Journal of Advances in Microbiology

16(1): 1-14, 2019; Article no.JAMB.48118
ISSN: 2456-7116

The Effect of Aerosols on the Air Microflora of the Indoor Air

E. O. Jeff-Agboola[1], O. E. Dada[2] and Y. A. Jeff-Agboola[3*]

[1]Department of Biological Sciences, Joseph Ayo Babalola University, Ikeji Arakeji, Osun State, Nigeria.
[2]Department of Biological Sciences, Elizade University, Ilara-Mokin, Ondo State, Nigeria.
[3]Department of Biological Sciences, University of Medical Sciences, Ondo City, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. Authors OED and EOJA designed the study, performed the statistical analysis. Author YAJA wrote the protocol and authors EOJA and YAJA wrote the first draft of the manuscript, managed the analyses of the study. Author OED and YAJA managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JAMB/2019/v16i130116
Editor(s):
(1) Dr. P. Rama Bhat, PG Biotechnology, Alva's College, Mood bidri, Karnataka, India.
Reviewers:
(1) Hideharu Shintani, University of Chuo Tokyo, Japan.
(2) K. Robinson, Victor, Rivers State University, Nigeria.
(3) Bharat Raj Singh, Dr. APJ Abdul Kalam Technical University, India.
Complete Peer review History: http://www.sdiarticle3.com/review-history/48118

Original Research Article

Received 08 February 2019
Accepted 15 April 2019
Published 25 April 2019

ABSTRACT

This research work assessed the microflora of rooms sprayed with different insecticides and air freshners with the aim of investigating the effect of the aerosols on the types of microflora in the room environment. Eight (8) different samples of chemical aerosols were used they are: Mobile insecticide(Imidacloprid), Raid multipurpose insect killer(1R-trans Phenothrin), Morten Insecticide(pyrethroids), Rambo Insecticide(pyrethroid compound). as categorized as Insecticides, while Febreze(hydroxypropyl beta-cyclodextrin), Air wick(Dipropylene glycol monomethyl ether (aka dipropylene glycol methyl ether), Glade(allyl 3-cyclohexylpropionate, allyl caproate, benzyl alcohol, butylated hydroxytoluene (BHT) and Top breeze(Cyclodextrin) were purchased as air fresheners/fragrance and eight (8) different rooms were used. Microorganisms isolated from the rooms before and after spraying with aerosols were: *Staphylococus aureus, Lactobacillus jensenii, Bacillus coagulans, Aspergillus flavus, Aspergillus niger, Micrococcus* spp., *Aerococcus viridans,*

**Corresponding author: E-mail: yjeffagboola@yahoo.com;*

Pediococcus cerevisiae, Streptococcus spp*., Aspergillus fumigatus and Aspergillus niger*. The result of eight different rooms sprayed with different aerosol as Insecticide and air fresheners showed that, some aerosols were able to inhibit some organisms that were initially present in some rooms while there were introduction of another organisms from some aerosols into some rooms. The occurrence of *Staphylococus aureus* (100%) was the highest in all the rooms followed by *Aspergillus niger* (87.5) and *A. flavus* (75%). *Lactobacillus jensenii, Bacillus coagulans* and *Micrococcus* spp*.* had the lowest frequency of occurrence (12.5%).

Keywords: Air environment; aerosols; microflora; Indoor; microbial load.

1. INTRODUCTION

1.1 Background to the Study

Each day people are exposed to millions of bio aerosols, including whole microorganisms, which can have both beneficial and detrimental effects. Assessment of the indoor of the built environment, the aerobiomes is important and they are bacteria, viruses, fungi and their spores are examples of bio aerosols present in the air, inhaled by human beings. According to Smith [1] major sources of these bioaerosols are: humans, pets, plants, plumbing systems, heating, ventilation, and air-conditioning systems, dust, suspension; aesthetic pollutant and the outdoor environment. Recent advances in molecular sequencing have generated a rush to characterize the microbiome of various environments including indoor and outdoor air [2]. This is because humans spend over 90% of their time indoors [3], Researchers have observed that there are diverse microbial communities in indoor environments such as schools, houses, and hospital [4,5] rooms within the same building. For instance, Dunn [6] revealed that microbial isolates in the bedroom differs from that of the bathroom within the same building.

Despite rapid advances in the characterization of airborne microbial communities through rRNA surveys, metagenomics, proteomics, and metabolomics, limited information is available about actual concentrations of airborne microorganisms in built environments. In one of the few studies of concentrations of total bacteria and viruses in indoor air by air sampler, a researcher [7] found virus-like and bacteria-like particle concentrations of approximately 10^5 and 10^6 particles m^3 in various indoor and outdoor air environment, respectively [8]. More over an average viable airborne fungi concentration of 80 CFU/m^3 were reported in samples collected from schools, hospitals, residences, and industrial buildings; However, in some instances concentrations were as high as 10^4 CFU m^3. Such information should be forthcoming as methods for quantitative metagenomics analyses air samplers become more powerful [9,10].

In confined environments geared for both industrial and non-industrial activities, the presence of microbial pollutants may elicit the deterioration of indoor air quality (IAQ). Generally, in healthy indoor occupational environments, microflora concentrations are lower than outdoor concentrations [11,12]. In indoor environments, air from identifiable sources may be responsible for exposure to microbial pollutants through phenomena like diffusion, accumulation and concentration. As people spend 80–95% of their time indoors, air pollution is frequently reported to cause health problems [13]. Diverse studies have demonstrated that dust particles, macromolecular organic compounds, Gram-negative bacteria and total volatile organic compounds may cause nasal, optical and physiological changes and sensory symptoms exemplified by irritation, slugginess, sleepiness, headache and reduced ability to concentrate [14]. The presence of any type of microorganism can be problematic to IAQ, particularly bacteria and fungi [15]. In residential and public buildings like schools. Microbial growth is associated with adverse health effects [16]. The presence of moisture damage in school buildings was a significant risk factor for respiratory symptoms in schoolchildren [17]. Because of their lower water activity (Aw) requirements compared with bacteria, fungi are the principal contaminant in various types of substrates. They tend to colonize a wide variety of humid building materials wetted by floods, condensation or plumbing leaks. Consequently, when fungal proliferation occurs, aerospores are abundantly distributed on and around the surfaces, and the indoor environment becomes a source of exposure to occupants. Knowledge of indoor environmental mycoflora is especially important from an allergologic view-point, which,

in many cases differs from that observed in outdoor environments. Although less frequent than the possible dangers caused by exposure to pollen and acari, fungal exposure causes hypersensitive reactions which characterize allergic respiratory pathologies like bronchial asthma and rhinitis [18]. Fungi may elicit allergic symptoms similar to those caused by pollen.

With an ever-increasing population utilizing different types of aerosols as insecticides and air fresheners, in order to improve and sustain health and vitality; and consuming products in which these supplements are used as room flavors, it is essential that these products are safe for human use. A very critical indicator of safety is the microbiological quality of these products. To improve the prediction of dispersion models and the environmental health assessment on the one hand and to get an insight on the airborne micro-organisms in other relevant environments, e. g. living spaces. However, these studies give insight in the internal structure of bio-aerosols and the distribution of micro-organisms on airborne particles themselves for developing guidelines in order to achieve and maintain safe microbial levels in these products.

Therefore, the aim of the study are to, isolate microorganism in air environment of rooms sprayed with selected chemical aerosols and investigate the effect of the aerosols on the load of microflora in the room environment.

2. MATERIALS AND METHODOLOGY

2.1 Study Area

The sampling area was an inbuilt living rooms in a house at Akure and the aerosols were purchased from Shoprite shopping mall located at alagbaka, Akure, Ondo State, Nigeria.

2.2 Collection of the Samples

Eight (8) different samples of chemical aerosols were purchased from shoprite shopping mall, alagbaka, Akure, Ondo State, Nigeria. The selected aerosols were; insecticideImidacloprid, 1R-trans Phenothrin, pyrethroids, pyrethroid compound. as categorized as Insecticides, while hydroxypropyl beta-cyclodextrin,dipropylene glycol methyl ether,allyl 3-cyclohexylpropionate, allyl caproate, benzyl alcohol, butylated hydroxytoluene (BHT) and Cyclodextrin were purchased as air fresheners/fragrance.

2.3 Experimental Design

The experimental design is 8x3; eight (8) rooms were sprayed with each of the eight selected chemical aerosols, Petri-dishes were prepared aseptically in triplicates and exposed to each room 10 minutes after spraying with insecticides and air fresheners.

2.4 Microbial Isolation and Determination of Total Viable Counts

The method used for isolation and identification of microorganisms was as described [19]. Twenty (20 ml) of nutrient agar and acidified potato dextrose agar cooled to 45˚C was poured separately onto each of the plates in triplicate and the plates were gently swirled and allowed to solidify. The plates were exposed to air in the room before and after spraying with aerosols for 10 minutes. Thereafter, the nutrient agar plates were incubated in an inverted position at 37±2˚C for 24 hours for isolation of mesophilic bacteria while Potato Dextrose Agar plates were incubated at 28±2˚C for 72 hours. Anaerobic plates were inverted in the anaerobic jar at 37±2˚C for 24 hours for isolation of anaerobic organisms present in the samples. After incubation, colonies on the plates were counted using colony counter and the number of viable cells obtained to be the total viable counts of the isolates. The viable colonies were sub cultured from mixed culture plate to obtain a pure culture. The colonies were then identified directly by their size, shape, colour of the pigment (chromo-genesis), opacity, elevation, surface, edge and consistency and stored on agar slants for further biochemical tests.

2.5 Determination of Microbiology of the Air Samples

Microbiological analyses were determined according to the procedure of Stetzenbach and Harry [20]. The microbiological analysis includes isolation of microorganisms from the air samples, direct and microscopic observation of the isolates, biochemical identification of the isolates [21], which include gelatin hydrolysis, a starch hydrolysis, casein hydrolysis, catalase test, coagulase test, indole test, urease test, nitrate

reduction test, sugar fermentation test, oxidative fermentation (O/F) test, methyl red Voges-proskaur test, citrate test, oxidase test and motility test.

2.6 Identification of Fungal Isolates

Moulds were identified based on cultural and morphological features using light microscope also number of colony isolated was recorded [21,22]. Cultural characterization was based on the rate of growth, presence of aerial mycelium, colour of aerial mycelium as well as colour on the obverse and reverse of the plates. Microscopic identification was based on spore and conidiophore morphology.

2.7 Calculation of Percentage Frequency of the Isolates

The isolation frequency (Fq) of each isolate from the eight rooms was calculated according to the formula by Gonzalez [23]. This was used to determine the distribution of the isolates in the eight sample rooms.

$$\text{Frequency of occurrence (\%)} = \frac{\text{Number of isolates of a genus x 100}}{\text{Total number of samples collected}}$$

2.8 Data Analysis

The experiment was conducted using a completely randomized design. Means of three replicates were computed using computer software Microsoft Excel.

3. RESULTS AND DISCUSSION

This present study was conducted to isolate and identify airborne microbes in some rooms sprayed with insecticides and air fresheners with a view to identify the microflora of the rooms and determine their sensitivity to the aerosols. A total of ten organisms were isolated from eight rooms during the course of this study. Seven bacterial genera were identified from the sampling sites as shown in Table 2 comprising *Staphylococcus aureus, Lactobacillus jensenii, Bacillus coagulans, micrococcus* spp*., Aerococcus viridans, Pediococcus cerevisiae* and *Streptococcus* spp. while *Aspergillus* was the only mould generally identified *Aspergillus niger, A. flavus* and *A. fumigatus* are the specific species of *Aspergillus* reported. The result of eight different rooms sprayed with different aerosol as Insecticide and air fresheners are as follows:

Table 1 revealed the bacteria Isolated before and after spraying all the rooms with different aerosols are: *Staphylococus aureus, Lactobacillus jensenii, Bacillus coagulans, Micrococcus* spp, *Aerococcus viridans, Pediococcus cerevisiae, Streptococcus* spp. Table 2 shows the fungi isolated before and after spraying; *Aspergillus flavus, Aspergillus niger, Aspergillus fumigatus* and *Aspergillus niger*. Before spraying the room with Mobil Insecticides, the microorganisms isolated were: *Staphylococcus aureus, Lactobacillus jensenii, Bacillus coagulans, Aspergillus flavus* and *Aspergillus niger,* after spaying the room with Imidacloprid, the Insecticide was able to inhibit the growth of *Lactobacillus jensenii, Bacillus coagulans,* however, there was an introduction of a new organisms (*Micrococcus* spp*.)* which was not present initially. The microorganisms isolated were able to inhibit the growth of *Lactobacillus jensenii, Bacillus coagulans* and *Aspergillus flavus* that were present in the room after spraying. However, there was an introduction of new organisms (*Micrococcus* spp*.)* which was not present initially before spraying the room with 1R-trans Phenothrin, microbes reported were: *Staphylococcus aureus, Aerococcus viridans,* and *Pediococcus cerevisiae. Streptococcus* spp*., Aspergillus fumigatus, Aspergillus flavus,* after spraying there was inhibition of *Streptococcus* spp. only by pyrethroids thereafter before spraying pyrethroid into the rooms, microorganism isolated were: *Staphylococcus aureus, Aerococcus viridans, Pediococcus cerevisiae. Streptococcus* spp*., Aspergillus fumigatus, A. flavus, A. niger* after spraying it was discovered that pyrethroid was able to inhibit all the organisms present initially except *Staphylococus aureus* and *Aspergillus flavus*.

Similarly, before spraying hydroxypropyl beta-cyclodextrin air fresheners, the microorganisms reported were: *Staphylococcus aureus, Streptococcus* spp*., Aspergillus fumigatus and A. niger*. Then after spraying, it was discovered that hydroxypropyl beta-cyclodextrinwas not able to inhibit all the initial organisms present. There was an introduction of three new organisms which are: *Lactobacillus jensenii, Bacillus coagulans, Aspergillus flavus,* likewise before spraying with Air wick, microorganism present were: *Staphylococcus aureus, Streptococcus* spp*., Aspergillus flavus* and *A. niger,* and after spraying; it was discovered that there was no difference between the type of organism present before and after spraying the room with dipropylene glycol methyl ether. Similarly, before

spraying both BHT and Cyclodextrin into the rooms, the following microorganisms were isolated: *Staphylococcus aureus, Streptococcus* spp.*, Pediococcus cerevisiae. Aspergillus flavus* and *Aspergillus niger* and for Cyclodextrin spray, the isolates were: *Staphylococcus aureus, Pediococcus cerevisiae. Aspergillus fumigatus,* and *A. niger.* However, after spraying the room, it was discovered that there was no difference between the type of organism present before and after spraying the room with BHT. Similarly, there was no difference between the type of organism present before and after spraying the room with Cyclodextrin. However, there was an introduction of *A. flavus.* The occurrence of *Staphylococcus aureus* (100%) was highest in all the rooms followed by *Aspergillus niger* (87.5) and *A. flavus* (75%). *Lactobacillus jensenii, Bacillus coagulans* and *Micrococcus* spp. had the lowest frequency of occurrence (12.5%) as shown on Table 3 and Figs.1-8. The result of the morphological, microscopic and biochemical characterization of all the organisms isolated before and after spraying are shown in Tables 4-7.

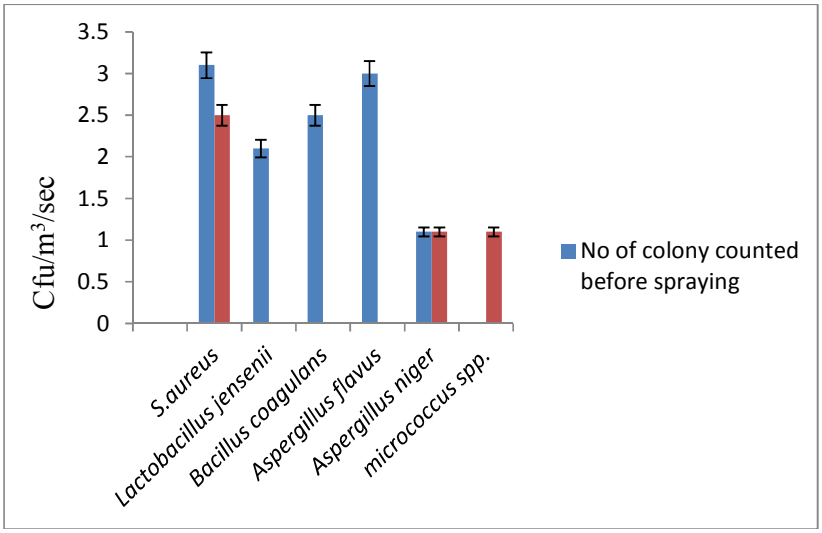

Fig. 1. The mean values of colony counted from each room before and after spraying with imidacloprid aerosol

S. aureus and A. flavus were recorded as ≥300 Cfu/m^3/sec

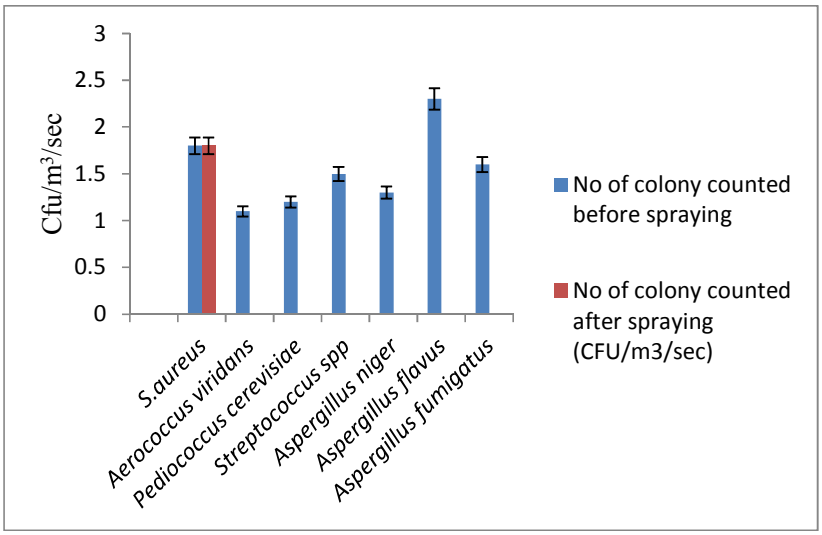

Fig. 2. The mean valuesof colony counted from each room before and after spraying with 1R-trans phenothrin aerosol

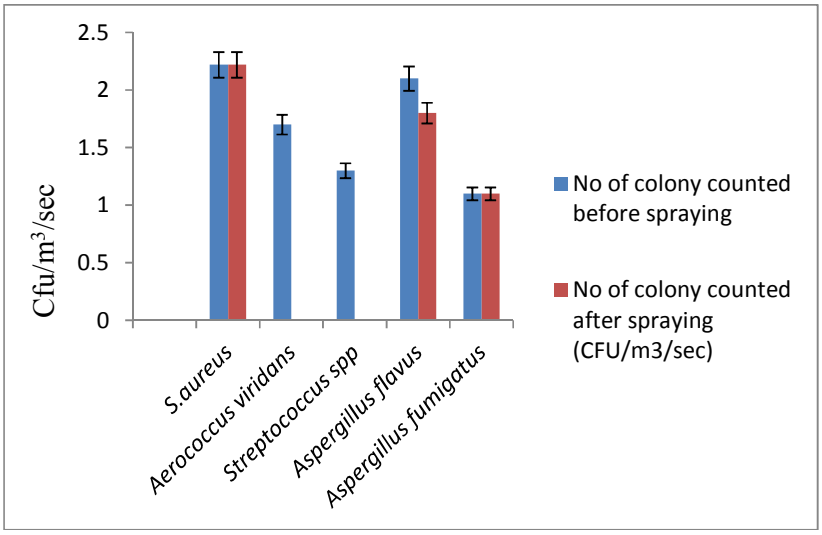

Fig. 3. The mean values of colony counted from each room before and after spraying with pyrethroids aerosol

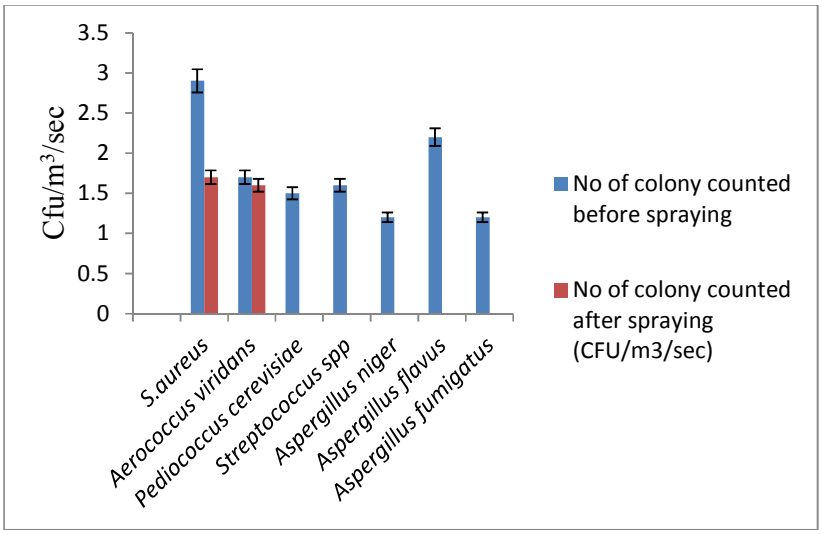

Fig. 4. The mean valuesof colony counted from each room before and after spraying with pyrethroid aerosol

The highest percentage occurrence (100%) was *Staphylococus aureus* followed by *Aspergillus niger* (87.5) and *A. flavus* (75%). While *Lactobacillus jensenii, Bacillus coagulans and Micrococcus* spp. had the lowest frequency of occurrence (12.5%). These pathogens could be linked with several infectious organisms responsible for gastroenteritis, respiratory tract infections, urinary tract infections and skin disorders. As *Staphylococcus aureus* belong to the normal flora of the human skin and nose, revealed that this organism may be originated from the nose and skin flora of the occupant of the rooms.

However, this higher incidence of *Staphylococcus aureus* obtained from this study correlates with several and similar findings of the studies conducted by several researchers. A study conducted by a researcher [24] who found that *Staphylococcus aureus* was the predominant bacteria isolated from an hospital enviroment. This study also supported the finding of [25], in which the occurrence was reported to be 38% in a research conducted to detect the airborne microorganism from a college. In a review of indoor bioaerosols, [26] suggested that the penetration efficiency of bioaerosols is close to 100% in a naturally ventilated building,

meaning that all bioaerosols following through leaks and openings in the building environment arrive indoors. In fact, researcher [27] showed that concentrations of bacteria-like and virus-like particles were approximately two times higher in outdoor air than in indoor air, suggesting that human occupant might not be the only component shaping the microbial structure of indoor air environment.

The microbial community structure of indoor air varies geographically, depending on the external factors such as temperature, humidity, oxygen etc. However, some specific chemical air pollutants insecticides and fresheners like the samples used in the experiment, affected the distribution of some microorganisms because microorganisms were discovered before spaying and some of the microbes found before spraying might not be seen after spraying due to the fact that the chemical aerosols inhibited the growth of some of these microbes, this shows that these microbes are very sensitive to the aerosols. For those microbes that were seen after spraying, they were not inhibited by the chemical aerosols, this means they adapt or tolerate the condition, so the spray do not have effect on the microbes.

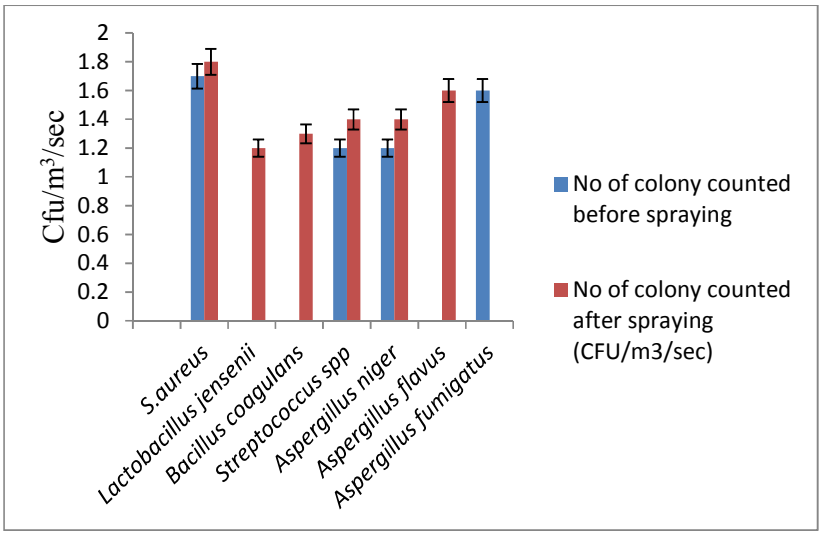

Fig. 5. The mean values of colony counted from each room before and after spraying with hydroxypropyl beta-cyclodextrin aerosol

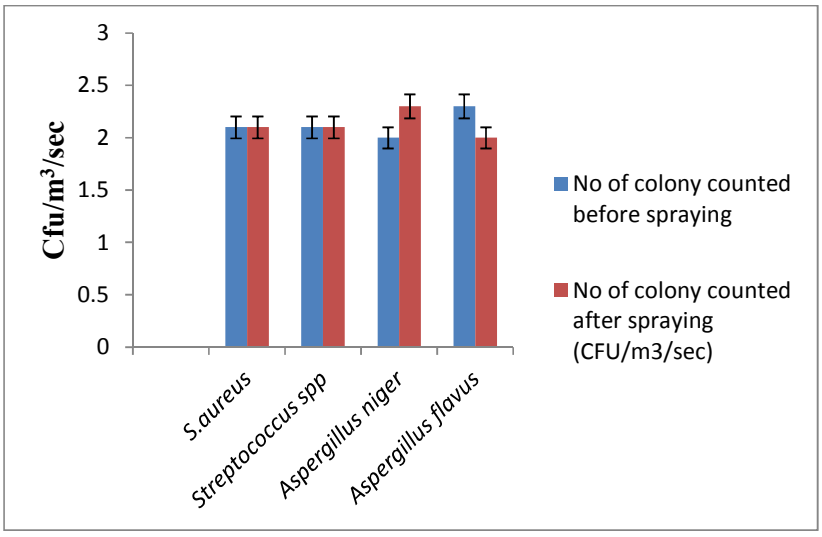

Fig. 6. The mean values of colony counted from each room before and after spraying with dipropylene glycol methyl etheraerosol

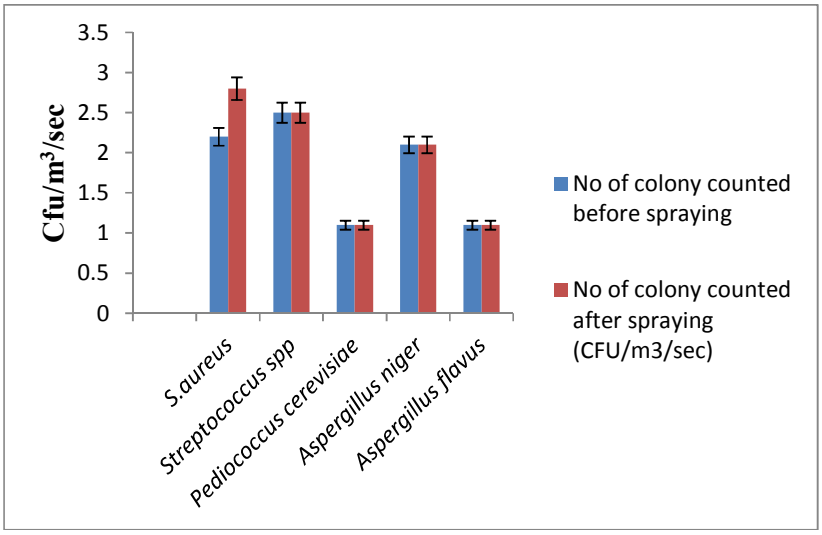

Fig. 7. The mean values of colony counted from each room before and after spraying with BHT aerosol

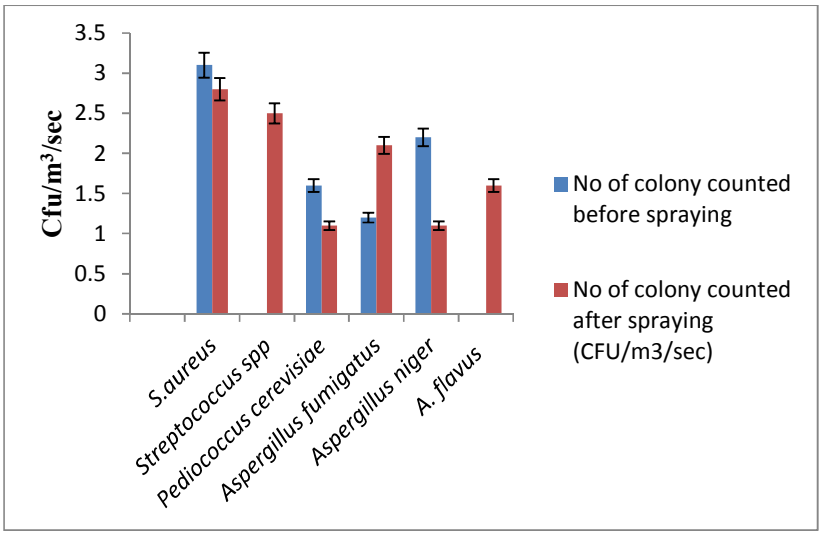

Fig. 8. The mean values of colony counted from each room before and after spraying with cyclodextrinaerosol

S. aureus were recorded as ≥300 Cfu/m^3/sec

From midacloprid Insecticides the microorganisms reported were: *Staphylococcus aureus, Lactobacillus jensenii, Bacillus coagulans, Aspergillus flavus* and *A. niger.* However, after spaying the room with the same insecticides, the Insecticide was able to inhibit the growth of *Lactobacillus jensenii, Bacillus coagulans,* from the report, there was an introduction of a new organisms (*Micrococcus* spp.) which was not present initially. Furthermore the insecticide was able to inhibit the growth of *Lactobacillus jensenii, Bacillus coagulans* and *Aspergillus flavus* that were present in the room after spraying. However, *there* was an introduction of a new organism (*Micrococcus* spp.) which was not present initially.

Before spraying the room with 1R-trans Phenothrin, the microbes isolated were: *Staphylococus aureus, Aerococcus viridans, Pediococcus cerevisiae. Streptococcus* spp., *Aspergillus fumigatus, A. flavus, A. niger* and after spraying there was inhibition of

Streptococcus spp. only by pyrethroids Insecticide. Before spraying pyrethroid into the rooms, microorganism identified were: *Staphylococus aureus, Aerococcus viridans, Pediococcus cerevisiae. Streptococcus* spp*., Aspergillus fumigatus, A. flavus, A. niger* after spraying it was discovered that the Insecticide was able to inhibit all the organisms present initially except *Staphylococus aureus* and *As pergillus flavus*.

Similarly, before spraying hydroxypropyl beta-cyclodextrin, the initial microorganisms identified were: *Staphylococus aureus, Streptococcus* spp*., Aspergillus fumigatus and Aspergillus niger* but after spraying it was discovered that the chemical was not able to inhibit all the initial organisms present. There was an introduction of three new organisms which are: *Lactobacillus jensenii, Bacillus coagulans*, *Aspergillus flavus,* and also before spraying with Air wick microorganism present are: *Staphylococus aureus, Streptococcus* spp*., Aspergillus flavus* and *A. niger,* and after spraying the it was discovered that there was no difference between the type of organism present before and after spraying the room with dipropylene glycol methyl ether. Similarly before spraying both BHT and Cyclodextrin into the rooms the microorganism that were isolated were: *Staphylococus aureus, Streptococcus* spp*., Pediococcus cerevisiae. Aspergillus flavus* and *A. niger* and for Cyclodextrin, the isolates were; *Staphylococus aureus, Pediococcus cerevisiae. Aspergillus fumigatus,* and *A. niger* after spraying it was discovered that there was no difference between the type of organism present before and after spraying the room with BHT and there was no difference between the type of organism present before and after spraying the room with Cyclodextrin. However, there was an introduction of *A. flavus,* so a single community profile cannot be applied to all indoor settings to account for the influence of outdoor air.

Adams [28] sought to determine how outdoor air and human occupancy affected bacterial microbial communities in a mechanically ventilated, office-like building. Although the authors found that human occupancy was associated with increased levels of bioaerosols associated with the human body, occupancy did not have the most profound effect on the microbiome. Rather, microbial communities observed in indoor air were closely related with those in outdoor air, and changes in microbial communities in outdoor air were mirrored by changes in indoor air. The observation recorded in this study showed an overlap in the microbial taxa in aerosol samples collected in indoor air. The observation indicated high abundances of *Staphylococus aureus, Lactobacillus jensenii, Bacillus coagulans, Micrococcus spp., Aerococcus viridans, Pediococcus cerevisiae* and *Streptococcus* spp., which are typically classified as outdoor-associated microorganism. This study led to the conclusion that outdoor air might exert a stronger influence on microbial communities than does human occupancy in the built environment that is well ventilated and has moderate occupancy.

Compared to airborne bacteria, fungi are even more strongly correlated between indoor and outdoor air [28]. Typically most airborne fungi found indoors are presumed to originate from outdoors, except in water-damaged buildings. In residential homes, Adams showed that indoor and outdoor air were dominated by *Cryptococcus victoriae*, *Cladosporium* spp*., Epicoccum* spp*.,and Penicillium* spp*.* and that the fungal community structure varied seasonally contrary to this finding. Lee *[29]* found an indoor/outdoor (I/O) ratio of 0.345 for total fungal spores and 0.025 for pollen grains. Additionally, indoor fungal and pollen concentrations followed trends in outdoor air concentrations. The low I/O ratio for pollen grains reflected the low penetration efficiency of large particles into the built environment compared to smaller spores.

This result is also inconformity with the result obtained by Barberan et al. [30], who reported *Staphylococcus aureus* as the highest bacteria isolated from their study.

In the present study *Staphylococcus aureus* was the dominant isolated organism and this bacterium is a common causative agent of various human diseases, it is responsible for many gastrointestinal tract infections, respiratory tract infections and skin disorders [31]. The reasons for high percentage frequency of occurrence of bacteria in this study could be due to low minimal usage of disinfection procedures against airborne pathogens,

It is well known that microorganisms is able to penetrate effectively from outdoor air into the built environment [31]. In fact, in some cases variation in outdoor microorganisms explains the majority of variation in microorganism in the built environment [32].

Table 1. Morphology and microscopic characteristic of the bacterial isolates

Code	Shape on Plates	Chromogenesis	Opacity	Elevation	Surface	Edge	Consistency	Gram reaction	shapes	Arrangement of cells	Spore	Spore position	Motility
1	Circular	Insoluble	Opaque	Low Convex	Smooth/ glistering	Entire	Smooth	tve	rod	Chains	-ve	-ve	-ve
2	Circular	Insoluble	Opaque	Raised	Dull	Tentate	friamble	tve	rod	singly	Oval Spore	Central	tve
3	filamentous	Insoluble	Opaque	Effuse	Smooth	Rhizoid	Friamble	tve	cocci	Pairs/ cluster	-ve	-ve	-ve
4	filamentous	Slightly soluble	translucent	raised	Dull	Rhizoid	friamble	tve	cocci	Pair/tetrad	-ve	-ve	-ve
5	Circular	Slightly soluble	Opaque	Raised	Smooth/ glistering	Entire	Smooth	tve	cocci	cluster	-ve	-ve	-ve
6	Circular	Slightly soluble	Opaque	Raised	Smooth/ glistering	Entire	smooth	tve	cocci	tetrad	-ve	-ve	-ve
7	Circular	Insoluble	Opaque	Raised	Smooth	Entire	smooth	tve	cocci	chains	-ve	-ve	-ve

Key: 1= Lactobacillus jensenii, 2= Bacillus coagulans, 3= Aerococcusviridans, 4= Pediococcuscerevisiae, 5=Staphylococcus aureus, 6= Micrococcus spp., 7=Streptococcus spp; +ve positive; -ve negative

Table 2. Morphological identification of the fungi isolates

Isolate	Morphological characteristics	Microscopic identification
Aspergillus flavus	Obverse: yellow-green becoming green with age. Reverse: creamish-yellow	Conidial head showing verrucose stipe, domed-shaped vesicle and philades borne directly on vesicle
Aspergillus fumigatus	Obverse: bluish-green Reverse: creamish-green.	Conidia head with philiades, metulae is absent.
Aspergillus niger	Obverse: blackish-brown often with yellow mycelium Reverse: creamish-yellow to yellow.	conidial head with metulae and philades, brownishcolour of stipe.

Table 3. Biochemical characteristic of the bacterial isolates

ASP	GA	GL	MN	SC	LA	MA	AR	XY	RA	SO	LM	GH	SH	CA	CO	UR	IN	CI	Probable ORG
-ve	-ve	+ve	-ve	+ve	-ve	+ve	-ve	-ve	-ve	-ve	-ve	-ve	+ve	-ve	-ve	-ve	-Ve	-Ve	*Lactobacillus Jensen*
-ve	-ve	+ve	-ve	-ve	-ve	-ve	-ve	+ve	-ve	-ve	-ve	-ve	+ve	+ve	-ve	-ve	-ve	-ve	*Bacillus coagulans*
-ve	-ve	+ve	+ve	+ve	+ve	+ve	-ve	-ve	-ve	-ve	-ve	-ve	+ve	+ve	-ve	-ve	-ve	-ve	*Aerococcus viridans*
-ve	-ve	+ve	-ve	+ve	+ve	-ve	+ve	-ve	+ve	+ve	+ve	-ve	+ve	+ve	-ve	-ve	-ve	-ve	*Pediococcuscerevisiae*
-ve	+ve A	+ve A	+ve A	+ve A	+ve A	+ve A	+ve A	+ve A	+ve A	+ve A	+ve	+ve	+ve	+ve	+ve	+ve	-ve	+ve	*Staphylococusaureus*
Tve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	ND	ND	ND	ND	ND	ND	ND	ND	*Streptococcus* spp.
-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	+ve	-ve	+ve	+ve	-ve	-ve	-ve	*Micrococcus* spp.

Keys: ND- not determined, +ve - positive, -ve -negative, ASP- ascospore, GA-galactose; GL- Glucose, MN-manitol, SC-Sucrose, LA- Lactose, MA -Maltose , AR- Arabinose , XY- Xylose , RA- Raffinose, SO- Sorbitol , LM- Litmus Milk, GH-Gelatin, SH -Starch Hydrolysis, CA- Catalase, CO-Coagulase, UR -Urease, IN -Indole, CI- Citrate

Table 4. List of bacteria isolates from rooms before and after spraying with aerosol

Room code	Type of aerosol used	Type of microorganisms isolated from the room before spraying with aerosol (control rooms)	Type of microorganisms isolated from the room after spraying with aerosol for 10 minutes	Remarks
A	Imidacloprid	*Staphylococus aureus, Lactobacillus jensenii, Bacillus coagulans*	*Staphylococus aureus*, and *Micrococcus* spp..	The Insecticide was able to inhibit the growth of *Lactobacillus jensenii, Bacillus coagulans,*However, there was an introduction of a new organisms (*Micrococcus* spp.*)* which was not present initially
B	1R-trans Phenothrin	*Staphylococusaureus, Aerococcusviridans, Pediococcuscerevisiae. Streptococcus*spp.	*Staphylococus aureus*	1R-trans Phenothrin was able to inhibit all organisms presents initially except *Staphylococcus aureus*
C	pyrethroids	*Staphylococusaureus, Aerococcusviridans, Streptococcus* spp.	*Staphylococus aureus, Aerococcus viridans*	There was inhibition of *Streptococcus* spp. only by pyrethroids Insecticide
D	permethrin	*Staphylococusaureus, Aerococcusviridans, Pediococcuscerevisiae. Streptococcus* spp.	*Staphylococus aureus*	permethrin Insecticide was able to inhibit all the organisms present initially except *Staphylococcus aureus*
E	hydroxypropyl beta-cyclodextrin	*Staphylococus aureus, Streptococcus* spp.	*Staphylococus aureus, Streptococcus* spp., *Lactobacillus jensenii, Bacillus coagulans,*	hydroxypropyl beta-cyclodextrin air freshener was not able to inhibit all the initial organisms present. There was an introduction of three new organisms which are: *Lactobacillus jensenii, Bacillus coagulans*
F	dipropylene glycol methyl ether	*Staphylococus aureus, Streptococcus s*pp.	*Staphylococcus aureus, Streptococcus* spp.	There was no difference between the type of organism present before and after spraying the room with dipropylene glycol methyl ether
G	BHT	*Staphylococcus aureus, Streptococcus* spp.*, Pediococcus cerevisiae.*	*Staphylococus aureus, Streptococcus* spp., *Pediococcus cerevisiae.*	There was no difference between the type of organism present before and after spraying the room with BHT
H	Cyclodextrin	*Staphylococus aureus, Pediococcus cerevisiae.*	*Staphylococus aureus, Pediococcus cerevisiae.*	There was no difference between the type of organism present before and after spraying the room with Cyclodextrin

Table 5. Fungi isolates from rooms before and after spraying with aerosol

Room code	Type of aerosol used	Type of microorganisms isolated from the room before spraying with aerosol	Type of microorganisms isolated from the room after spraying with aerosol for 10 minutes	Remarks
A	Imidacloprid	*Aspergillus flavus, Aspergillus niger*	*Aspergillus niger*	The Insecticide was able to inhibit the growth of *Aspergillus flavus.*
B	1R-trans Phenothrin	*Aspergillus fumigatus, Aspergillus flavus, Aspergillus niger*		The Insecticide was able to inhibit all organisms presents
C	pyrethroids	*Aerococcus viridan, Aspergillus fumigatus, Aspergillus flavus*	*Aerococcus viridans Aspergillus fumigatus* and *Aspergillus flavus*	There was no inhibition of any microorganism
D	permethrin	*Aspergillus fumigatus, Aspergillus flavus, Aspergillus niger*	*Aspergillus flavus*	The Insecticide was able to inhibit all the organisms present initially except *Aspergillus flavus*
E	hydroxypropyl beta-cyclodextrin	*Aspergillus fumigatus and Aspergillus niger*	*Aspergillus fumigatus, Aspergillus flavus, Aspergillus niger*	The freshener was not able to inhibit all the initial organisms present. There was an introduction of a new organisms as *Aspergillus flavus,*
F	dipropylene glycol methyl ether	*Aspergillus flavus* and *Aspergillus niger*	*Aspergillus flavus* and *Aspergillus niger*	There was no difference between the type of organism present before and after spraying the room
G	BHT	*Aspergillus flavus* and *Aspergillus niger*	*Aspergillus flavus* and *Aspergillus niger*	There was no difference between the type of organism present before and after spraying the room
H	Cyclodextrin	*Aspergillus fumigatus,* and *Aspergillus niger*	*Aspergillus fumigatus, A. flavus* and *Aspergillus niger*	There was no difference between the type of organism present before and after spraying the room with the air freshener . However, there was an introduction of *A. flavus* after spraying

Table 6. Percentage (%) occurrence of bacteria isolates

Isolates	No of rooms	No of occurrence	% Occurrence
Staphylococus aureus	8	8	100
Lactobacillus jensenii	8	1	12.5
Bacillus coagulans	8	1	12.5
Micrococcus spp.	8	1	12.5
Aerococcus viridans	8	3	37.5
Pediococcus cerevisiae	8	5	62.5
Streptococcus spp.	8	6	75

Table 7. Percentage occurrence (%) of fungi isolates

Isolates	No of rooms	No of occurrence	% Occurrence
Aspergillus flavus	8	6	75
Aspergillus niger	8	7	87.5
Aspergillus fumigatus	8	5	62.5

4. CONCLUSION

Conclusively, it was important to determine the type of microflora present in the built environment. The outcome of this research revealed that some aerosols were able to inhibit some organisms that were initially present in experimental rooms while there were introduction of another organisms from some aerosols into some rooms. This shows that, airborne microbiome can be emitted into any environment through the use of aerosols.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Smith DJ, Timonen HJ, Jaffe DA, Griffin DW, Birmele MN, Perry KD. Intercontinental dispersal of bacteria and archaea by transpacific winds. Appl Environ Microbiol. 2013;79:1134–1139.
2. Smith DJ, Jaffe DA, Birmele MN, Griffin DW, Schuerger AC, Hee J. Free tropospheric transport of microorganisms from Asia to North America. Microbial Ecol. 2012;64:973–985.
3. DeLeon-Rodriguez N, Lathem TL, Rodriguez-RLM, Barazesh JM, Anderson BE, Beyersdorf AJ. Microbiome of the upper troposphere: Species composition and prevalence, effects of tropical storms, and atmospheric implications. Proc Natl Acad Sci. 2013;110:2575–2580.
4. Kelley ST, Gilbert JA. Studying the microbiology of the indoor environment. Genome Biol. 2002;14:2-202.
5. Rintala H, Pitkäranta M, Toivola M, Paulin L, Nevalainen A. Diversity and seasonal dynamics of bacterial community in indoor environment. BMC Microbiol. 2008;8:56.
6. Tringe SG, Zhang T, Liu X, Yu Y, Lee WH, Yap J. The airborne metagenome in an indoor urban environment. J. Pone. 2008;10:1371.
7. Kembel SW, Jones E, Kline J, Northcutt D, Stenson J, Womack AM. Architectural design influences the diversity and structure of the built environment microbiome. ISMEJ. 2012;6: 1469–1479.
8. Dunn RR, Fierer N, Henley JB, Leff JW, Menninger HL. Home life: Factors structuring the bacterial diversity found within and between homes. J Pone. 2013;10:13-71.
9. Adams RI, Miletto M, Lindow SE, Taylor JW, Bruns TD. Airborne bacterial communities in residences: Similarities and differences with fungi. J Pone. 2014;10:13-71.
10. Prussin AJ, Garcia II, Marr EB. Total concentrations of virus and bacteria in indoor and outdoor air. Environ Sci Technol Lett. 2015;2:84–88.
11. Shelton BG, Kirkland KH, Flanders WD, Morris GK. Profiles of airborne fungi in buildings and outdoor environments in the United States. Appl Environ Microbiol. 2002;68:1743–1753.
12. Frank JA, Sørensen SJ. Quantitative metagenomic analyses based on average genome size normalization. Appl Environ Microb. 2011;77:2513–2521.
13. Gilbert JA, Dupont CL. Microbial metagenomics: Beyond the genome. Ann Rev Mar Sci. 2011;3:347–371.

14. Duhaime MB, Deng L, Poulos BT, Sullivan MB. Towards quantitative metagenomics of wild viruses and other ultra-low concentration DNA samples: A rigorous assessment and optimization of the linker amplification method. Environ Microbiol. 2012;14:2526–2537.
15. Klepeis NE, Nelson WC, Ott WR, Robinson JP, Tsang AM, Switzer P. The national human activity pattern survey (NHAPS): A resource for assessing exposure to environmental pollutants. J Expo Anal Env Epid. 2001;11:231–252.
16. Macher JM, Chatigny MA, Burge HA. Sampling airborne microorganisms and aeroallergens. In Air Sampling Instruments for evaluation of atmospheric contaminants, cap. 23. 8th Edition ACGIH, Cincinnati, Ohio; 1995.
17. Grinshpun SA, Chang CW, Nevalainen A, Willeke K. Inlet Characteristic of Bioaerosol Samplers. J. Aerosol Sci. 1994;25(8):1503-1522.
18. Abt E, Suh HH, Allen G, Koutrakis P. Characterization of indoor particle sources: A study conducted in the metropolitan Boston area. Environ Health Persp. 2000;108:35–44.
19. Knights D, Kuczynski J, Charlson ES, Zaneveld J, Mozer MC, Collman RG. Bayesian community-wide culture-independent microbial source tracking. Nat Meth. 2011;8:761–763.
20. Stetzenbach LD, Harry R. Microorganisms and indoor air quality. Clinical Microbiology Newsletter. 1998;20:19.
21. Sudharsanam S, Swaminathan S, Ramalingam A, Thangavel G, Annamalai R, Steinberg R. Characterization of indoor bioaerosols from a hospital ward in a tropical setting Afr Health Sci. 2012;12(2):217-225.
22. Sautour M, Sixt N, Dalle F, L'Ollivier C, Fourquenet V, Calinon C, Profiles and seasonal distribution of airborne fungi in indoor and outdoor environments at a French hospital Sci Total Environ. 2009;407:3766-3771.
23. Tormo-Molina R, Gonzalo-Garijo MA, Fernández-Rodríguez S, Silva-Palacios Monitoring the occurrence of indoor fungi in a hospital. Rev Iberoam Micol. 2012;29(4):227-234.
24. Yagoub SO, Elagbashi A. Isolation of potential pathogenic bacteria from the air of hospital Delivery and nursing rooms. Int J Appl Sci. 2010;10(11):1011-1014.
25. Sheik GB, Abd Al Rheam AI, Al Shehri ZS, Al Otaibi OM. Assessment of Bacteria and fungi in air from college of applied medical sciences (Male) at AD-Dawadmi, Saudi Arabia. Int Res J Biol Sci. 2015;4(9):48-53.
26. Naruka K, Gaur J. Distribution pattern of airborne bacteria and fungi at market area. American Eurasian J Sci Res. 2014;9(6):186-192.
27. Bond TC. Bounding the role of black carbon in the climate system: A scientific assessment. J.Geophys. Res. – Atmospheres. 2013;11:118.
28. Adams RI, Bateman AC, Bik HM, Meadow JF. Microbiota of the indoor environment: A meta- analysis. Microbiome. 2015;3:1–18.
29. Lee LD, Hachem RY, Berkheiser M, Hackett B, Jiang Y. Hospital environment and invasive aspergillosis in patients with hematologic malignancy. Am J Infect Control. 2012;40:247–249.
30. Barberan A, Ladau J, Leff JW, Pollard KS, Menninger HL, Dunn RR. Continental-scale distributions of dust-associated bacteria and fungi. Proc Natl Acad Sci U. 2015;112:5756–5761.
31. Chen C, Zhao B. Review of relationship between indoor and outdoor particles: I/O ratio, infiltration factor and penetration factor. Atmos Environ. 2011;45:275–288.
32. Cyrys J, Pitz M, Bischof W, Wichmann H, Heinrich J. Relationship between indoor and outdoor levels of fine particle mass, particle number concentrations and black smoke under different ventilation conditions. J Expo Sci Env Epid. 2004;14:275–283.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle3.com/review-history/48118