ABSTRACT

Bioaerosols are particulate matter of biological origin which include, living organisms such as bacteria, virus, fungi, their metabolites, toxins and fragments. Bioaerosols contribute to about 5-34% of indoor air pollution and their role in healthcare settings has always been a topic of interest for researchers. Hospital environment contains a diverse range of bioaerosol population. The importance of estimation of quantity and type of these bioaerosols has been emphasized due to their effect on human health. They have been implicated in conditions ranging from allergies to disseminated infections in susceptible patients. The paper serves as a review of the current literature on different bioaerosols (bacteria and fungi) present in the hospital environment, their sources, impact of their presence and also suggests control measures.

Keywords: Bioaerosols, Hospital, Indoor Air Pollution, Allergies

INTRODUCTION

Air pollution is the addition of any harmful substance to the atmosphere. Due to industrialization and urbanization air pollution is becoming a major threat to human health and environment. Pollutants can be classified as particulate and gaseous matter. Particulate matter of biological origin is bioaerosol which include living organisms such as bacteria, virus, fungi and their metabolites, toxins or fragments. Bioaerosols vary in size (20 nm to 100 μm) and composition depending on the source, aerolization mechanism and environmental conditions prevailing at the site (Pillai and Ricke, 2002). Several sources found to be responsible for emission of these bioaerosols in air. These sources include natural such as soil, water, plants, and animals and human as well as anthropogenic like agricultural practices, healthcare units and industrial operations (Cullinan et al., 2001). Airborne particles are readily transferred from one environment to the other as they are light weight. Air does not serve as a natural environment for them, it act as a transport environment in which microorganisms can be transported over considerable distance. The sampling and analysis of airborne microorganisms in indoor air has received attention in recent years (Kim and Kim, 2007; Huttunen et al., 2008; Stanley et al., 2008). Bioaerosol contribute to about 5-34% of indoor air pollution (http://www.pollutionissues.com/Ho-Li/Indoor-
http://www.airqualitydirect.com/bio-aerosols/). These microorganisms may be harmful when present in higher concentration in indoor environment. The common health effects of bioaerosols are infectious diseases, acute toxic effects, allergies and cancer (Douwes et al., 2003).

Airborne Microbial Load in Hospitals

Hospital indoor air contains a diverse range of microorganisms. Airborne microbes were detected in hospitals by various workers. Jaffal et al., (1997) isolated Staphylococcus aureus, Staphylococci (CNS), Micrococcus spp., alpha hemolytic Streptococci, Diphtheroid bacilli, Gram negative bacilli, Bacillus spp., Streptomyces spp., from different wards of a hospital. Seven bacterial species were isolated from five different wards in the Faith Medical Center and Central Hospital in Benin City by Ekhaise et al., (2008). Staphylococci and Micrococcus spp. were the predominant Gram positive bacteria isolated from different healthcare settings (Sudharsanam et al., 2008; Quodiesat et al., 2009; Youn et al., 2010; Gaur, 2013). High concentration of Gram positive cocci in the air may attribute to their lower susceptibility to environmental stress (Borriello et al., 2005). Presence of Gram negative bacteria in the indoor air, also taken into consideration because they release endotoxins which cause adverse health effects. Enterobacter spp. and Pseudomonas spp. were the predominant potentially pathogenic Gram negative bacteria isolated from hospitals (Sudharsanam et al., 2012; Gaur, 2013). These organisms are often found to grow on moist surfaces. Their presence may be attributed to the presence of wash-room in the vicinity of the sampling...
area, which may provide moisture required for survival and growth (Rughooputh, 2001). Presence of *Escherichia coli* in the environment reflects the degree of purity of water used for various purposes like floor cleaning and other activities in hospital (Prescott et al., 2005). The common genera of fungi frequently isolated from hospital air by Williams and coworkers (1956) include *A. niger*, *Chaetomium* and *Alternaria*. Lukaszzek et al., (2007) isolated 9 fungal species from selected rooms of the department of dermatology, venerology and allergology of medical university in Wroclaw. In another study, 6 fungal genera *Aspergillus*, *Rhizopus*, *Mucor*, *Penicillium*, *Verticillium* and *Candida* were isolated from two hospitals (Bhatia and Vishwakarma, 2010). *Aspergillus niger* was isolated throughout the year by Sudharsanam et al., (2012) from a hospital ward in a tropical setting.

**Sources and Factors Influencing Bioaerosols**

The source and spread of microorganisms inside the hospital are important issues. The most potential source of airborne microbes inside the hospital is the infected patients (Hambraeus, 1988). Airborne transmission occurs when pathogenic microorganisms are transferred from an infected to a susceptible individual via the air (Atlas, 1995). Another source of microorganisms in the hospital are occupants of the building i.e. hospital personal and visitors. Amount of materials brought from outside such as personal belongings, food and fruits are recognized as source of contamination. Bacteria in indoor air are mainly Gram positive cocci which arise from occupants (Nevalainen, 1989). Generally they are not dangerous for human health but high viable counts are used as markers of crowded conditions and poor ventilation. A positive correlation between bacterial counts and occupant density in different hospitals was suggested by Warner and Glassco (1963), Al-shahwani (2005) and Kaur and Hans (2007). Dressings and bedding also can be the sources of airborne microorganisms. Sweeping of floors and changing of bed linens also can cause suspension of bio-aerosols in air (Ayliffe et al., 1999). Various studies suggest that the distribution of microorganisms in the air, varies among geographic areas and is also influenced by seasonal environmental and climatic factors such as temperature, humidity, time and wind speed. Significant monthly variation and daily fluctuation (time of sampling) in concentrations of airborne bacteria and fungi in a hospital ward was shown by Augustowska and Dutkiewicz (2006). Kind of hospital along with the type of room and the time of sampling is a significant factor that influences the rate of indoor air microorganisms (Qudiesat et al., 2009). Among all possible sources, outdoor air is thought to be the most important source of indoor microflora. Many studies have reported the role of outdoor microbial concentration through opened windows and doors in raising the microbial rates and homogenization of indoor air of building (Jaffal et al., 1997; Rainer et al., 2001).

**Health Risks**

Airborne microflora of hospital environment has been a subject of numerous studies as it is a potential cause of hospital infection (Li and Hou, 2003; Lukaszuk et al., 2007). Exposure to air borne bacteria and fungi causes potential biological hazard and have been associated with adverse health effects. Many species of bacteria as *Streptococcus pyogenes*, *Mycobacterium tuberculosis*, *Legionella pneumophila* and viruses may cause severe human infections. *Staphylococcus aureus* is a known opportunistic pathogen, which causes infection at sites of lowered host resistance, such as damaged skin and mucous membranes (Arbuthnott, 1992). There are numerous reported cases of emerging nosocomial infections caused by methicillin resistant *S. aureus* (MRSA), vancomycin-resistant *S. aureus* (VRSA) and other multi-drug (MDR) resistant strains (Courvalin and Weber, 2005; Kuehnert et al., 2005; Moran et al., 2005). Prevalence of *S. aureus* and *Ps.aeruginosa* in almost all sampling sites, irrespective of season indicating their long term survival and consequent threat to hospitalized patients as well the working employees (Nandalal and Somashekar, 2007 and Yagoub and Agbash, 2010). Gram negative bacteria found in the air of the hospital ward could be a source of adverse endotoxin (Dutkiewicz, 1997; Lacey and Dutkiewicz, 1994) and *Acinetobacter* strains may be a potential cause of hospital infections transmitted by air (Allen and Green, 1987). *Pseudomonas spp.* is difficult to eradicate from hospital as it is resistant to many of the disinfectant and antiseptics commonly used in hospitals (Whitby and Rampling, 1972). Fungal infections of hospital origin have also been gaining importance in recent years due to their progressive increase and high rates of morbidity and mortality (Centeno and Machado, 2004). Many
genera of fungi can cause allergic responses but particularly species of *Cladosporium*, *Alternaria*, *Penicillium*, and *Aspergillus*. The major allergic diseases induced by fungi are asthma, rhinitis, allergic bronchopulmonary mycoses and hypersensitivity pneumonia (D’Amanto *et al.*, 2000; Sarica *et al.*, 2002). Jaffal *et al.* (1997) isolated *Aspergillus niger* and *A. flavus* from the hospital settings which are involved in incidence of aspergillosis, ear and skin infection. *Aspergillus fumigatus* is recovered commonly from the hospital environment, posing a particular risk of invasive aspergillosis in immunocompromised patients (Hospenthal *et al.*, 1998; Morris *et al.*, 2000; Pini *et al.*, 2004). Hospitalized patients with immune suppression are susceptible to infections from naturally occurring airborne fungi.

Pulmonary Aspergillosis is caused by inhalation of airborne dust particles that carry the spores of *Aspergillus* sp. Mortality rates due to this disease have been reported as high as 95% in bone marrow transplant patient, 13-80% in leukemia patients and 8-30% in kidney transplant patients (Martone, 1992).

Some other fungi isolated from the air of the hospital such as *Fusarium* spp., *Rhizopus* spp. also pose a respiratory risk as potential sources of allergens and toxins (Dutkiewicz, 1997). In addition to molds, yeasts have also been found, as potential human pathogens, especially the *Candida* genus, which is the main causative agent of hospital fungemia (Moretti, 2007). High abundance of potentially allergenic and toxic actinomycetes and moulds is highly disadvantageous to the patients especially those who have respiratory tract diseases (Fraczek and Gorny, 2011).

**Maximum Acceptable Levels**

There is no uniform internationally accepted threshold limit value for airborne bacteria and fungi. Published values vary from country to country according to their sampling methods and climatic conditions. For the hospital environment 100 CFU/m$^3$ is the maximum limit for bacteria and 50 CFU/m$^3$ for fungi (WHO, 1988). Type of microbes should also be taken into consideration as microbial quality of indoor air is created not only by a total concentration of bacteria and fungi but by the presence of some particular species, which is very important for the health of people occupying the room.

**Control Measures**

Control of airborne pathogens in hospitals is important for the safety of both the patient and hospital personnel.

Although it is not possible to eliminate all nosocomial infections, their incidence can be significantly reduced by implementation of appropriate infection control policies (Abussaud, 1991). These are certain control measures which can be used to reduce microbial load in healthcare settings.

- In Hospital, appropriate ventilation is necessary. Circulation of fresh filtered air dilutes and removes airborne microbial contamination, in addition to removing odor.
- Ventilation systems in all hospital areas and in particular the high-risk areas, should be designed and maintained to minimize microbial contamination.
- The air conditioning filters should be cleaned periodically and fans that can spread airborne pathogens should be avoided in high-risk areas.
- Some carbon absorbers have pore sizes too small to remove viruses and are effective at removing VOCs produced by some fungi and bacteria.
- Some housekeeping activities (such as sweeping, using dry mops or cloths or shaking linen) can aerosolize dust particles that may contain micro-organisms. Therefore, wet mopping should be preferred.
- There should be restricted entry for peoples especially in high risk area.
- Patients with infectious disease should be hospitalized in quarantine.
- Temperature and humidity should be maintained between 20-22° C and 30-60%, respectively to inhibit microbial multiplication.
- Fumigation by formaldehyde at weekly intervals in hospital rooms may reduce load of airborne microbes.
- Bacillocid (Ghosh *et al.*, 2004) a commercially available surface and environmental disinfectant that has good cleaning properties along with bactericidal, viricidal, sporicidal and fungicidal activity, should be sprayed or use in mopping in hospitals.
Research Article

CONCLUSION

Hospitals are complex facilities designed to fight infections. In recent past, there had been a tremendous increase in resistant infection specially hospital infection and also increasing awareness to control and improve outcome of good results. In this context bio-aerosol monitoring in hospitals can serve as a useful tool to control hospital associated infections (HAI). This will also increase awareness regarding the air quality of hospital environment and its impact on human health.

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