrysasporium sp	3	-	3	-	6	6.12
Total occurrence	35	16	12	35	98	
% occurrence	35.71	16.32	12.24	35.71		

Discussion

At the time of this study, the VFT observed in Otioto location was in a bad state with some patches of bare floor exposed. Also, the presence of a pet was observed which obviously may have contributed to the increase in the bacterial load observed in VFT in this location. It was followed by BFT and then the TFT. The BFT has no floor cover on it just the rough cemented surface with patterned cracks. Bacterial population present on the BFT was relatively high although, less than the CFT. The least bacterial population was observed in TFT $1.4x10^3$cfu/g. Although an increased bacterial population was also observed on TFT in Swali location, but bacterial population observed in Vinyl floor cover was high with an average range of $1.9x10^4$cfu/g–$1.7x10^6$ cfu/g. Vinyl flooring is a synthetic material made of chlorinated

petrochemicals that does not trap dust which when combined with moisture can produce microbial contamination (Leonas and Annis, 2003). With the high bacterial population it goes to reveal that high traffic and personal hygiene of the occupants could be the reasons for the increased microbial load (Folden and Tanner, 2003).

In the third location Amarata location, the bacterial population observed showed the same pattern with the Swali location. The highest bacterial population was recorded in the CFT, followed by the BFT, VFT and TFT in decreasing order.

From our study, location seemed to play a major role in the increased bacterial load. The increase in bacterial load observed in Swali could be due to the high activities observed in the Yenagoa main marketed located in this area. The outdoor environment has much to reveal about the indoor environment. Although, Barberan *et al*. (2015) had reported that bacteria present in house dust is strongly influenced by the number and types of people residing in the homes. If 60% of dust particles gain access to the homes through shoe soles this then suggests that location of the homes will significantly affect the bacteria population found on the house dust (Kluger, 2010). The bacteria in the home may be obviously introduced into the house by the soles of the shoes. And if this is true, the bacteria present in the house dust is only a representation of the bacteria found in that location. Increase in the bacteria load found on floor types can also be influenced by the food particles and drink spills (Leonas, 2003).

According to Green T carpet cleaning services, the average bacteria found in a homeowner's carpet is 200,000 organisms per square inch. This amount is 4000 times more than that found on a toilet seat in an average home (Carpet &Rug Institute, 2003).

Fungal population in the floor types followed same pattern observed in the bacterial load. The highest fungal load was recorded in CFT, followed by the BFT, TFT and then the VFT. The fungi population was relatively stable, averaging about 10^5cfu/g, in all the locations for all the floor types.

The microbiological qualitative analysis of house dust in the four floor types is not only by the microbial population but also by the presence of specific microbial species, which is very important for the health of the occupants. The bacterial flora composition in the four floor types revealed the following genera; *Staphylococcus* sp, *Streptococcus* sp, *Bacillus* sp, *E. coli* sp, *Serratia* sp, *Micrococcus* sp and *Azotobacter* sp. According to Green T carpet cleaning services the common bacteria found in the home on carpet are *Escherichia coli, Staphylococcus aureus* and *Salmonella,* however, in our study *Salmonella* was not isolated.

Staphylococcus and *Streptococcus* were both found on all the floor types at 31% and 27% occurrence level. *Bacillus, E. coli, Micrococcus* and *Serratia* were found on CFT and BFT at 16%, 12%, 8% and 5.3% occurrence level respectively. *Azotobacter* was found only on BFT at a very low concentration 1.3%.

Staphylococcus sp with the highest concentration has been reported to be carried around with about 25% of this bacteria living in the nose or/ and skin as a potential health threat (Turnidge, *et al*., 2008). The infections vary from skin infections to life threatening diseases especially in children and immune-compromised individuals. The high occurrence of *Stapylococcus* in the four floor types is actually expected, this is because about 25-33% of *staphylococcus* is found on normal individuals (Turnidge, *et al*., 2008). Hong and Leonas (2006) reported the efficiently

transfer of *Stapylococcus* from carpet to human skin which pose a serious threat to children particular who are always crawling around the home. Lawton and Fierer (2010) attributed the diversity in bacteria species found in house dust to the number of men and women residents, skin types and the personal hygiene of the occupants. *Stapylococcus* can spread on the carpet through skin, dirty hands, fingernails and mucous (sneezing).

Streptococcus was also of a high percentage occurrence (27%). *Streptococcus* is common bacteria that are found on human skin, nose, and genital tract. These bacteria are of different groups. Groups A and B are often associated with disease.

Group A strep (GAS) infections range from superficial skin infections and strep throat to serious and life-threatening illness such as toxic shock syndrome and necrotizing fasciitis. While the Group B strep (GBS) is a leading cause of life threatening infections in newborns. In pregnant women GBS can lead to bladder infections, infections of the womb, and death of the fetus (US CDSC).

In this present study, *Bacillus* was isolated from CFT and BFT although it was not isolated from Tripoli mosque carpet. The percentage occurrence was high (16%). This Gram positive rod under stressful environmental conditions can produce oval endospores that are not true spores' but to which the bacteria can reduce themselves and remain in a dormant state for very long period. *Bacillus* causes pulmonary anthrax from inhaling spore-laden dust (Turnbull, 1996).

E. coli had been reported in carpets, and their presence is an indicator of fecal contamination. Rahouma (2010) reported the isolation of *E. coli* from mosque carpet, which indicates that a large variety of enteric bacteria can be found in the environment. *E. coli* although some can be harmless, they have been reported as the major cause of bacterial diarrhea among children (Ghenghesh, *et al*., 2008) and urinary tract infections, respiratory illness, and pneumonia in adults. It can be deposited onto carpet directly from pets, splashing out of toilets, and transferred from outside by shoes soles.

In this study, a total of 8 genera of fungi were isolated, the genera *Aspergillus, Rhizopus, Mucor* and *Penicillium* contributed the majority of the isolated flora of terrestrial fungi. The predominance of *Aspergillus* and *Penicillium* is in concordance with the report made by Alwakeel and Nasser (2010). *Aspergillus* and *Fusarium* were the most prevalent genera in carpet floor type, while *Penicillium*, *Rhizopus* and *Alternaria* recorded a moderate occurrence in carpet floor type. The Barefloor type recorded *Aspergllus, Mucor* and *Rhizopus* as the most prevalent. *Penicillium, Candida* and *Alternaria* recorded moderate occurrence.

Aspergillus was the most prevalent in Vinyl floor type. *Mucor* and *Rhizopus* recorded a moderate occurrence and Candida had a low occurrence in this floor type. *Fusarium*, *Penicillium* and *Alternaria* were not isolated. *Mucor* was the most prevalent in Tile floor type, though at a moderate occurrence, while, *Penicillium*, *Chrysaparium,Candida* recorded a very low occurrence. *Aspergillus*, *Alternaria*, *Fusarium*, *Rhizopus* were not isolated in Tile Floor type.Although, our statistical analysis revealed that there was no significant difference between the fungal species isolated and the locations. Fierer (2015) stated that fungal diversity found in the homes is dependent on location and environmental factors such as temperature and humidity. All the eight fungal species found in our four floor types were found present in the three locations with the exception of *Chrysaparium* species not found in Amarata location.

About three classes of fungal were identified in our study, the Zygomycetes (*Mucor* and *Rhizopus*) that are becoming pathogenic to humans. Their zygospores can remain dormant when the environment is too harsh for the growth of the fungus (Mohapatra, 2008). This characteristic of the zygospores explained the abundance of this class on the CFT and BFT where the spores can lie dormant until any favourably condition such as the wetness of the carpet will contribute to the germination of the zygospores.

The phylum Ascomycota was abundantly isolated in our four floor types. The *Penicillum*, *Aspergillus*, *Alternaria*, *Fusarium* and *Chrysasporium* are the common genera of this phylum. They were found in high abundance in all the four floor types. Researchers have shown that this phylum of fungi will produce many symptoms in allergic individuals. Leonas (2003) reported that exposure to these fungi is related to childhood asthma and respiratory symptoms. *Alternaria* and *Fusarium* from class Dothideomycetes and Sordariomycetes respectively were isolated from CFT and BFT in high abundance. They were not isolated in VFT and TFT. They are mainly human pathogens, causing diseases like athlete's foot, ring room and histoplasmosis. The abundance of this class in the carpet and Barefloor will definitely pose a health risk on the occupant especially individuals that will want to relax on the carpet and children playing on the floor. *Alternaria* causes common allergies in humans, being an indoor fungus it has been associated with hay fever or hyper sensitivity reactions that sometimes lead to asthma. *Chrysasporium* a member of the class Eurotiomycetes was isolated on Carpet and Tile floor type and had been identified as an emerging infectious disease. Their presence on these floor types can be a health threat, although no report of its transfer from floor coverings to humans has been recorded (Kuhn and Ghannoum, 2003; Jarius and Miller, 2005).

Interestingly, *Candida* a genus of yeast was isolated in all the floor types with the exception of CFT. A harmless commensals of humans however, when mucosal barriers are disrupted or the immune system is compromised the can invade and cause candidasis.

The isolation of the above molds from house dust had been reported as indoor allergic fungi in several studies (Hardin *et al*., 2003, Bush and Patel, 2008; Fierer, 2015). Tile and Vinyl floor types are smooth surfaces that have no crevice or adsorbent fibers, the fungal load and genera isolated from them can be deposited on the floor surfaces through foot traffic. This agrees with Fierer (2015) findings that fungal in the homes is dependent on location and environmental factors such as temperature and humidity.

The high microbial population and diversity observed at Swali district could be attributed to increased commercial activities coming from Yenagoa main market. This agrees with the fact that activities in a location can lead to the generation of more dust particles and high traffic can lead to re-suspension of dust particles in homes around the location. Hangreares *et al.,* (2003); Layton and Beamer, (2009) allude that the outdoor dust source of fungal population from a given vegetative area will apparently affect the population of the indoor fungal dust. This agrees with our study that location affects the indoor fungal population. Bacteria and fungi will naturally thrive on wet floor types such as Carpet and Barefloor with cracks and patches. Indoor microbial growth is often as result of inadequate cleaning, poor ventilation and increase humidity (Dotterud *et al*., 1995). Inadequate cleaning is a major reason for the presence of the microorganisms isolated in the floor types.

Limitation of the study

A major limitation of this study was the refusal of residents of homes from collecting dust samples due to superstitious belief, that the dust samples may be used for rituals. This restricted the number of homes sampled.

Conclusion

The 24 homes visited were not using vacuum cleaner but the traditional brooms and total efficiency cannot be achieved with the traditional broom. We therefore propose the use of vacuum cleaner in our homes. Also, personal hygiene should be encouraged among the occupants of the home to reduce microbial contamination in the homes. Care should be taken to fore stall food particles from dropping and drinks from spilling on the floor. Shoes used outside should be restrained at the corridors. This study, the microbiological quality of house dust from four different floor types (Carpet, Tile, Vinyl and Barefloor) showed the presence of a number of potential human pathogenic microorganisms such as *Bacillus, Staphylococcus, Fusarium* and *Alternaria*. This study also confirms that some floor types have the affinity to retain dust particles that can be transferred from the floor type directly to humans. We therefore conclude that Vinyl and Tile floor types will provide sanitary advantages over the other floor types and should be encouraged in homes, school and health care facilities because it is impervious to water, resist stain and can easily be disinfected.

Correspondence
Daokoru-Olukole, C. G.
Department of Biological Sciences
Niger Delta University
P.M.B 071 Wilberforce Island
Bayelsa State, Nigeria
Tel.: +234 (0)7038730020
E-mail: n_chinma@yahoo.com

References

Alwakeel, S.S and Nasser, L.A. (2011). Indoor Terrestrial Fungi in Household Dust Samples in Rigada, Saudi Arabia. *Microbiology Journals* 1;17-24.

Anderson, R.L., Mackel, D.C., Stoler, B.S., Mallison, G.F. (1982) Carpeting in hospitals: an epidemiological evaluation*. J. Clin. Microbiol*.15:408–15.

Barberan, A., Dunn, R.R., Reich, B.J., Pacifici, K., Laber, E.B., Menninger, H.l., Morton, J.M., Henley, J.B., Leff, J.W., Miller, S.L. and Fierer, N. (2015). The ecology of microscopic life in household dust. *Proceedings of Royal Society B-Biological science*, 282, (1814), 212-220.

Barberan, A, Ladau, J., Leff, J.W., Pollard, K.S., Menninger, H.L., Dunn, R.R., and Fierer, N. (2015). Continental-scale distributions of dust-associated bacteria and fungi *Proc. Natl. Acad. Sci. U. S. A.*, *112*, (18), 5756 – 5761.

Burge, H.A. (1995) Aerobiology of the indoor environment *Occupational Medicine* 10 (1): 27-40;

Carpet and Rug Institute, http://www.carpet-rug.com/, July 12, 2003. http://www.newworldencyclopedia.org/entry/Carpet Retrieved 19 August 2010

Dotterud, L.K, Vorland, L.H, and Falk, E.S. "Viable fungi in indoor air in homes and schools in the Sor-Varanger community during winter." *Pediatric Allergy and Immunology*, 6: 181-186, 1995.

Fierer, N. (2015). The wild life of our Homes. *Proceedings of Royal Society B.*

Folden, C. and Tanner, C.K. (2002). "Perceptions of Middle School Principals Regarding Carpets' Function in the School's Physical Environment and a Comparison of Middle School Students' Performance with Sound Intensity Levels in the Classroom". http://www.coe.uga.edu/sdpl/research/SDPLStudiesInProgress/cathyfolder/crifolden.html; 2/0/2003. Retrieved July 2014.

Ghenghesh, K.S,, Franka, Z.A., Tawil, K.A., Abeid, S., Ali, M.B., Taher, I.A., (2008). Infectious acute diarrhea in Libyan children: causative agents, clinical features, treatment and prevention. *Libyan J Infect Dis*. 2:10–9.

Hardin, B.D., Kelman, B.J., Saxon, A. (2003) "Adverse human health effects associated with molds in the indoor environment" *Journal of occupational and environmental medicine*; 45,5; 470-478.

Hargreaves, M., Parappukkaran, S., Morawska, L. (2003). "A pilot investigation into associations between indoor airborne fungal and non-biological particle concentrations in residential houses in Brisbane, Australia" *The Science of the Total Environment* 312; 89-101;

Jarius, B.B. and Miller, J.D. (2005). Mycotoxins as Harmful Indoor Air Contaminants. *Applied Microbial Biotechnol*., 66:367-772.

Kluger, J. (2010). What's in Household Dust? Don't Ask. *TIME Magazine (Health &Science).* Retrieved November 2014 http://www.time.com/time/health/article/0,8599,1966870,00.html

Kuhn, D.M. and M.A. Ghannoum, (2003). Indoor mold, toxigenic fungi and Stachybotrys chartarum: Infectious disease perspective. *Clin. Microbiol. Rev*., 16: 144-172.

Lawton, G. and Fierer, N. (2010). Your house is a microbe jungle. *New Sci*. 215, (2873) 26-27.

Layton, D.W. and Beamer, P.I. (2009). Migration of contaminated soil and airborne particulates to indoor dust. *Environmental Science Technology 43*, 8199-8205.

Leonas, K.K. (2003). Microorganisms in carpets. *Int E-J Flooring Sci*. Available from: http://www.flooringsciences.org/e-journal/author.cfm [Retrived August 2010]

Leonas, K.K. and Annis, P.A "Microbial Transfer from Carpet to Skin-Like Materials – Phase 2". A proposal submitted to the Carpet and Rug Institute, July 2003.

Noritzuna, T. (2002). A study of fungal flora of house dust and its importance to public health. *J. Jap. Assoc. Mycotic*, 52: 45-55.

Rahouma, A., Elghamoudi, A., Nashnoush, H., Belhaj, K., Tawil, K. and Ghenghesh, K. S.(2010). Isolation of antibiotic-resistant pathogenic and potentially pathogenic bacteria from carpets of mosques in Tripoli, Libya. *Libyan Journal of Medicine.* 5(10).