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Comparative assessment of indoor air quality within office environments with reference to indoor biopollutants, suspended particulate matter and relative humidity

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Abstract: The present study was undertaken to evaluate Indoor Air Quality with special reference to IAQ parameters viz. indoor biopollutants (bacteria & fungi), suspended particulate matter (SPM) and relative humidity (RH) in the office environments i.e. banks. A comparative assessment was made to characterize IAQ between banks located at different sites of Jammu viz. Residential area, Commercial area, Sub-urban area, on Road-crossing and on National Highway as well as between AC and Non-AC banks. Statistically derived correlation was also applied to determine the influence of related parameters i.e. SPM and RH on the bacterial and fungal measurements. Total average bacterial and fungal count was observed to be higher in AC banks as compared to Non AC banks at majority of sites. Gram positive bacteria were found to be abundant as compared to gram negative bacteria among bacterial types and Deuteromycetes were observed to be higher as compared to Ascomycetes and Phycomycetes among fungal types. Significant positive correlations were observed between SPM and indoor biopollutants as well as between RH and indoor biopollutants at majority of the studied sites.

Key words: Correlation; Indoor biopollutants; Relative humidity; Suspended particulate matter.

Introduction

Changes in life styles worldwide have resulted in a shift from open air environments to air tight, energy efficient environments at home and work places, where people spend a substantial portion of their time (Chao et al.,2003; Molhave,2011). Indoor environments are fundamental factors capable of impacting health and air quality of indoor environments is one of the key factors affecting health, wellbeing and productivity of the occupants. Exposure to bioaerosols is inevitable in a wide range of enclosed environments due to their ubiquitous presence in nature. Under favorable conditions, air borne biopollutants are able to grow and propagate on a variety of building materials and indoor surfaces causing indoor air pollution (Kodama et al., 1986; Lighthart, 1994). The microorganisms in indoor air originate not only from the activities of occupants but also from contaminated building materials, furnishings and from entering outdoor air ; therefore an adequate indoor air change and ventilation rate is commonly accepted as an essential procedure for the occupants health and for the lowering of the indoor microbial charge (Jaakkola and Miettinen, 1995). Use of certain electronic appliances such as air conditioners and humidifiers in enclosed spaces in order to maintain a comfortable environment is often associated with the proliferation of microorganisms. ACs are often contaminated with microorganisms when poorly maintained, which they discharge with strong air currents, causing microbial proliferation in indoor environment (Jo and Lee, 2008). The air borne

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microbial contamination can cause health problems and can also compromise the normal activities in a work environment, such as hospitals, dental offices, pharmaceutical and cosmetics facilities and could affect affect performance, morale and productivity of staff. (Pasquarella et al., 2007).

The health risks connected with exposure to fungi involve not only immunosuppressed patients but also healthy persons among whom hyper reactivity to the fungal allergen may develop; such hyper reactivity may cause respiratory disorders and may exacerbate asthma (Institute of Medicine, 2004). Besides allergic and respiratory problem, some indoor moulds, when ingested or inhaled, could produce mycotoxins, including aflatoxins and microbial volatile organic compounds which may lead to several health complaints, for example headache, dizziness, and inability to concentrate, consistent with mycotoxicosis. (Burge and Amman, 1999). Keeping in view of degrading indoor air quality and adverse health effects on occupants owing to the prevalence of biocontaminants within working environments, the current study was was envisioned with the following objectives:

i. To provide a qualitative and quantitative assessment of Indoor Air Quality (IAQ) in terms of Indoor Biopollutants (Bacteria and Fungi)and influencing factors viz. SPM and RH with in the office environment.
ii. To make a comparative assessment of IAQ within different office environments i.e. between banks located at different sites viz. Residential, Commercial, Road Crossing, National Highway & Sub-urban as well as between Air-conditioned and Non- Air conditioned banks.
iii. To obtain a statistically derived relation between indoor biopollutants (bacteria & fungi) and influencing factors (SPM and RH).

The present study was aimed to evaluate IAQ with special reference to IAQ parameters viz. indoor biopollutants (bacteria & fungi), suspended particulate matter and relative humidity in the banks located at different sites of Jammu.

Material and Methods

Study area

The study area was divided into 5 major sites :- Site I- Banks located in Residential area with two sub sites-Ia (AC bank) and Ib (Non AC bank), Site II- Banks located in Commercial area with two sub sites-IIa (AC bank) and IIb (Non AC bank), Site III- Banks located in sub urban area with two sub sites-IIIa (AC bank) and IIIb (Non AC bank), Site IV-Banks located at Road crossing area with two sub sites-IVa (AC bank) and IVb (Non AC bank), Site V- Banks located at National highway area with two sub sites-Va (AC bank) and Vb (Non AC bank).

At each site and sub site, sampling of air for Suspended Particulate Matter (SPM) and biopollutants (bacteria and fungi) was done using Handy Air Sampler APM 821 for two hours (for SPM) and 10 minutes (for biopollutants). The impinged water was inoculated on culture media (Nutrient Agar, MacConkey Agar and BTB Lactose Agar for bacteria and Potato Dextrose Agar and Czapek Dox Agar for fungi). From the sampled air, SPM $\mu g/m^3$, number of bacteria CFU/m^3, number of fungi CFU/m^3 were calculated.

1) SPM in ($\mu g/m^3$) was calculated by following formula:
   $SPM(\mu g/m^3) = (W_2-W_1) \times 10^3/V$
   Where W_1& W_2= initial and final weight of filter paper in mg; V =Volume of air in litres and V= $(F_1+F_2) \times T /2$
   Where, F_1 & F_2 = Initial and final rates of air in lpm which were converted into m^3/min
   Using conversion formula; 1LPM = 10^{-3} m^3/min, T = time of sampling in minutes.
   The quantification of bacteria and fungi was done using the formula:
   No. of microbes (CFU/m^3) =No. of microbes collected by Impinger/ volume of air
   No. of microbes collected by impinger = No. (CFU/ml) x vol. remaining in impinger
   Volume of air = Sampling time × flow rate

The bacteria were identified on the basis of their growth, colony appearance, microscopic observation and biochemical tests (catalase test, carbohydrate fermentation test, nitrate reduction test, urease test, coagulase test and IMViC reactions-indole test, methyl red test, voges proskauer test & citrate utilization test). Bacteria were identified up to genus level but *Staphylococcus aureus* was identified to the species level. Fungal sps. were identified on the basis of their growth, colony appearance, microscopic characteristics of the spore and hyphae and using standardized fungal identification keys. Fungi were identified up to the genus level but *Aspergillus* was identified up to the species level.

The value of RH (%) was calculated from the temperature in dry bulb thermometer and depression in temperature in wet bulb thermometer using standard table of relative humidity.

Results

Quantitative and Qualitative status of Bacteria in indoor air of banks of study area: Analysis of bacterial count in the indoor air of different banks revealed that total average bacterial count was found to be maximum in AC bank located at sub-urban area whereas minimum in Non-AC bank located at residential area with a range value of 5.74×10^3 to 10.10×10^3 CFU/m^3.

In all the banks both AC as well as Non-AC, the percentage of Gram Positive bacteria was observed to be higher than Gram Negative bacteria. Among gram positive bacteria, different genera of bacteria were identified as *Bacillus species, Staphylococcus sps*., *Micrococcus sps*. and *Staphylococcus aureus* whereas among gram negative bacteria, different genera of bacteria were identified as *Acinetobacter sps*., *Klebsiella sps*., *Pseudomonas sps*. and *E. coli*. (Table 1)

Quantitative and Qualitative status of Fungi in indoor air of banks of study area: Analysis of fungal count in the indoor air of different banks revealed that total average fungal count was found to be maximum in AC bank located at sub-urban area whereas minimum in Non-AC bank located at residential area with a range value of 4.52×10^3 to 8.56×10^3 CFU/m^3.

Table 1. Quantitative (CFU/m^3) and Qualitative status of Bacteria in indoor air of banks of study area.

S.No.	BACTERIA	RESIDENTIAL SITE		COMMERCIAL SITE		SUB-URBAN SITE		ROAD CROSSING SITE		NATIONAL HIGHWAY SITE	
		AC	Non-AC	AC	Non-AC	AC	Non-AC	AC	Non-AC	AC	Non-AC
1.	**GRAM POSITIVE BACTERIA**	**$3.93x10^3$ (59.3%)**	**$3.35x10^3$ (58.4%)**	**$6.02x10^3$ (70.4%)**	**$5.41x10^3$ (72%)**	**$6.32x10^3$ (62.5%)**	**$6.43x10^3$ (68%)**	**$4.74x10^3$ (69.4%)**	**$4.96x10^3$ (75.4%)**	**$5.73x10^3$ (65.9%)**	**$5.32x10^3$ (61.4%)**
a.	*Bacillus sps*	$1.28x10^3$ (19.3%)	$1.10x10^3$ (19.4%)	$1.03x10^3$ (12%)	$1.16x10^3$ (15.5%)	$1.83x10^3$ (18.1%)	$1.66x10^3$ (17.6%)	$1.46x10^3$ (21.4%)	$1.53x10^3$ (23.3%)	$1.37x10^3$ (15.8%)	$1.75x10^3$ (20.2%)
b.	*Staphylococcus sps*	$1.18x10^3$ (17.8%)	$1.13x10^3$ (19.7%)	$1.93x10^3$ (22.5%)	$1.27x10^3$ (16.9%)	$1.97x10^3$ (19.5%)	$2.14x10^3$ (22.5%)	$1.20x10^3$ (17.6%)	$1.65x10^3$ (25.1%)	$2.24x10^3$ (25.8%)	$1.85x10^3$ (21.4%)
c.	*Micrococcus sps*	$0.95x10^3$ (14.3%)	$0.78x10^3$ (13.6%)	$1.65x10^3$ (19.4%)	$2.19x10^3$ (29.1%)	$1.74x10^3$ (17.2%)	$1.69x10^3$ (17.9%)	$1.77x10^3$ (25.9%)	$1.52x10^3$ (23.1%)	$1.60x10^3$ (18.4%)	$1.72x10^3$ (19.8%)
d.	*Staphylococcus aureus*	$0.52x10^3$ (7.9%)	$0.33x10^3$ (5.7%)	$1.41x10^3$ (16.5%)	$0.79x10^3$ (10.5%)	$0.78x10^3$ (7.7%)	$0.95x10^3$ (10%)	$0.31x10^3$ (4.5%)	$0.26x10^3$ (3.9%)	$0.52x10^3$ (5.9%)	
2.	**GRAM NEGATIVE BACTERIA**	**$2.69x10^3$ (40.7%)**	**$2.39x10^3$ (41.6%)**	**$2.53x10^3$ (29.6%)**	**$2.26x10^3$ (28%)**	**$3.78x10^3$ (37.5%)**	**$3.02x10^3$ (32%)**	**$2.09x10^3$ (30.6%)**	**$1.61x10^3$ (24.6%)**	**$2.97x10^3$ (34.1%)**	**$3.35x10^3$ (38.6%)**
a.	*Klebsiella sps*	$0.97x10^3$ (14.6%)	$0.86x10^3$ (15%)	$1x10^3$ (11.7%)		$1.37x10^3$ (13.6%)	$0.94x10^3$ (10%)	$0.42x10^3$ (6.2%)	$0.69x10^3$ (10.5%)	$0.73x10^3$ (8.4%)	$0.78x10^3$ (9%)
b.	*Acinetobacter sps*	$1.15x10^3$ (17.5%)	$1.23x10^3$ (21.4%)	$1.10x10^3$ (12.9%)	$0.93x10^3$ (12.4%)	$1.79x10^3$ (17.7%)	$1.56x10^3$ (16.5%)	$0.52x10^3$ (7.6%)	$0.21x10^3$ (3.2%)	$1.46x10^3$ (16.7%)	$1x10^3$ (11.5%)
c.	*Pseudomonas sps*	$0.21x10^3$ (3.2%)	$0.29x10^3$ (5.2%)		$0.64x10^3$ (8.5%)	$0.33x10^3$ (3.3%)	$0.20x10^3$ (2.1%)	$0.52x10^3$ (7.6%)	$0.21x10^3$ (3.2%)	$0.79x10^3$ (9%)	$1.57x10^3$ (18.1%)
d.	*E.coli*	$0.36x10^3$ (5.4%)		$0.43x10^3$ (5%)	$0.69x10^3$ (7.1%)	$0.29x10^3$ (2.9%)	$0.32x10^3$ (3.4%)	$0.63x10^3$ (9.2%)	$0.51x10^3$ (7.7%)		
3.	**TOTAL BACTERIA**	**$6.63x10^3$ (100%)**	**$5.74x10^3$ (100%)**	**$8.56x10^3$ (100%)**	**$7.51x10^3$ (100%)**	**$10.10x10^3$ (100%)**	**$9.45x10^3$ (100%)**	**$6.83x10^3$ (100%)**	**$6.58x10^3$ (100%)**	**$8.70x10^3$ (100%)**	**$8.67x10^3$ (100%)**

Difference in Total Bacteria in AC and Non AC banks at all the sites insignificant (p>0.1) at 10% (0.1) significance level.

The overall percentage of Deuteromycetes was observed to be higher as compared with Ascomycetes at majority of the sites whereas the Phycomycetes exhibited lowest percentage values at all the studied sites, both AC as well as Non-AC banks. Among Deuteromycetes, different genera of fungi were identified as *Fusarium sps*., *Alternaria sps., Curvularia sps*., *Cladosporium sps*. and *Bipolaris sps.* Among Ascomycetes, different genera of fungi were identified as *Aspergillus sps.(A. niger,A. glaucus, A. versicolor & A. fumigatus) ,Penicillium sps. and Saccharomyces sps.* Among Phycomycetes, different genera of fungi were identified as *Rhizopus sps. and Mucor sps.*(Table 2)

Suspended Particulate Matter (SPM) in the indoor air of banks of the study area: The overall compiled SPM data at different sites of Study Area revealed that the AC banks in the study area exhibited average indoor SPM of 1288.93±307.83µg/m^3 with a range of 793.65 to 1666.67 µg/m^3 whereas the Non-AC banks in the study area exhibited average indoor SPM of 1421.95±341.25 µg/m^3 with a range of 980.39 to 1960.78 µg/m^3. The critical analysis of the data showed that indoor SPM in AC banks at all the sites exhibited statistically insignificant lower values (p>0.1) as compared with the Non-AC banks at these respective sites. (Table 3)

Relative Humidity (RH) in the indoor air of banks of the study area: The overall analysis of data at different sites of the study area revealed that the AC banks in the study area exhibited average indoor RH of 74±8.0 % with a range value of 60-96 % whereas the Non-AC banks in the study area exhibited average indoor RH of 75±9.0 % with a range value of 60-91%. The critical analysis of the data showed that the average indoor RH in AC banks in the total study area exhibited statistically significant lower value (p=0.08 at 0.1 significance level) as compared to Non-AC banks in the total study area (Table 4).

Correlation of indoor biopollutants (bacteria and fungi) with influencing factors-indoor

Table 2. Quantitative (CFU/m^3)and Qualitative status of Fungi in indoor air of banks of study area.

S.NO.	FUNGI	RESIDENTIAL SITE		COMMERCIAL SITE		SUB-URBAN SITE		ROAD CROSSING SITE		NATIONAL HIGHWAY SITE	
		AC	NonAC	AC	NonAC	AC	NonAC	AC	NonAC	AC	NonAC
1.	**Ascomycetes**	**$2.60X10^3$ (54.6%)**	**$1.55x10^3$ (34.3%)**	**$2.1x10^3$ (31.3%)**	**$1.38x10^3$ (20.9%)**	**$2.75x10^3$ (32.1%)**	**$2.28x10^3$ (29.1%)**	**$1.61x10^3$ (28.6%)**	**$1.86x10^3$ (30.9%)**	**$3.02x10^3$ (36.7%)**	**$3.74x10^3$ (47.4%)**
a.	*Aspergillus sps*	$0.91x10^3$ (19.11%)	$1.03x10^3$ (22.8%)	$1.44x10^3$ (21.4%)	$1.18x10^3$ (17.8%)	$0.67x10^3$ (7.8%)	$1.26x10^3$ (16.1%)	$1.30x10^3$ (23.1%)	$1.30x10^3$ (21.6%)	$1.72x10^3$ (20.9%)	$2.05x10^3$ (25.9%)
b.	*Penicillium sps*	$0.73x10^3$ (15.3%)	$0.31x10^3$ (6.9%)	$0.10x10^3$ (1.5%)	-	$0.11x10^3$ (1.3%)	$0.39x10^3$ (5%)	$0.10x10^3$ (1.8%)	$0.46x10^3$ (7.6%)	$0.33x10^3$ (4%)	$0.86x10^3$ (10.9%)
c.	*Saccharomyces sps.*	$0.96x10^3$ (20.2%)	$0.21x10^3$ (4.6%)	$0.56x10^3$ (8.3%)	$0.20x10^3$ (3%)	$1.97x10^3$ (23%)	$0.63x10^3$ (8%)	$0.21x10^3$ (3.7%)	$0.10x10^3$ (1.7%)	$0.97x10^3$ (11.8%)	$0.83x10^3$ (10.6%)
2.	**Deuteromycetes**	**$1.84x10^3$ (38.5%)**	**$2.72x10^3$ (60.2%)**	**$2.96x10^3$ (43.9%)**	**$3.27x10^3$ (49.3%)**	**$4.42x10^3$ (51.7%)**	**$4.89x10^3$ (62.4%)**	**$2.98x10^3$ (52.8%)**	**$3.42x10^3$ (56.8%)**	**$4.94x10^3$ (59.9%)**	**$3.69x10^3$ (46.7%)**
a.	*Fusarium sps*	$0.54x10^3$ (11.2%)	$0.67x10^3$ (14.8%)	$0.77x10^3$ (11.5%)	$1.58x10^3$ (23.9%)	$0.58x10^3$ (6.8%)	$0.58x10^3$ (7.4%)	$0.42x10^3$ (7.5%)	$0.69x10^3$ (11.5%)	$1.27x10^3$ (15.4%)	$0.39x10^3$ (4.9%)
b.	*Alternaria sps*	$0.86x10^3$ (18.1%)	$0.61x10^3$ (13.5%)	$1.20x10^3$ (17.8%)	$0.89x10^3$ (13.4%)	$1.42x10^3$ (16.6%)	$1.70x10^3$ (21.7%)	$0.63x10^3$ (11.2%)	$1.05x10^3$ (17.4%)	$0.94x10^3$ (11.4%)	$0.89x10^3$ (11.3%)
c.	*Curvularia sps*	-	$0.62x10^3$ (13.7%)	$0.39x10^3$ (5.8%)	-	$0.22x10^3$ (2.6%)	$0.63x10^3$ (8%)	$0.21x10^3$ (3.7%)	$0.20x10^3$ (3.3%)	-	$1.52x10^3$ (19.2%)
d.	*Cladosporium sps*	$0.44x10^3$ (9.2%)	$0.39x10^3$ (8.6%)	$0.60x10^3$ (8.9%)	$0.11x10^3$ (1.6%)	$2.20x10^3$ (25.7%)	$1.98x10^3$ (25.3%)	$0.99x10^3$ (17.5%)	$1.27x10^3$ (21.1%)	$1.69x10^3$ (20.5%)	$0.56x10^3$ (7%)
e.	*Bipolaris sps*	-	$0.43x10^3$ (9.5%)	-	$0.69x10^3$ (10.4%)	-	-	$0.73x10^3$ (12.9%)	$0.21x10^3$ (3.5%)	$1.04x10^3$ (12.6%)	$0.33x10^3$ (4.2%)
3.	**Phycomycetes**	**$0.33x10^3$ (6.9%)**	**$0.25x10^3$ (5.5%)**	**$1.67x10^3$ (24.8%)**	**$1.98x10^3$ (29.9%)**	**$1.39x10^3$ (16.2%)**	**$0.67x10^3$ (8.6%)**	**$1.05x10^3$ (18.6%)**	**$0.74x10^3$ (12.3%)**	**$0.28x10^3$ (3.4%)**	**$0.47x10^3$ (5.9%)**
a.	*Rhizopus sps*	$0.11x10^3$ (2.3%)	$0.15x10^3$ (3.3%)	$0.33x10^3$ (4.9%)	-	$0.33x10^3$ (3.9%)	-	$0.37x10^3$ (6.5%)	$0.10x10^3$ (1.7%)	-	-
b.	*Mucor sps*	$0.22x10^3$ (4.6%)	$0.10x10^3$ (2.2%)	$1.34x10^3$ (19.9%)	$1.98x10^3$ (29.9%)	$1.06x10^3$ (12.3%)	$0.67x10^3$ (8.6%)	$0.68x10^3$ (12.1%)	$0.64x10^3$ (10.6%)	$0.28x10^3$ (3.4%)	$0.47x10^3$ (5.9%)
4.	**Total Fungi**	**$4.76x10^3$ (100%)**	**$4.52x10^3$ (100%)**	**$6.72x10^3$ (100%)**	**$6.62x10^3$ (100%)**	**$8.56x10^3$ (100%)**	**$7.84x10^3$ (100%)**	**$5.63x10^3$ (100%)**	**$6.02x10^3$ (100%)**	**$8.24x10^3$ (100%)**	**$7.91x10^3$ (!00%)**

Difference in Total fungi in AC and Non AC banks at all the sites insignificant i.e. p>0.1 at 10% (0.1) significance level.

SPM and RH: Significant ($p<0.1$) positive correlations were observed between SPM and bacteria in all the Non-AC banks and AC bank at Commercial area and between SPM and Fungi in all the AC and Non- AC banks except the AC banks located at Sub-urban area & National Highway and Non-AC bank located at the Road Crossing area [Tables 5(a,b)].

Significant ($p<0.1$) positive correlations were observed between RH and bacteria in all the Non-AC banks except Non-AC bank at Commercial area and AC banks at Residential and Road Crossing site and between RH and Fungi in all the AC and Non-AC banks except the Non-AC bank at the Road Crossing site [Tables 5(c,d)].

Discussion

As per the stated objectives of the study and critical analysis of compiled data, it may be implied that:

The percentage of Gram positive bacteria was observed to be higher than Gram negative bacteria and the predominant bacterial genera includes *Staphylococcus sps*., *Micrococcus sps*. and *Bacillus sps.* which is in accordance with the studies of Zhu et al., 2003; Giulio et al., 2009; Aydogdu et al., 2010 and Bonetta et al., 2010. Simard et al. (1983) while evaluating the ventilating ducts of an apartment building observed that the bacteria were mainly gram positive cocci followed by gram positive bacilli and further by gram negative bacilli.

The percentage of Deuteromycetes was observed to be higher as compared with Ascomycetes at majority of the sites whereas the Phycomycetes exhibited lowest percentage values at all the studied sites as reported by Kulkarni and Karne, 2010. The predominant fungal genera includes *Aspergillus sps, Penicillium sps, Fusarium sps*., *Alternaria sps., Curvularia sps, Cladosporium sps*., *Rhizopus sps* etc.(Jain, 2000; Stryjakowska-Sekulska et al.,2007; Khan et al., 2009; Hasnain et al., 2012).

Significant positive correlations were observed between SPM and bacteria and

Table 3. Indoor Suspended Particulate Matter (SPM) (µg/m^3) in banks located at different sites of Jammu.

S.No.	SITES	Indoor SPM (µg/m^3) in	
		AC BANK	Non-AC BANK
1.	RESIDENTIAL SITE (SITE I)	1098.40±253.04 [925.93-1388.89] (Ia)	1164.22±267.09 [980.39-1470.59] (Ib)
2.	COMMERCIAL SITE (SITEII)	1327.62±247.64 [1041.67-1470.59] (IIa)	1557.90±336.75 [1190.48-1851.85 (IIb)
3.	SUB-URBAN SITE (SITE III)	1412.04±260.61 [1111.11-1562.50] (IIIa)	1446.76±295.31 [1111.11-1666.67] (III b)
4.	ROAD CROSSING SITE (SITE IV)	1217.71±369.51 [793.65-1470.59] (IVa)	1334.88±449.06 [1041.67-1851.85] (IVb)
5.	NATIONAL HIGHWAY SITE (SITE V)	1388.89±481.13 [833.33-1666.67] (Va)	1605.98±388.72 [1190.48-1960.78] (Vb)
	Average in Study Area	1288.93±307.83* [793.65-1666.67] Avg. of Ia, IIa, IIIa, IVa &Va	1421.95±341.25* [980.39-1960.78] Avg. of Ib, IIb, IIIb, IVb & Vb

*Values statistically insignificant at 5% (0.05) significance level

between SPM and Fungi at majority of the studied sites indicating the close association of microbes with particulate dust as reported by Mancinelli and Shulls, 1978; Subramanyam et al., 1999 and Rampal and Sharma, 2010a,b.

Average Total Bacterial and Fungal count (CFU/m^3) in indoor air of AC banks was more than that of Non-AC banks at nearly all the sites although indoor SPM and RH was found to be less in AC banks. This may be attributed to poor maintenance of AC units in such offices as the level of hygiene was found to be more in AC banks and signs of dampness/ water damage were rarely encountered when compared to Non-AC banks. Moreover, in comparison to outdoor air environment, dilution of indoor biocontaminants by ventilation is reduced and the germicidal effect of sunrays is also protected as the windows are closed during the operation of AC units. This

Table 4. Indoor Relative Humidity (%) in banks located at different sites of Jammu.

S.No.	SITES	Indoor RH (%) in	
		AC BANK	Non-AC BANK
1.	RESIDENTIAL SITE (SITE I)	65±6.0 [60-71] (Ia)	67±7.0 [60-73] (Ib)
2.	COMMERCIAL SITE (SITE II)	74±7.0 [68-82] (IIa)	74±8.0 [68-83] (IIb)
3.	SUB-URBAN SITE (SITE III)	80±14 [71-96] (IIIa)	85±5.0 [81-91] (IIIb)
4.	ROAD CROSSING SITE (SITE IV)	70±7.0 [64-78] (IVa)	73±9.0 [67-83] (IVb)
5.	NATIONAL HIGHWAY SITE (SITE V)	78±5.0 [74-83] (Va)	80±9.0 [73-91](Vb)
	Average in Study Area	74±8.0* [60-96] Avg. of Ia, IIa, IIIa,IVa & Va	75±9.0* [60-91] Avg.of Ib, IIb, IIIb, IVb & Vb

*Values significant at 10% (0.1) significance level.

Significant positive correlations were observed between RH and bacteria and between RH and Fungi at majority of the studied sites indicating the importance of moisture or humidity as an influencing factor for the proliferation of biocontaminants in indoor environment (Chao et al., 2002; Zhu et al., 2003; Aydogdu et al.,2010 and Goncalves et al., 2010).

Table 5a. Correlation Coefficient (r) of SPM and Bacteria & its Significance (p) in banks located at different sites of Jammu city.

S.No.	SITES	Correlation between SPM & Bacteria			
		AC		Non-AC	
		R	P	r	p
1.	RESIDENTIAL SITE	+0.97	0.128***	+0.54	0.017*
2.	COMMERCIAL SITE	+0.72	0.085**	+0.98	0.064**
3.	SUB-URBAN SITE	+0.32	0.120***	+0.89	0.005*
4.	ROAD CROSSING SITE	-0.39	0.032*	+0.24	0.100**
5.	NATIONAL HIGHWAY SITE	-0.86	0.023*	+0.95	0.001*

*Significant at both 5% (0.05) & 10% (0.1) level; **Significant at 10% (0.1) level only; ***Insignificant at 10% (0.1) level

Table 5b. Correlation Coefficient (r) of SPM and Fungi & its Significance (p) in banks located at different sites of Jammu City.

S.No.	SITES	Correlation between SPM & Fungi			
		AC		Non- AC	
		r	p	R	p
1.	RESIDENTIAL SITE	+0.79	0.012*	+0.99	0.049*
2.	COMMERCIAL SITE	+0.95	0.004*	+0.49	0.037*
3.	SUB-URBAN SITE	+0.63	0.110***	+0.99	0.103**
4.	ROAD CROSSING SITE	+0.37	0.090**	+0.69	0.160***
5.	NATIONAL HIGHWAY SITE	-0.45	0.012*	+0.70	0.024*

*Significant at both 5% (0.05) & 10% (0.1) level; **Significant at 10% (0.1) level only; ***Insignificant at 10% (0.1) level

fact is supported by the studies of various researchers who laid stress on the timely replacement or periodical cleaning of AC filters and proper maintenance of AC units so that filters may not be clogged due to dust load and microbial infestation and serve as reservoirs of microbial growth (Khan et al., 2009, Ruping et al., 2011, Khan and Karuppayil, 2011 and Khan and Karuppayil, 2012.) In contrast to this, the improved microbiological quality of indoor air and medium-low level of microbial contamination in indoor air of office environment was attributed to good or proper maintenance of air conditioning system (Jo and Lee, 2008; Bonetta et al., 2010; Vonberg et al., 2010).

Conclusion

The current study clearly revealed that the indoor bacterial and fungal measurements exceeded maximum recommended limits i.e. 1000 CFU/m^3 for total no. of bioaerosol particles set by National Institute of Occupational Safety and Health (NIOSH), 1000 CFU/m^3 set by the American Conference of Govermental Industrial Hygienists (ACGIH) with the culturable count for total bacteria not to exceed 500 CFU/m^3. Although predominant bacterial types were observed to be gram positive *Staphylococcus sps*., *Micrococcus sps*. and *Bacillus sps.* representing normal microflora of skin but the prevalence of opportunistic pathogens like *Staphylococcus aureus, Acinetobacter sps*., *Klebsiella sps*., *Pseudomonas sps* as well as immunotoxic and allergenic fungal types like *Aspergillus sps, Penicillium sps, Fusarium sps*., *Alternaria sps., Curvularia sps, Cladosporium sps*., *Rhizopus sps*., presents potential health risks for the office occupants. Exposure to

Table 5c. Correlation Coefficient (r) of Relative Humidity (RH) and Bacteria and its Significance (p) in banks located at different sites of Jammu City.

S.No.	SITES	Correlation Between RH & Bacteria			
		AC		Non-AC	
		r	p	R	p
1.	RESIDENTIAL SITE	+0.95	0.106**	+0.31	0.014*
2.	COMMERCIAL SITE	-0.50	0.069**	-0.20	0.052*
3.	SUB-URBAN SITE	-0.79	0.096**	+0.95	0.005*
4.	ROAD CROSSING SITE	+0.86	0.018*	+0.42	0.071**
5.	NATIONAL HIGHWAY SITE	-0.98	0.010*	+0.69	0.002*

*Significant at both 5% (0.05) & 10% (0.1) level; **Significant at 10% (0.1) level only.

Table 5d. Correlation Coefficient (r) of Relative Humidity (RH) and Fungi and its Significance (p) in banks located at different sites of Jammu City.

S.No.	SITES	Correlation Between RH & Fungi			
		AC		Non-AC	
		r	P	r	p
1.	RESIDENTIAL SITE	+0.99	0.012*	+0.97	0.018*
2.	COMMERCIAL SITE	+0.54	0.005*	+0.99	0.026*
3.	SUB-URBAN SITE	+0.94	0.087**	+0.70	0.083**
4.	ROAD CROSSING SITE	+0.97	0.064**	+0.82	0.123***
5.	NATIONAL HIGHWAY SITE	+0.24	0.005*	+0.96	0.020*

*Significant at both 5% (0.05) & 10% (0.1) level; **Significant at 10% (0.1) level only; ***Insignificant at 10% (0.1) level

bioaerosols is inevitable in enclosed environments due to their ubiquitous presence but efforts should be inclined towards reducing or eliminating practices contributing to indoor biotic pollution. The microbiological quality of air is an important criterion that must be taken into account when indoor workplaces are designed in order to minimize adverse health effects and to provide a safe working environment.

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