It is essential to evaluate the quality of air we breathe whether indoors or outdoors. The number and type of air borne microorganisms can indicate the degree of cleanliness and may be a source of human discomfort. The present study examined the bioaerosol level of five different microenvironments each from outdoor and indoor air. The major parameters associated with the bioaerosol measurements included the microenvironment type, sampling time and seasonal distribution. No major environmental problems were reported at the microenvironment investigated during the entire survey period.

5.1. Outdoor microbial concentration

5.1.1. Bacteria

Regardless of the season, bacteria were detected (total counts in $\text{cfu/m}^3$) in all the outdoor air samples. However, the occurrence of individual bacterial species and the outdoor bacterial concentrations ($5495 \text{ cfu/m}^3$) (Table 1) and their seasonal distributions were significantly higher than the outdoor total fungal concentrations ($4845 \text{ cfu/m}^3$) (Table 5). This is also supported by Pastuszka et al. (2000) with an outdoor total bacterial count ($4344 \text{ cfu/m}^3$) significantly higher than the outdoor total fungal count ($4121 \text{ cfu/m}^3$) from an outdoor environment in Upper Silesia. One possible cause is that the soil surface would be a significant source of bacteria, since higher concentrations of bacteria were present when dust was raised (Jones and Harrison, 2004). Moreover, the variation of outdoor bacterial concentrations according to atmospheric height is closely related to local meteorological parameters such as turbulence and mixing height (Hirst et al., 1967). Mandrioli et al. (1983), who measured bioaerosol concentration at various heights from the ground to 6000m, reported a similar decreasing trend with height in bioaerosol concentrations. However, Mandrioli et al. (1983) also found that, on another day under a different meteorological condition, a profile of culturable bacteria concentrations with height showed little variations.

The outdoor exposure to bioaerosols can be obtained from the detailed analysis of the bacterial genera. *Staphylococcus* spp. was the predominant bacterial type in almost all the outdoor air studied and had the highest count; constituting 21.1% (Table 3) of the total bacterial genera whereas the second and the third predominant groups were *Bacillus*, constituting 18.5% and *Micrococcus* of 17.2% of total respectively. Other bacterial genera were also present at a
lower frequency. The outdoor bacterial concentration of *Bacillus* spp. in 2007 was significantly (Mean ± SD 11.5 ±2.7 cfu/m³) (Table 4) higher than those of other species (P< 0.05) from the microenvironment of Bus stand. Concentrations of *Staphylococcus* and *Micrococcus* were significantly (P< 0.05) greater than 2008 than those of other species in that year. In general, these two bacterial groups were significantly higher in microenvironments of railway station, recreation ground and vegetable market. On the other hand *E.coli* with a concentration of 12.9±7.0 cfu/m³ (Mean ± SD; 2007) and 11.5±6.8 cfu/m³ (Mean ± SD; 2008) were significantly higher (P< 0.05) than those of other species from sewage treatment plant. The present study reveals the presence of higher total bacterial concentrations from outdoor environment which is comparable to those in other reports with mean bacterial values between 10 and 10³ cfu/m³ (Jo and Seo, 2005).

The last decade has a significant increase in scientific data on non-occupational exposure as well as occupational exposure to bioaerosols in many developed countries for the purpose of evaluating the relationship between exposure and health effects (Gorny and Dutkiewicz, 2002). However, there is only limited amount of information currently available for Chennai on individual exposure to bioaerosols, including a few reports on certain public access facilities such as hospitals. Thus it is reasonable that such recreation grounds, bus stands and railway stations with a high human occupancy should be investigated as regards the exposure of the individuals to bioaerosols, and the results used to evaluate the relationship between exposure and health effects. Children spend a large portion of their week end time in recreation ground and are also considered as potentially more vulnerable than adults, and their health is more susceptible to environmental exposure (Guzelian *et al*., 1992; Aprea *et al*., 2000).

Any reports on the prevalence of such microbes in outdoor environment in major cities are of importance in providing protection to the population of the city. Most bacteria or bacterial agents are not very potent allergens with the exception of the spore forming Actinomycetes. Bacterial cell wall components, such as endotoxin of Gram negative bacteria and peptidoglycan of Gram positive bacteria are agents with important pro inflammatory properties that may induce respiratory symptoms. The toxigenic and pathogenic potential of these microbes have been well documented in literature (Rylander and Jacob, (1997). The microbial load which is commonly found has been implicated in causing primary and secondary infections in susceptible individuals. To minimize the exposure, spitting in public places to be banned and water stagnation to be drained.
Bacteria from Enterobacteriaceae in high quantities were detected in the air at the aeration tank, during the operation. The presence of pathogenic bacteria in aerosols does not always cause pathogenic alterations. Induction of the latter is directly related to the quantity of microorganisms and an organism vulnerability to infection. It is reported that Sewage Treatment Plant (STP) employees gain resistance to sewage aerosols. On the other hand, the presence of pathogenic microorganisms can be especially risky to persons accidentally present in a STP area (Filipkowsk et al., 2002). Sewage treatment plant facilities have been found to generate bioaerosols, which are transported by the prevailing winds down streams to areas that can be up to several hundred meters away. STP represents an important source of bioaerosol emission, especially the stages that include moving parts or sudden drop of over flowing liquids resulting in bioaerosols formation (Sawyer et al., 1993; Brandi et al., 2000; Ranali et al., 2000; Bauer et al., 2002; Pascual et al., 2003). Droplets produced might contain therefore, varying amounts of pathogenic microorganisms, some of them with the ability to infect a person through the respiratory system, contact or swallowing. Studies show a significant connection between bioaerosols and cases of respiratory and intestinal diseases (Sawyer et al., 1993).

The present study estimated the presence and concentration of bioaerosols in the air surrounding installations of sewage treatment plants especially *E.coli* and *Klebsiella* spp. as being indicators for intestinal infection. Many other sources of microorganisms containing aerosols are, however, generated through human activities in both urban and rural areas. Population growth in urban areas increased the density of domestic wastes which must be disposed off in a safe and environmentally sound manner. Consequently, expansions of existing waste treatment in utilization facilities are necessary. Some of these facilities have, however, been shown to emit microorganisms containing aerosols under certain conditions. Sewage treatment plants have been considered as potential sources of air borne infectious microorganisms (Sawyer et al., 1993). Because of economic, environmental or political constraints, some of these facilities are located in densely populated regions of urban or suburban communities. In these cases, a determination of the contribution of the facilities to the microorganism’s content of the ambient air may allow an elevation of the potential for adverse health or environmental effect.

The air near residential environments is not sterile but contains microorganisms, some of potential enteric origin. This study confirms, in the case of small treatment plants, the presence of airborne bacteria from aerated sewage. It is particularly note worthy that enteric bacteria were isolated frequently from upwind samples taken close to aerated sludge tanks. Aerosol samples
collected at least 10 km from any known sources of aerated sewage seldom yielded enteric bacteria. In a study of coliforms emitted from effluents sprays, Teltsch and Katznelson (1978) reported the effects of variation from other factors. Under these conditions, there was a positive correlation between bacterial counts and relative humidity and negative correlation with solar irradiation.

The hazards associated with exposure to airborne enteric microorganisms are not known but, based on available evidence the risk cannot be disregarded. This study indicates that persons residing or working close to such sewage plants may have an increased probability of contact with enteric organisms. As already pointed out, Sewage treatment facilities have been found to generate bioaerosols which are transported by the winds downstream to areas that can be up to several 100 meters away. Number of aerosols is slowly added to the environment through various means. The load may be suddenly increased due to various treatment processes. People working in such sewage treatment plants can prove to be a hazardous occupation, with illness deriving from water infection, representing the basic point of interest in the study of workers health. The cause of bioaerosol can be controlled by maintaining proper and hygienic environment.

5.1.2. Fungi

Any atmospheric air contains spores of certain fungal species. Depending on the living conditions, environmental and climatic conditions, fungal concentrations in outdoor air can vary greatly. The present investigation recorded a total fungal count of 4845 cfu/m³ (Table. 5) during the study period from various microenvironments.

In Chennai, the fungal concentrations in outdoor samples (Table. 5) were less, compared to those of some other world cities (Fang et al., 2005; Solomon et al., 2006). For example, Fang et al. (2005) reported a concentration ranging from 24 to 13,960 cfu/m³ in the city of Beijing, China. Solomon et al. (2006) estimated a very high mould spore concentration ranging from 21,000 to 102,000 spores/m³ of outdoor air in New Orleans, Louisiana, USA. In European hospital (Italy), the maximum fungal concentration recovered in outdoor air was 3150 cfu/m³ (Pini et al., 2004), almost six times more than the maximal value observed at the Dijon site (Sautour et al., 2009). These differences could be explained by different sampling methods used to measure fungal concentrations, air flow rate, duration of sampling and culture medium. However, the present results were consistent with those reported in Paris (Dassonville et al., 2008).
The present study reveals that the outdoor fungal concentration (Mean±SD) of *Aspergillus* in 2007 and 2008 was significantly (P < 0.05) greater than those of other species in the corresponding years from the microenvironments of the study areas. No significant (P > 0.05) difference between 2007 and 2008 in means of *Aspergillus* in all the outdoor microenvironments. *Aspergillus* seems to be the predominant fungus followed by *Penicillium* (Mean ±SD) in 2007 and 2008 was significantly (P<0.05) greater than those of other species in the corresponding years from the microenvironments of bus stand, sewage treatment plant and vegetable market. Among the remaining fungal groups, genera such as *Alternaria* (3.5±2.3; 2007 and 6.7± 3.3; 2008), *Fusarium* (2.1 ± 1.8; 2007 and 4.4 ± 2.4; 2008) and *Rhizopus* (0.8± 1.6; 2007 and 2.7± 2.3; 2008) were significantly greater over other groups of fungi in sewage treatment plant (P< 0.05) (Table.8).

Just as the present study, Ren et al. (1999) showed that *Aspergillus, Penicillium, Cladosporium* and *Alternaria* are the predominant genera in outdoor air (Table.7). Ebner et al. (1989) found species of *Aspergillus* in high concentrations especially in late fall and following rainy weather.

According to Reiss (1998), thin walled colorless spores such as from *Aspergillus* are quickly eliminated by the ultraviolet radiation in the sun light. Possibly the absence of significant sources in summer and the extremes of temperature and humidity besides the fungicidal effect of ultraviolet might explain why species of *Aspergillus* and *Penicillium* were found more frequently in outdoor in spring, fall and winter. Generally, the spores of *Penicillium* spp. and *Alternaria* spp. were found in relatively low concentrations. Previous studies report

Concerning the percentage of fungi isolated in outdoor air during the study period (Table.7), it was noticed that many of the main fungal genera that recovered were similar to those observed in some other cities. *Aspergillus* was the most prominent fungus and was reported almost from all samples. The percentage of *Aspergillus* was 33 in Chennai which supported the other results (Sautour et al., 2009). *Penicillium* was always the most frequently identified genus with the percentage ranging from 10 to 28 in other cities (12.3% in Chennai) (Sautour et al., 2009), *Alternaria* from 4 to 14% in other cities (7.7% in Chennai) (Pini et al., 2004; Fang et al., 2005; Gomez de Ana et al., 2006; Lee and Jo, 2006) and inturn *Cladosporium* ranging from 43 to 78%, greatly higher than the present result (6.4% in Chennai). Other fungal genera were also present at a lower frequency.

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comparatively on the concentrations of fungal species in outdoor air (Li et al., 1995; Millington and Corden, 2005).

In addition, Hyvarinen et al. (1993) and Niemeier et al. (2006) reported that more fungal species were identified by air sampling than by swab sampling. All of these methods complement each other and may be useful in specific cases. The species of Penicillium have been identified as important causative agents of extrinsic bronchial asthma (Shen and Han, 1998). It has been reported that most common genera namely Aspergillus, Penicillium, Cladosporium and Alternaria should always be considered as a cause of fungal allergy (Peat et al., 1993). In the present study, although some degrees of seasonal variations of the major genera were detected, the most notable ones were the Aspergillus and Penicillium.

Many sources of bioaerosols are man – made such as sewage treatment and vegetable waste disposal facilities and so on. Dust levels in an open air are relatively high, especially when the outdoor activity is more. Higher bioaerosol levels occur when dust is stirred up during outdoor cleaning, playing and dumping waste materials. Similarly, these cause a lot of human health problem. The amount of refuse collected from urban areas in India ranges in the order of 0.3 to 0.5 kg/person per day including night soil (Rao, 1995). Microorganisms are introduced into the atmosphere from these sources, transmitted via the air stream, and finally get deposited on some surface (Lighthart and Frisch, 1976). Particles may be carried by air currents to some distance, their source and may present occupational as well as public health considerations.

Concentrations at most sampling locations indicated atmospheric dispersion from the facility. However bioaerosol levels at some locations deviated from the pattern. Several colonies of Bacillus, soil bound microorganisms were identified on outdoor samples only and apparently was the primary cause of high concentrations upwind of the building.

The organic sources for proliferation of moulds were ample in the environments. This is same in case of vegetable markets. There are many reports available on the level of mesophilic fungi present in the atmosphere of occupational environments (Udaya Prakash and Vittal, 2005). Accumulations of waste vegetables are thrown in and around the market which favour the growth of microbes in vegetable market. The humidity generated while rotting of vegetables and heats generated due to piling of decaying vegetables provide a cocktail for these organisms to grow and proliferate. It was reported that moist, sun heated piles of plant substrates favour the growth of these fungi (Mouchacca, 1995).
5.2. Indoor microbial concentration

5.2.1. Bacteria

The present study shows the total indoor bacterial concentration (4902.5 \( cfu/m^3 \)) (Table.9) slightly less from the indoor fungal concentration (5055 \( cfu/m^3 \)) (Table.13). However the indoor bacterial concentrations were significantly higher in few microenvironments than the indoor fungi and outdoor bacterial concentrations. Similarly Scheff et al. (2000) reported that in a middle school of Spring field, Illinois, which had no known environmental problems, for total bacteria, the indoor concentrations (AM: 561 \( cfu/m^3 \)) were significantly higher than the outdoor concentrations (AM: 389 \( cfu/m^3 \)). The present study also showed a significant higher indoor bacterial concentration of 1200 \( cfu/m^3 \) from a microenvironment of home (Table.9). The same result was reported by Pastuszka et al. (2000) in healthy homes of Upper Silesia, Poland and Hargreaves et al. (2003) reported for homes in Brisbane, Australia. In contrast to this report, the present study revealed a lower indoor bacterial concentration from the microenvironments of office premises, public toilets and theatres than the outdoors. The bioaerosol concentrations in Chennai are similar to those from other reports, with bacterial values between 10 and 10^3 \( cfu/m^3 \) (Nevalainen, 1989; Flannigan, 1993; Gall up et al., 1993; Ren et al., 1993; Dekoster and Thorne, 1995; Seltzer, 1995). Reports are also available on the bacterial levels of residences, which varied between 10 and 10^4 \( cfu/m^3 \) (Macher et al., 1991; Nevalainen et al., 1991; Reponen et al., 1992; Dekoster and Thorne, 1995; Rautiala et al., 1996; Ross et al., 2000; Pessi et al., 2002).

In this study, the highest concentration of airborne bacteria measured in the office buildings was 580 and 485 \( cfu/m^3 \) during 2007 and 2008 respectively (Table.9). Most of these buildings were equipped with a modern ventilation system. This result differs from an annual concentration level of bacterial aerosol in a microenvironment of office premise from Upper Sielsia (Pastuszka et al., 2000) with a total bacterial count of 956 \( cfu/m^3 \) and was more than about 1.5 times higher than the present work. In the office environment, the concentration of airborne bacteria was approximately 1065 \( cfu/m^3 \) (2 year study) which was slightly less than in home environment (1200 \( cfu/m^3 \)). The reason may be more sources of bacteria in homes (for example dogs, cats and other animals). The difference can also be the result of conditions less conducive to bacterial growth in offices than in homes as typically in contrast to homes, there are no carpets in Chennai offices and in most of the floor is wet cleaned daily. Similar concentration levels of bacterial aerosols were observed from hotel and in home environments. In case of public toilet, the risk of illness or infection has been linked to faecal contamination of
the water, due to faeces released or introduced into the water when a person has an accidental faecal release is also a potential source of pathogenic organisms. In addition, infected users can directly contaminate and opportunistic pathogens (mainly bacteria) can also be shed from users and transmitted via aerosols. In addition, facilities (ventilation, air conditioning system, proper disposal) or on other wet surfaces within the facility to a point at which some of them may cause a variety of infections such as bacterial diarrhoea, throat infection, fungal skin infections and so on. Proper guidance and self hygiene is most important for any person availing public facilities.

Important information about the indoor exposure to bioaerosols in Chennai can be obtained from the detailed analysis of the bacterial genera. Species of *Staphylococcus* were present in almost all the indoor air studied; these bacteria also had the highest count, constituting 26.6% of the total bacterial genera (Table.11). The second most common bacterial aerosol was *Micrococcus* spp. constituting 24.1% of total. The present results differ from the indoor exposure to bioaerosols in Upper Silesia where species of *Micrococcus* were present in all homes studied and have the highest count, constituting 36% of the total bacterial genera and the second most common bacterial aerosol was *Staphylococcus epidermidis* present in 76% of home studied constituting 14% of the total. However species of *Staphylococcus* were the most frequently occurring indoor bacteria in Chennai followed by *Micrococcus* which contributed both together about 50% of the total bacteria concentration. The present results support the general statement that the bacteria in the indoor air are dominated by species of *Staphylococcus* and *Micrococcus* likely to be the most prominent (CEC, 1993; Gall up et al., 1993; Maroni et al., 1993). Other bacterial genera were present at a lower frequency. Most people are exposed to contaminated indoor environments regardless of its climatization situation (Sorenson, 1987; Rylander et al., 1989; Burge, 1990; Gravesen et al., 1990).

The present study also reveals, the indoor bacterial concentration (Mean± SD) of species of *Staphylococcus* in 2007 and 2008 significantly (19.0 ± 6.1 and 11.7± 6.2 cfu/m³) (Table.12), different and greater than those of other species in the respective years (P< 0.05). The concentration of species of *Micrococcus* was significantly greater than those of other species other than *Staphylococcus* from the microenvironment of home. Similarly, the concentration of *Staphylococcus* (Mean± SD) was significantly greater (12.5± 6.9; 2007 and 8.3± 5.4; 2008), (Table.12), than those of other species (P<0.05) in hotel environment where as in office premise and public toilets, species of *Micrococcus* were significantly greater (P< 0.05) with 17.9±7.8; 11.3±5.2 during 2007 and 2008 respectively. Theatre environment also showed with the
concentration of species of *Staphylococcus* in 2007 and 2008, and species of *Micrococcus* in 2008 significantly greater in the respective years.

5.2.2. Fungi

While occupational exposure to air borne pollutants such as asbestos and coal dust is known to cause lung cancer and Pneumoconiosis (black lung disease), consequences of air contaminants especially bioaerosols, in homes and non industrial work sites such as office buildings are not yet fully understood. In the 1970’s and 1980’s microbial contamination was identified as the primary cause for poor air quality in only 5% of more than 500 indoor air quality (IAQ) investigations conducted by National Institute for Occupational Safety and Health (NIOSH); while the remaining 95% resulted from inadequate ventilation, entrainment of outdoor air contaminants, contaminants in building fabric and unknown sources (NIOSH, 1989). However, in the last 10 years microorganisms were the primary source of indoor air contamination in as many as 35 – 50% of IAQ cases (Lewis, 1994). This change has been attributed atleast partially to a paradigm shift from chemical contaminant based investigations to an interdisciplinary approach combining evaluation of physical, chemical and microbiological constituents of indoor air environments. As regards the type of microenvironment, indoor total bacterial count was lower than the total fungal count. One possible cause for this difference was the higher occupancy and activity in indoor was found to be closely related indoor microbial levels (Scheff et al., 2000), while settled spores were resuspended in indoor air by air movement caused by human activities such as walking and running (Buttner and Stetzenbach, 1993).

Fungi are ubiquitous organisms that make up approximately 25% of earth’s biomass. Moulds are very adaptable and can colonize dead and decaying organic matter (Wood, Paper, leather, textiles) and even damp, inorganic material (glass, painted surfaces, bare concrete) if organic nutrients such as dust or soil particles are available. Because various genera grow and reproduce at different substrates, water concentrations and temperatures, moulds occur in a wide range of habitats (Sandra et al., 2003).

Mould types and concentrations of indoors are primarily a function of outdoor fungi and substrate water (related to indoor humidity level). Most indoor moulds originate from exterior sources; some species of *Aspergillus* and *Penicillium* can grow and reproduce effectively indoors and are commonly found in air samples of normal “dry” buildings (Sandra et al., 2003). Moulds are composed of linear chains of cells (hyphae) that branch and intertwine to form the fungus body (mycelium). All fungal cell walls contain (1- 3) - \( \beta \) – D – glucane, a medically significant
glucose polymer that has immunosuppressive, mitogenic and inflammatory properties. This mould cell wall component also appears to act synergistically with bacterial endotoxins to produce airway inflammation following inhalation exposure (Fogelmark et al., 1994).

Moulds are important potential producers of toxins of indoors that can contain species of *Aspergillus, Penicillium and Fusarium* (Beasley, 1994). Two classes of mycotoxins have been isolated from house dust samples: aflatoxins from some strains of *Aspergillus flavus* and trichothecenes from some species and strains of *Fusarium, Cephalosporium, Stachybotrys* and *Trichoderma*. Several reports have associated over growths of trichothecene producing fungi with human health effects such as cold and flu like symptoms, head ache and general malaise (Croft et al., 1986; Johanning et al., 1993; Nikulin et al., 1994). However, isolation of a toxogenic fungus from a building does not imply the presence of mycotoxin, since the physical conditions necessary for mycotoxin production are very specific, and are often different from those required for growth of parent mould. Likewise, failure to produce toxins *invitro* does not mean that a mould known to be toxogenic will not produce toxins in a field situation (Beasley, 1994). Moulds also produce a large number of volatile organic compounds (VOCs). These chemicals are responsible for the musty odors produced by growing moulds. There is little evidence that fungal VOCs cause specific human health effects (Batterman, 1995) but the most common VOC, ethanol is a potent synergizer of many fungal toxins.

A strong relation was found between outdoor and indoor airborne fungi. Many authors also reported that outdoor air is the major source of indoor fungi (Li et al., 1995; Ren et al., 1999; Su et al., 2001; Chew et al., 2003; O’ Connor et al., 2004; Lee and Jo, 2006). Supporting to the present work, indoor *Aspergillus* and *Penicillium* levels tended to be higher due to potential indoor sources (Table.15). No association was noted with these fungal concentrations probably due to the fact that these fungi had indoor sources. In a previous study by Ren et al. (2001), the presence of air conditioning was associated with a decrease in total air borne fungal levels, perhaps due to a lack of window opening. In other studies, it has been reported that total airborne fungal genera and their concentrations were lower in winter than in other seasons (Ren et al., 1999, 2001; Chew et al., 2003; Lee and Jo, 2006) but the present study revealed differently and correlates with a study reported in southern Taiwan (Pei – Chih et al., 2000; Su et al., 2001) with a higher level of indoor fungi obtained during the month of January (winter), (Table .14).
Concerning percentages of fungi isolated in indoor air during the study period, it was noticed that many of the main fungal genera that recovered were similar to those that observed in some other cities. Aspergillus was the most predominant fungus and was reported almost from all the indoor samples and its distribution revealed 36.8% (Table 15) which is higher than the outdoor percentage (33%) (Table. 7). Penicillium spp. was always the most frequently identified genus with the percentage of 12.8 in Chennai which supports in other cities (Li and Kendrick, 1995; Lee and Jo, 2006). It is followed by Cladosporium (7.6%) and Alternaria (7.4%). Other fungal genera were also present at a lower frequency (Table 15). Concerning percentages of fungi isolated in indoor air, species of Aspergillus and Penicillium were by far the most frequently encountered genera. The prevalence of these two genera has been previously observed in Dijon hospital (Sautour et al., 2007), other hospitals (Wu et al., 2000), and recently in new born babies’ homes (Paris, France) (Dassonville et al., 2008). This suggests that most of the indoor contamination concerns with Mycomycetes that have a particular ability to adapt to the environment inside the buildings. Because fungi concentrations vary over a wide range, threshold values are difficult to determine (Gots et al., 2003). Much data on fungi concentration have been published with respect to home environments. For example, Miller et al. (1988) suggested that fungi concentrations should be below 150 cfu/m$^3$ in home environments. According to Finnish guidelines for urban or suburban residences (Reponen et al., 1992), spore concentrations exceeding 500 cfu/m$^3$ in the indoor air and bacteria concentrations of over 5000 cfu/m$^3$, indicate abnormal microbe sources of indoors.

The present data indicated that culturable air borne fungi were found in almost all homes. Many of the main fungal genera that recovered (Aspergillus, Penicillium, Cladosporium and Alternaria) were similar to those commonly found in residential environments air in other studies conducted in different countries (Li et al., 1995; Garrett et al., 1998; Dharmage et al., 1999; Ren et al., 1999, 2001; Pei – Chih et al., 2000; Duchaine and Merials, 2001; Su et al., 2001; Chew et al., 2003; Stark et al., 2003; Horner et al., 2004; O’Connor et al., 2004; de Ana et al., 2006; Lee and Jo, 2006; Claire Dassonville et al., 2008). As previously described (Ren et al., 2001; Chew et al., 2003; Horner et al., 2004; O’Conner et al., 2004; Lee and Jo 2006; Claire Dassonville et al., 2008) species of Aspergillus and Penicillium were found more commonly in indoor air, where as Alternaria and Cladosporium were the next dominant groups other than Aspergillus and Penicillium in outdoors. Other fungal genera such as Curvularia, Fusarium, Mucor, Rhizopus and Trichoderma were less frequently detected in air. In the study of Hyvarinen et al. (2001a), the total concentrations of viable fungi and the concentrations of
Penicillium and Aspergillus were significantly higher in residences with moisture problems than in the reference buildings. Species of Penicillium have been reported to be associated with moisture damage also in other studies (Li and Kendrick, 1995; Mahooti – Brooks et al., 2004). These findings agree with the results of the present study (i.e.,) increased concentrations or occurrence of the Penicillium spp. were the commonest indicators from indoor air. Higher air borne concentrations of Aspergillus, Penicillium, Cladosporium and non sporing fungi have previously been observed in buildings with moisture damage or visible mould growth (Pasanen, 1992; Pasanen et al., 1992a; Dekoster and Thorne, 1995; Garrett et al., 1998; Salonen, 2007).

The indoor fungal concentration of Aspergillus spp. differs significantly (P<0.05); the mean concentration of 2007 being significantly higher than that of 2008. The means of Aspergillus are significantly, higher than those of other species from the microenvironment of home (Table.16). It also showed that the 2008 mean of Penicillium (9.2 ± 5.5) was significantly (P<0.05) greater than that of 2007 (4.2 ± 5.1) other than Aspergillus. In hotel environment only in the cases of Alternaria, Aspergillus and Penicillium, the respective means of 2007 and 2008 differed significantly. The mean concentration of Aspergillus was significantly higher during 2007 (21.7 ± 11.0) and 2008 (13.8 ± 4.1) (P<0.05) and the mean of Penicillium was significantly higher than other species other than Aspergillus. The present work also reveals, the Aspergillus was the predominant fungus and significantly higher than other species reported from the microenvironments of office premise, public toilet and theatre. However, 2007 mean of Cladosporium was significantly (5.6 ± 3.7) (P<0.05) greater than its 2008 mean (1.5 ± 1.7) in office premise.

Although airborne fungal concentrations were low or high, they were consistent with those reported elsewhere in indoor environments in USA and Canada (Ren et al., 1999, 2001; Duchaine and Meriaux, 2001; Chew et al., 2003; Stark et al., 2003; Horner et al., 2004), in Australia (Garrett et al., 1998; Dharmage et al., 1999; Matheson et al., 2003; Cheong and Neumeister – Kemp, 2005), in Asia (Li et al., 1995; Pei – Chih et al., 2000; Su et al., 2001; Lee and Jo, 2006) and in Argentina (Basilico Mde et al., 2007). However, comparisons must be carried out with care as different sampling methods are used to measure fungal concentrations, air flow rate, duration of sampling, culture agar and in addition, it could also be explained by geographic differences in climate with high humidity (Sometimes up to 90%) and temperature (Dharmage et al., 1999; Matheson et al., 2003). In the present study, the homes were selected randomly and recruited from middle income and low income populations (O’ Connor et al.,
2004), so the fungal concentrations were not lower than those described by Clarisse et al. (2007) from a high socio economic status.

The present study revealed the presence of *Aspergillus* as the predominant fungi in Chennai. Moreover species of *Aspergillus, Cladosporium* and *Penicillium* were the most common fungi recovered inside the homes. Tilak and Saibaba (1985) also observed a high concentration of *Aspergillus* in most indoor environments. They also noted that *Alternaria, Cladosporium, Curvularia, Penicillium* and *Rhizopus* were invariably present in all indoor environments. Similar observations were made by Levetin *et al.* (1978) and Chanbal and Kotmore (1983). Rajan *et al.* (1952) have recorded *Aspergillus* as the most common in Kanpur. Thilak and Saibaba (1985) reported *Cladosporium* to be dominant in Aurangabad. *Alternaria* was noted to be the predominant type in Jaipur (Gupta *et al.*, 1960) and Poona (Chandbal and Deodikar, 1964). The finding of the present study is in agreement with the findings of several other researchers (Katz *et al.*, 1999; Dharmage *et al.*, 2002; Unlu *et al.*, 2003; Hedayati *et al.*, 2005). Fungi are now seen as having a wider role in respiratory ill health (Li *et al.*, 1995; Dharmage *et al.*, 2002).

These were seven species of *Aspergillus* with *Aspergillus niger* predominating. It has been reported that the air inside air conditioned homes has fewer fungi than outdoor air, but has a significantly greater number of species of *Aspergillus* (Kodama and MacGee, 1986). The poor quality houses had a generally low hygienic standard, a high number of residents, and less provision for effective ventilation systems. The higher number of residents confined to a small space, the higher is the buildup air borne microbes shed by the human body.

The fungal aerosol concentrations in healthy homes were ranging from 10 to $10^3$ cfu/m$^3$ (Solomon, 1976; Hyvärinen *et al.*, 1993; Kao and Li, 1994; Dekoster and Thorne, 1995) and the literature for mouldy buildings are diverse with some concentrations of $10^4$ cfu/m$^3$ reported (Verhoeff *et al.*, 1992; Hyvarinen *et al.*, 1993). Chew *et al.* (2003) analysed the level of fungi inside homes, and found that characteristics of the habitat could predict higher or lower concentrations in the dust, depending, for example on the existence of carpets. They also compared the fungal levels in indoor and outdoor air and found *Alternaria* to be more frequent fungus in outdoor air, while *Aspergillus* was more prevalent in house.

While evaluating the mould allergy in other indoor environments, Reponen *et al.* (1992) and Gravesen (1979) indicated that a level of 500 cfu/m$^3$ might be considered as unacceptable and 3000 cfu/m$^3$ of *Cladosporium* spp. and 100 cfu/m$^3$ of *Alternaria* spp. may function as a threshold
limit for evoking allergic symptoms. It has been reported that a substantial amount of toxins may be absorbed from the inhaled fungal spores (Flannigan et al., 1991). Since recorded toxic fungi from various microenvironments could have contributed toxins, particularly contribution of *Aspergillus* species, a potent source of the carcinogenic toxin, might be a matter of concern for the workers and the people used to visit places such as hotel, office premise and theatre. The presence of fungi in the atmosphere of hotel is of great concern as the fungal propagules are found to have a great role in food spoilage. They are found to produce off flavours, toxins, discoloration, rotting and are of pathogenic or allergenic nature (Chelkowski, 1991; Bigelis, 1992; Gravesen *et al.*, 1994 and Tipples, 1995). The associated micro flora from different sources, such as citrus fruits, pomaceous and stone fruits, garlic and onion, potato tubers, tomatoes, cereals, nuts, cheese, fats, bread etc., are well defined by Filtenborg *et al.* (2000). Identification and quantification of large number of species in higher concentrations in hotels is of concern in spoiling the food prepared in those units.

The results of the present investigation have clearly demonstrated that the concentration of air borne culturable moulds, especially *Aspergillus* and *Penicillium* is high in the hotels. These are relatively greater risk to work force. The allergenic, toxigenic and pathogenic potentials of these fungi have been well documented in earlier literature (Flannigan *et al.*, 1991). It is necessary to control or minimize the air borne spore levels in hotels. To maintain the hygienic levels in these places: accumulation of moisture in food preparing units should be avoided; indiscriminate throwing of waste in the premises should be avoided; the contaminated food products like vegetables, dough should be destroyed immediately rather than piling them up with in the premises and the floor is to be mopped using antiseptic solution at frequent intervals.

Isolation of large number of species from upholsteries proves that they too serve as a good source for the growth of mould within office premises. It is suspected that moulds from outdoor are found to adhere to the external cover ups of the occupants of buildings and they may get deposited on upholsteries and on carpets which in turn provide favorable niche for their growth. Kemp *et al.* (2002) reported that furnishings and mattresses without moisture damage can provide a habitat with enough moisture to support fungal growth despite, the lack of an obvious moisture sources.

Menetrez and Foarde (2004) explain the role of heating, ventilation and air conditioning (HVAC) system in the spread of toxic mould spores. The moisture prevents in the filters of AHU and near A/C vent favours the growth of mould spores. The organic stub dropped due to eating
and drinking habits of the work force or occupants within buildings provide organic source for their growths in carpets and upholsteries.

An inherent difficulty in conducting airborne microbiotic studies is that there are no recognised health standards such as Permissible Exposure Limits or Threshold Limit Values. At the same time studies have shown that typical air born microbial levels found in office premises tend to be less than 200 cfu/m$^3$ (Mullins et al., 1976; Sugawara and Yoshizawa, 1984; Hansan, 1986). Because of such findings, it is suggested that levels of microorganisms exceeding 500 cfu/m$^3$ are sufficiently high to warrant an environmental survey; the 500 cfu/m$^3$ value should be incremented to the microorganism’s level in the outdoor site. In such situations, an environmental survey should then be conducted to attempt to locate the predominant sources of amplification of viable particulate for preventive maintenance purposes.

The current fungal aerosol concentrations in homes were ranging from 10 to $10^4$ cfu/m$^3$ which is consistent with other results (Solomon, 1976; Kuo and Li, 1994; DeKoster and Thorne, 1995; Pastuszka et al., 2000). However, the total fungal counts were not as high as the maximum seasonal levels reported in other literature, for example, Solomon (1976) reported maximum of almost 17, 000 cfu/m$^3$ in Upper Silesia, Poland. The current fungal concentrations found in most indoor microenvironments fell within the specified guidelines, between 10 and 1000 cfu/m$^3$, suggested by the American Conference of Government Industrial Hygienists (ACGIH, 1989). However, if the indoor bioaerosol concentration exceeds the guideline then it is recommended that remedial action should be taken to identify the source of emission and methods to reduce the counts. Consequently, the current findings suggest the need for remedial action for indoor microorganisms at the surveyed microenvironment such as home.

Usually fungi produce large amount of spores, which easily become airborne and are able to colonize indoor environments which can utilize nutritional sources and moisture available in indoor materials (Burge, 1992). Indoor spaces with low humidity and characteristic air movements as a result of heating and natural ventilation do not provide favourable conditions for the survival of fungi (Reiss, 1991). In case of sufficient humidity, however fungi may grow on almost all organic substances. Conditions of above 70% relative humidity may be optimal for fungal growth (Burge, 1985).
5.3. Meteorological studies

For the past 200 years, the field of aerobiology has explored the abundance, diversity, survival and transport of microorganisms in the atmosphere. Microorganisms have been explored as passive and severely stressed riders of atmospheric transport systems. Recently, an interest in the active roles of these microbes has emerged along with proposals that the atmosphere is a global biome for microbial metabolic activity and perhaps even multiplication. As part a series of papers on the sources, distribution and roles in atmospheric processes of biological particles in the atmosphere, here it is need to be described the pertinence of questions relating to the potential roles that air borne microorganisms might play in meteorological phenomena. For the upcoming era of research on the role of air borne microorganisms in meteorological phenomena, one important change is to go beyond descriptions of abundance of microorganisms in the atmosphere towards an understanding of their dynamics in terms of both biological and physico - chemical properties and the relevant transport processes at different scales. Another challenge is to develop this understanding under contexts pertinent to their potential role in processes related to atmospheric chemistry, the formation of clouds, precipitation and radiative forcing.

In the present investigation, all the microbial concentrations measured in both the outdoor and indoor air depended strongly on the season. Summer was generally found to have higher indoor microbial concentration than winter. This seasonal trend for the bacteria and fungi was consistent with previous indoor measurements (Pastuszka et al., 2000), except there was no seasonal difference in the bacterial concentrations in the previous indoor measurements. The temperature and relative humidity measured along with the microbial measurements in the current study revealed that the summer values for both the outdoor and indoor air were relatively higher (Table 2&14), meantime during the month of January (winter) both bacterial and fungal counts of both the environments were also found to be higher. Typically a higher environmental temperature and relative humidity favour microbial growth (Ren et al., 2001). Accordingly, it is suggested that the temperature and relative humidity were important factors causing the seasonal difference in the microbial concentrations.

Supporting to the statement, a higher total bacterial count (cfu/m³) was observed during the month of January (winter) and a lower count was noticed during the month of October, 2007 and December, 2008 from outdoor microenvironments (Table 2). In contrast to this, indoor total bacterial counts were found to be higher during April, 2007 and March, 2008 and a lower count
was observed in July, 2007 and December, 2008 (Table 10). *Staphylococci, Micrococci* and *Bacilli* were the dominant groups. *Staphylococci* were found to be present throughout the study period. This may be due to the favorable mean monthly temperature 30.4° C (2007) and 29.7° C (2008) during the month of January (Table 17) which supports the growth of bacteria. In addition to this, relative humidity 77% (2007) and 80% (2008) is an important factor to increase the bacterial load. The mean monthly wind speed also showed little influence in bacterial concentrations.

The occurrence of *Aspergillus* was a major factor in the seasonal variation in the number of fungal propagules in outdoor and indoor air. In the current study, *Aspergillus* was observed throughout the year with mean monthly concentration 18.3 ± 8.4 (2007) and 17.5 ± 5.1 (2008) reckoned in the month of June (summer) and February (spring) respectively in current study (Table .19a). The distribution of *Aspergillus* was also higher during winter (December and January) which was supported by Fernandez et al. (1998) in Leon, noted that the spores of *Aspergillus* were prevalent in Winter. This was also followed by *Penicillium*, the second predominant fungus.

Rainfall and relative humidity almost always have profound effects on the level of fungi. It has been stated that *Alternaria* level may decrease in winter as opposed to *Penicillium* and *Aspergillus* levels which may be high in spring and fall, despite the fact that they may be found in the atmosphere all year round (Al – suwaine et al., 1999). The present study revealed that the total number of fungal colonies increase in winter which is consistent with the results of other studies. (Al – suwaine et al., 1999). Although some differences were observed between the two years with respect of the cfu/m³ and average monthly concentrations, but no statistically significant difference was observed when the total over all yearly concentrations were considered. The possible reason might be the insignificant changes of environmental factors during the two sampling years.

5.4. Prevalence of *Aspergillus* in various microenvironments:

Moulds produce acute health effects through allergy or infection. Hypersensitivity pneumonitis, a particular form of granulomatous lung disease, is a syndrome caused by inhalation of large concentrations of dust containing organic material including fungal spores. It is generally an occupational hazard in agriculture, but has been reported in individuals exposed in home (Flannigan et al., 1991). Other symptoms include head ache, dizziness, dermatitis
diarrhoea and impaired or altered immune function. Indoor fungal allergens probably affect a significant proportion (10 – 32%) of all asthmatics are sensitive to fungi.

Opportunistic fungal pathogens such as *Aspergillus* are common in indoor air. A normal, healthy individual can probably resist infection by these organisms regardless of dose, although high exposures may cause hypersensitivity pneumonitis. However, any mould that can grow at body temperature can become a pathogen in an immuno–compromised host. Individuals undergoing chemotherapy, organ or bone marrow transplantation or those with HIV/AIDS are especially susceptible to invasive infection by species of *Aspergillus* (Sandra et al., 2003).

The present results showed a significant increase in fungi isolated from the indoor air. The identified genera suggest a mix contamination and the dominant colonies isolated from the air (Home) were *Aspergillus*, *Penicillium*, *Cladosporium*, *Alternaria*, *Rhizopus* and *Mucor*. *Aspergillus* and *Penicillium* were isolated more frequently than other fungi. *Aspergillus* was the most common fungus in indoor and outdoor probably due to their thermo tolerant ability. The most common air borne fungi encountered indoor nearly paralleled to those found outdoors. Concerning percentages of *Aspergillus* isolated from various microenvironments, the vegetable market recorded the highest percentage (41.6) among the outdoor microenvironments whereas, a very high percentage distribution (48.6%) of *Aspergillus* in home and a less distribution (25.1%) in office premise were observed in indoor microenvironments. The total count of *Aspergillus* from indoor environments showed 36.8% where as outdoor seems to be 33% (Table 18) in two year study period.

Exposure to some fungi can induce allergic or asthmatic reactions, while other species can cause primary infectious diseases. Affected individuals often experience relief when they leave the building for several days (Bush, 1989). Miller et al. (2000) studied the extent and nature of fungal colonization of building materials in 58 naturally ventilated apartments that had suffered various kinds of water damage in relation to air sampling done before the physical inspections. Approximately 90% of the apartments that had significant amounts of fungi in wall cavities were identified by air sampling.

Ren et al. (1999) characterized the nature and seasonal variation of fungi inside and outside homes in the Greater New Haven. No significant difference in concentration and type of fungi between living room and bed room or by season was observed. *Penicillium* and *Aspergillus* were dominant in indoor air during January (winter) but were equally dominating in almost all seasons from outdoor air. Air sampling in every suspected house is suggested for year
round fungal exposure assessment. The present result also showed the highest monthly mean concentration (cfu/m³) of 18.3±8.4 during the month of June (summer) for the year 2007 and lowest of 5.8 ± 5.0 (cfu/m³) during the month of September (fall) for the same year (Fig. 21). This is supported by many other workers and concluded that due to their thermo tolerant ability, *Aspergillus* is the most common fungus in indoor. The distribution of *Aspergillus* was slightly lower during 2008 than 2007. However, the highest monthly mean concentration of 17.5 ± 5.1 (cfu/m³) was observed during the month of February (spring) and less concentration of 11.5±5.0 (cfu/m³) was noticed during May 2008 (summer) (Table19.a).

Pei – Chih *et al.* (2001) evaluated the air borne fungal concentrations at urban and suburban areas in Taiwan. In summer, the total fungal concentration, both indoors and outdoors of suburban homes, were significantly higher than those of urban homes. Shelton *et al.* (2002) examined 12, 026 fungal air samples from 1717 buildings in United States and found the most common cultivable air borne fungi, both indoors and outdoors and in all season were *Penicillium, Cladosporium, Aspergillus* and non sporulating fungi. This result also supports the present work where the same type of cultivable air borne fungi was obtained. The statistical analysis for the annual concentrations (cfu/m³; Mean ±SD) of *Aspergillus* from various microenvironments of outdoor and indoor was carried out for the year 2007 and 2008 and compared under parametric and non parametric test (Fig.19b). From the atmosphere of home, the annual concentrations of 26.7 ± 7.5 (2007) and 19.8 ± 9.2 (2008) were noticed as the highest and found to be significant (P<0.05) both in t – test and Mann - Whitney test. In general, *Aspergillus* was the only predominant fungus present almost in all the microenvironments. (Table 19b).

More than 80 genera of fungi have been associated with symptoms of respiratory tract allergies (Horner *et al.*, 1995). *Aspergillus, Alternaria, Cladosporium* and *Fusarium* are amongst the most common allergenic genera. Metabolites of fungi are also believed to irritate the respiratory system. Furthermore non biological particles may serve as carriers of fungal allergens molecule into the lung independently of the whole fungal spores. Allergenic molecules could conceivably be carried into the lung at a greater depth than a fungal spore would be expected to penetrate (Lippman *et al.*, 2003). Airborne bacteria and fungi can be the cause of a variety of infectious diseases as well as allergic and toxic effects. Particles smaller than 5 μm, the so called respirable fraction, are able to penetrate into the alveoli and can lead to allergic alveolitis and other serious illnesses (Lacey and Croock, 1988; Chatigny and Macher, 1989; Burge, 1990; Owen *et al.*, 1992; Seltzer, 1995)
Inhalation of mould spores and hyphal fragments commonly leads to allergy, especially to asthma (Gravesen, 1979; Braback and Kalvesten, 1991; Ninan and Russel, 1992; Dutkiewicz, 1997). Among the respiratory symptoms reported has been nasal congestion or runny nose, shortness of breath and wheezing (Goldfarb, 1968; Platt et al., 1989; Strachan and Sanders, 1989). Also a study carried out in Sosnowice, located in Upper Silesia, Poland showed that asthmatic children very often live in dwellings belonging to a group of homes with an elevated level of airborne respirable particles and fungi (Pastuszka et al., 1998). Therefore, in mouldy homes the risk of asthma for its residents, associated with an exposure to the total mould or to some specific genera, probably increases with the inhalation of fungal particles as well as their products (voltaic organic compounds, toxins, glucans). However, the lacks of relation between the occurrence of the respiratory symptoms, including asthma and the measured concentrations of bioaerosols have been found by others. Dotterud et al. (1996) observed that prior to asthmatic attacks the child could always notice a smell of mould but when sampling the air only a few spores were found. Some fungi, for example Mucor are more often found in floor dust and carpets than in air samples (Gravesen et al., 1994; Koshinen et al., 1995 and Gravesen, 1978, 1979) studied respiratory symptoms and infections among children in a day care centre with mould problems. Mouldy growth on the walls also adds to the number of allergenic spores in the air within the building. It has been stated that an average concentration below 500 allergenic spores/m$^3$ air causes only minor symptoms in persons known to react very strongly to allergenic species while concentrations above 500 or 600spores/m$^3$ induce symptoms of disease in all person who suffer from allergy (Rapiejko, 1997).

5.4.1. Immunological studies

Mainly, but not exclusively, exposure to pollutants from biological origin (Edwards, 1980; Patterson et al., 1981) promote illnesses and irritant, toxic and allergenic symptoms (Flannigan et al., 1990; Sorenson, 1990; Strachan et al., 1990; Su et al., 1992). The majority of the health effects linked to dampness and moisture of buildings are those of the respiratory system. Excess humidity promotes the growth of microorganisms such as moulds and bacteria that lead to release of pollutants into indoor air. Allergy is one of the health problems in the world and serum IgE level is a means of diagnosis of allergy (Host and Halken, 2005; Dennis, 2003). Chan and Mckenzie (2003) reported that total IgE levels in healthy subjects are higher than the previous references argued that the pollution may be the cause of this elevation. It was observed that IgE levels in Indian population were relatively higher than the western values (Chowdary et al., 2003). According to Wittig et al. (1980) healthy, non allergic adults have an
expected IgE concentration up to 120 IU/ml. The higher IgE levels in normal controls in India are explained probably by the higher incidence of parasitic infestations.

Atopy is a tendency to produce excessive amounts of IgE antibodies when exposed to allergens (Burrows et al., 1989). IgE is produced by B lymphocytes moreover a trace protein and normally accounts for less than 0.001% of total serum immunoglobulin. The concentration of IgE in serum is age dependent and normally remains at levels less than 10 IU/ml in most infants during the first year of life. There is a wide distribution of expected serum IgE values in healthy individuals of same age group (Kjellman et al., 1976). An atopic individual responds to antigenic stimuli to which normal people will not respond. B lymphocytes and plasma cells in airways, gastro intestinal tract and regional lymph nodes produce IgE. The initial formation of IgE antibody depends upon the signals from lymphocytes and IL – 4 and IL – 13. The molecular mechanism underlying (responds and the subsequent production of IgE antibody) immune system activation for allergen induced asthma includes stimulation of CD4+ Th2 immune response and the subsequent production of IgE antibody. Re - exposure to allergen results in the recruitment of mast cells (via high affinity IgE Fc receptors), eosinophils and other leukocytes. In particular, mast cells that release the vaso active amines, histamine and other ligands from large granules produce a local systemic hypersensitivity reaction (Janeway et al., 2001). The ensuring inflammation amplifies an individual’s hypersensitivity reaction by the recruitment of other cells and perpetuates the clinical symptoms (wheezing, shortness of breath, and chest congestion) (King, 1999). In atopic individuals, the IgE receptors send unusually strong signals when cross linked, resulting in secretion of abnormally high levels of IL – 4 from mast cells, which further results in over production of IgE antibodies.

According to Halonen et al. (1982), a significant relationship exist between serum IgE levels and eosinophilia in individuals where IgE levels presumably provide a better clue to allergy than do skin test. Yamada et al. (1998) were of the opinion that detection of specific IgE is a prerequisite for both, the definitive diagnosis and the therapeutic strategy of allergic disorders. Di Lorenzo et al. (1997) reported that there is an interrelationship of the allergen type, total serum IgE, eosinophil and bronchial hyper responsiveness suggesting that all three may play role in development of allergic disorders. Fahy (2000) stated that IgE secretion by lymphocytes defines the allergic state and nearly all asthmatics have a higher IgE levels in serum than normal’s, following adjustment with age and sex. Depending on their age children may be more vulnerable than adults to air pollutants. The general presumption that fungi induced allergy is associated with peripheral eosinophil which did not correlate with our findings. In fact, about
106 out of 115 subjects showed peripheral blood eosinophil counts within the normal range. Though, differential eosinophil count was used for evidence of allergy, in our study, it did not give satisfactory information about allergy state because it was negative in more than 90% of the subjects studied.

Interpretation of IgE antibodies as biomarkers of exposure is problematic, because such antibodies last in the blood for months, thus it is not known to what extent IgE levels reflect the magnitude of exposure. The use of raw OD values only allows comparisons to be made within a single assay and does not address the problem of sera assayed at different dilutions. Misra et al. (1983) used a system of a cut off OD values related to negative controls and dilution factor to define positivity. Increased IgE concentration in allergic aspergillosis has been reported by Heiner and Rose (1970) as being in excess of 800 ng/ml and by Patterson et al. (1973).

The analysis of results can vary considerably depending on whether the whole taxa (genera) are considered or the analysis carried out according to species (Horner et al., 2004). Specific antigens, that are usually the most important allergens, are not always shared by the species of the same genera. Hence, in environmental mycological studies, it is advisable to identify the species in order to obtain valid data that correlate with levels of sensitization and clinical manifestations. The potential role of specific IgE antibody against Aspergillus has still to be investigated. This points out the interest of quantitative measurements of IgE antibody. Various studies show that IgE antibody is directed against the antigenic fraction of the fungus that supports cross reactivity with other Aspergillus species, a fact which may explain the common features of immediate type hypersensitivity associated with infection by the various Aspergillus species (Dessaint et al., 1975). There are no international standardized species – specific control sera available. Recent studies showed that the level of IgE in normal individuals was significantly higher than that was reported previously (Chan and McKenzie, 2003). There are some possible factors, such as parasitic diseases, smoking, alcohol drinks and malnutrition that may increase total IgE serum level (Finkelman and Urban, 2001; Forte et al., 2003). Therefore, defining a reference range in normal subjects for IgE level is very difficult (Klink et al., 1990). In the present study normal values of total IgE in males were relatively higher than females, similar to the study reported by Berciano et al. (1982). The total IgE levels were elevated in 18.3% (21 of 115) subjects with allergic disorders. The value was about 1000 IU/ml at the maximum (Table.24), when this was associated with fungal elements (Aspergillus induced allergy), the IgE values ranged from 500 IU/ml to more than 2000 IU/ml (Fahy, 2000) (Fig.25). The total IgE levels obtained here as reference ranges in individuals from a microenvironment of
home might be useful for the diagnosis of allergic disease. However, due to the variation of allergens in cities and air pollutions, it is recommended to monitor local normal range of serum total IgE every ten years. Based on the present study, it is recommended therefore that total serum IgE levels and peripheral eosinophil counts to be done in all subjects along with other investigations like specific serum IgE level in Indian population.

More females than males develop asthma during puberty, so prevalence of adult asthma becomes higher in females than males (Bapna et al., 1998). More than 50% of the subjects in this study had any one of the allergic symptoms before the age of 40 years. This is in accordance with other studies, which have been shown that, in the majority of subjects, with extrinsic allergy, the symptoms develop before the age of 30 years (Duane et al., 1995).

When comparing the severity of allergy with serum IgE levels in subjects from a home environment, the present data indicated that the more severity of allergic disorder, the greater is the elevation in serum IgE. The most important risk factor for the development of extrinsic allergy is atopy (Lebowitz et al., 1984; Peat et al., 1996). The basic pathology is hyper responsiveness. The airway response is an excessive response of the airway epithelium to antigenic stimuli. This response is mediated by T – Lymphocytes. Antigenic exposure to T – lymphocytes leads to their differentiation in to active T – cells, which secrete a series of biologically active proteins called cytokines. The secretion of IgE by lymphocytes defines the allergic state of an individual. The cellular events associated with IgE dependent processes are very much important in asthma (Villar et al., 1985). Higher IgE levels indicate some types of inheritant susceptibility and/or presence of a disease process involving airway inflammation (Sherril et al., 1995; Chowdary et al., 2003; Anupama et al., 2005).

The clinical syndrome produced by an allergic reaction depends critically on three variables; the amount of allergen specific, the root by which the allergen is introduced and the dose of allergen.

Anaphylaxis is an acute, systemic, hypersensitivity response to allergen which typically involves multiple organ system and which if untreated can lead rapidly to death. Allergic rhinitis results if allergen is introduced through airway through inhalation symptoms which includes sneezing, nasal congestion and itching, rhinorrhea, probably primarily reflect IgE dependent release of mediators by effector cells in response to aeroallergens (Richard deshazo., 2000).
Asthma affects millions of people worldwide and allergic asthma is triggered by allergen induced activation of sub mucosal mast cell in the lower airways. Allergic disorder that are associated with IgE not only causes significant morbidity and lost productivity, but also are increasing in incidence and in human and economic impact in many parts of the developed world. In recent years, the increasing incidence of allergy is well recognized not only in the developed but also in developing countries across the globe. Allergy can develop at any age and heredity plays a key role in who will develop it. The likelihood that a given individual will develop an allergic disease reflects a combination of genetic and environmental factors.

5.5. Air sanitation

No other area in occupational and environmental health has experienced such rapid changes in the recent past as has indoor air quality. Due to an emphasis on energy conversation buildings are more dependent on mechanical ventilations systems for the delivery of fresh air. At the same time, the use of building furnishings maid from synthetic chemicals has increased, as has the recognition of microbiological organisms as potential exposure hazards. The sum result of these factors has been a steady increase in the frequency of indoor air quality complaints. No standard method has been adopted for evaluating air sanitizers.

Air fresheners are rarely necessary because they cannot substitute for good ventilation; the best solution is to open windows to bring in fresh air or to use fans to maintain air circulation. Air fresheners also are not a solution to poor quality, they mask bad odours but they do not eliminate the chemicals that cause them.

Of all the products in home, clean smelling air fresheners seen to pose little risk. But the fresh scent of air fresheners may mask a health threat – chemicals called phthalates that can cause hormonal abnormalities, birth defects and reproductive problems. To protect consumers, government regulators should follow up by doing more thorough tests on these products and enacting basic measures to limit exposure to these chemicals. Meanwhile, consumers may wish to avoid using air fresheners especially in places where there are children or pregnant women. Hence, the Consumer Product Safety Commission should ban hazardous phthalates in consumer products and should require that manufacturer provide ingredient information on the label. In particular, the European study detected cancer causing chemicals such as benzene and formaldehyde in some air fresheners. Benzene is known to cause leukaemia in humans and formaldehyde has been linked to cancers of the upper airways. People with allergies to these
chemicals could have adverse reactions, including rashes or even asthma attacks from exposures to air freshener products (SCHER, 2006).

There is considerable evidence that glycol vapour produce significant decreases in numbers of viable airborne bacteria to maintain suitable concentrations in the air of enclosed spaces. Several investigators have shown that glycols (triethylene, dipropylene or propylene glycol) at concentrations of 5% or more in such formulations will temporarily reduce numbers of airborne bacteria when adequate amounts are dispensed under relatively ideal conditions.

In order to reduce bioaerosol loads in indoor environments, certain control measures can be followed. These include proper identification and elimination of the microbial source in occupational and household settings, maintenance of equipments, humidity control, natural ventilation, use of filters in ventilation and air cleaning by the use of disinfectants, air sanitizers and biocides. Periodical use of disinfectants and biocides is one of the methods to ensure controlled bioaerosol concentrations.