



BIOAEROSOLS LOAD IN INDOOR AND OUTDOOR ENVIRONMENT: A BRIEF REVIEW.

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ABSTRACT

Rapid industrialization and urbanization though have resulted in booming the economy of the country but it has also contributed in enhancing the problems of patients suffering from respiratory disorders as the quality of air deteriorated due to addition of large number of pollutants in air. Most people spend over 90% of their lives indoors: in house, offices, and schools, where they are exposed to some indoor environmental factors (bioaerosol) that influences their health and physical condition. Although bioaerosols are present throughout the year. The major source of information has been the papers published in related journals in India and abroad. This literature study has been contributed to the knowledge of the levels of microorganisms and their identification constituents in various indoor and outdoor environments.

The bacteria prevalent in indoor environment *Micrococcus* sp., *Staphylococcus*, *streptococcus* sp., *Pseudomonas* sp. & *Bacillus* sp. *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Micrococcus luteus* & *Pseudomonas aeruginosa* were recorded. In outdoor environment mostly *Micrococcus* sp., *Staphylococcus* sp., *streptococcus* sp., *Pseudomonas* sp. & *Bacillus* sp. *Acinetobacter*, *Enterococcus faecalis*, *E coli* bacteria recorded. The proportion of pathogenic microorganisms is higher in indoor air than outdoor air. The concentration of gram-negative bacteria was more in indoors than outdoor.

KEYWORDS : Indoor and outdoor Air Pollution, Bioaerosols.

INTRODUCTION

Air lets our living planet breath it's the combination of 78% nitrogen and 21% oxygen gas with a few other gases such as carbon dioxide & argon present in minute quantities. Air giving life to the living thing that make Earth such a vibrant place. (Chris Woodford Oct. 9/2015). Physical, biological or chemical alteration to the air in the atmosphere can be termed as pollution. It occurs when any harmful gases, smoke, dust & smog enters into the atmosphere & make it difficult for humans, animals & plants to survive as the air becomes dirty. Atmospheric pollution is one of the most serious problems of our age. This pollution has now reached an advance level that possesses threat to the health of the people⁽¹⁰⁾. The earth's atmosphere is abounds with airborne microorganisms, these organisms are thought to express correlations between air pollution & weather. Most airborne bacteria originate from natural sources such as the soil, lakes, animals, oceans & humans' activity⁽⁴⁷⁾. The air pollution caused by the uncontrolled municipal waste incineration, industrial emissions, vehicular traffic etc. & induced degradation of quality instability and degradation of quality of environmental factors.

Rapid urbanization and industrialization though have resulted in growing the economy of the country but it has also contributed in enhancing the problems of patients suffering from respiratory diseases as the quality of air decaying due to addition of lot of pollutants in air. Most people spend mostly 90% of their time in indoors such as house, schools and offices, where they are exposed to some environmental indoor bioaerosol, that affect their physical condition and health. So, there has been developed interest in indoor & outdoor bioaerosol studies in recent years⁽¹⁾. Studies on aeromicrobial pollution in outdoor air indicate the presence of smoke, dust, dirt, spores, pollen & other pollutant. Microorganisms such as bacterial and fungal spores are almost present in the air throughout year. The indoor environment quality, is not easily defined or controlled, and can possibly place human occupants at health risk⁽¹²⁾. Physical, chemical and biological characteristics of indoor air can influence human health and progress. Motions of bioaerosols in the air depend on, electromagnetism, gravity and the turbulence of air. Bioaerosol is a suspension of airborne particles that include generally live and dead bacteria or may be liberated from living organisms^(17, 19). These microorganisms may be harmful when present in higher concentration in indoor & outdoor environment. Air borne bacteria and fungi are the most common organisms in environment. They were proposed be caused an adverse health effects on humans, animals & plants.

Bioaerosols can be liberated through dirt, dust and water droplets in the nature. Contact with bioaerosols in different environments is associated with a risk of allergies, respiratory infections and acute

toxic effects⁽³⁴⁾. Dust particles are macromolecular organic compound, total volatile organic compounds and Gram-negative bacteria may cause nasal problem, optical and physiological changes and symptoms illustrate by sluggishness, irritation, headache and sleepiness, and reduced concentration ability⁽⁴³⁾. Public spaces in a metropolis are fragile environments for public health risk and characteristics of microbial air in public space are a serious matter. Biological contamination of indoor and outdoor air is mostly induced by moulds, bacteria and yeast. They can be serious as pathogenic living cells and can also secrete some toxic metabolism substances like mycotoxins, its harmful for health⁽¹⁵⁾. Airborne bacteria can also change climate, visibility and the quality of life^(2, 16, 37). The most common health effects of bioaerosols such as allergies, infectious diseases, cancer and acute toxic effects are found in human⁽⁶⁾.

Most bioaerosols are non-pathogenic and only cause illness or infection in people with low immune systems. Bacterial bioaerosols, such as *Arthrobacter globiformis*, *Bacillus* sp., *Corynebacterium* sp. *Pantoea agglomerans*, *Pseudomonas chlororaphis*, *Streptomyces albus*, and *Thermoactinomyces Vulgaris* have probable allergenic characteristics and cause of airborne diseases or infectious⁽⁹⁾. Recent epidemiological studies as explained that very low concentrations of some particular microorganisms in the air can cause serious diseases and sometimes even higher concentration of microorganisms can be allergenic⁽¹⁸⁾.

MATERIAL AND METHODS

An attempt has been made in this review to analysed important aerobiological surveys with reference to bacteria and fungi carried out in different parts of India and abroad. The publications pertaining to qualitative and quantitative prevalence of air borne bacteria in indoor and outdoor environment have been analysed. The papers appearing in related journals in India and in other international publications have been reviewed. There is no denying the fact that bulk of the papers reviewed appeared in Indian journal of Aerobiology an official publication of Indian Aerobiological Society.

Survey of Airborne bacterial load in indoor environment

The information on the indoor and outdoor microbial diversity of airborne bacteria is necessary both to estimate the health hazard and to create standards for indoor and outdoor air quality control. Thousands of people spend several hours working in enclosed spaces every day, so the microbiological quality of indoor air can influence their health and physical condition. The main bacterial contamination suspended in the indoor air from human presence.

The soil surface is a significant source of bacteria. Many factors affect

indoor air pollution such as building materials, furnishings, equipment, maintenance activities, the outdoor contamination, the season, indoor humidity, temperature & poor ventilation. It is possible that the presence of rat, cow, dogs, cats and other domestic animals could influence house associated microbial communities. It is observed that depositional environment within kitchen, store room are not regularly cleaned so in those area found higher levels of microbial diversity. When dust was raised the concentration of bacteria is higher present. The outdoor bacterial concentration was higher in the low floor apartment than in high floor apartment. The quantity and types of bacteria and fungi found varied by location and sites. Similar result found in high rise apartment building in a Korean city⁽²⁴⁾. The outdoor bacterial concentration was higher in summer than winter season. The Indoor bacterial concentration was higher than the outdoor concentration. The indoor air of ruler residential houses of Uttarakhnad has also reported bacterial species such as *Brevibacillus brevis*, *Arthrobacter* sp., *Bacillus cereus* & *Brevibacillus brevis*⁽²⁶⁾. Sample campaigns were conducted in several public building in Timisoara (Romania). Mesophilic bacteria was the main determinant of indoor air quality in investigated building, Such as *S. aureus*, *Stenotrophomonas maltophilia*, *Sphingobacterium multivorium*, *B. cereus* or *E. coli* was recorded⁽⁵⁵⁾. It is observed that depositional environment within kitchen, store room are not regularly cleaned so in those area found higher levels of microbial diversity. Poor quality houses generally had a lower hygienic standard, a higher number of residents. The indoor air quality in heavily trafficked buildings is affected by high mesophilic bacteria load. A medium low level of bacteria recorded in indoor air of an Italian office equipped with heating, ventilation & air condition system. *Staphylococcus* & *Micrococcus* bacteria were commonly recorded⁽⁴⁾. A total of 632 bacteria isolated from 31 homes environments in Beijing, China with ranged from 47 CFU/m³ to 12341 CFU/m³. *Micrococcus* (26.74%), *Micrococcus luteus* (14.56%), *Bacillus* (14.56%), *Kocuria* (12.66%), *Staphylococcus* (12.03%) were determined as the most common culturable airborne bacteria found in different season and different regions. The dominant bacterial species were isolated *Micrococcus luteus*, *Micrococcus lylae*, *Staphylococcus cohnii* and *Kocuria roseus* (57).

In this study different types of indoor environment (pri school, kindergarten, restaurant, dwelling, office, sport salon, library, classroom & laboratory) & their outdoor environment were investigated in term of bioaerosol contamination. A total 120 environment were investigated in Ankara, Turkey. The highest total bacteria count level was measured in kindergartens, school, high school, restaurant, office & home. *Micrococcus* sp., *staphylococcus*, *Bacilli* spp. was recorded predominant bacteria. The indoor to outdoor ratio of the observed bacteria count their ratio were higher than 1. Clean environment it's necessary to reduce the microbial concentration⁽⁵³⁾.

Educational facilities are densely populated, so its create the problem of maintaining good quality in indoor environment. The poor indoor air quality causes in many cases illness, infection and acute health symptoms, so decreasing performance in education. Children are more easily to suffer the consequences of indoor pollutants than adults, because they are still developing physically. From one-year study of airborne bacteria at the roof of the Pharmaceutical laboratory building, Andhra University campus, Vishakhapatnam, India, the 3804 airborne viable bacteria carried out. *Flavobacterium indoltheticum* was the most prevalent. The ratio of the pigmented bacteria to non-pigmented was 66 34% respectively. Airborne bacteria show their seasonal variability, December to February displayed peak period⁽⁴⁶⁾. *Staphylococci* & *Micrococci* are predominant Gram-positive bacteria & *Pseudomonas* sp. & *Enterobacter* sp. are predominant pathogenic Gram negative bacteria isolated from air of senior secondary school in Jodhpur, Rajasthan⁽⁴¹⁾. The predominant bacterial genera isolated from the various sampling station of faculty of science building of the University of Port Harcourt, such are *Staphylococcus* sp., *Bacillus* sp. & *Pseudomonas* sp.⁽¹³⁾. Bacterial counts in dry season ranged from 1.8 to 0.03x10³cfu/ml and in wet season ranged from 8.0 to 0.1x10³cfu/ml with the highest in clinical laboratories in campus of Ahmadu Bello University & SarkinPawa Street in Samaru Zaria town. The predominant bacteria are *Bacillus* spp., *Micrococcus* spp., *Staphylococcus* spp., *Proteus* spp., *Streptococcus* spp., *E. coli*⁽⁵²⁾. This study reported that the abundance of airborne bacteria during monsoon & winter season in Jawaharlal Nehru University campus at the

building of school of environmental science. The concentration of bacteria recorded during monsoon & winter season were 2.37x10⁷ & 0.57x10⁷CFU/m³ respectively. Higher Gram-positive bacteria such as cocci then Gram negative bacteria were reported⁽³⁰⁾. According to research the air in the main reading room, main hall, the cafeteria & toilet of Torun University library was contaminated with bacteria. The total amounts of bacteria were present in indoor air ranged from 7-3313 cfu m³ & in outdoor air ranged from 10-310 cfu/m³⁽²⁸⁾. In research of Jimma University room the most isolated bacteria from the indoor environment were *Micrococcus* sp., *Staphylococcus aureus*, *Streptococcus pyogenes*⁽²⁰⁾. A study in various room of University building in Poznan, Poland isolated predominant bacteria from air which are *Staphylococcus* spp., *Micrococcus* spp. & *Serratia* spp.⁽⁶⁰⁾. *Staphylococcus* & hemolytic bacteria were found in the kindergarden classroom & laboratory room and only coli-group bacteria were found in laboratory room, corridor & class room of some educational setting in Warsaw⁽²⁷⁾. Total 57 airborne bacteria were isolated from different site of center for molecular genetics, University of Karachi⁽¹⁴⁾.

A total of 69 bacterial isolate belonging to 4 genera isolated from College of Applied Medical Sciences, Dawadmi. Among them *Staphylococcus aureus*, Coagulase negative *Staphylococcus*, *Bacillus* species and *Micrococcus* species were dominant⁽⁴⁸⁾. Samples collected from 25 public and Special schools (Middle Schools) of Riyadh in, Saudi Arabia. The most common bacteria isolated were, Gram negative bacteria such as *Pseudomonas stutzeri*, *Francisella tularensis* and *Ralstonia mannitolilytica* and Gram positive bacteria were *Staphylococcus aureus* and *Kocuria kristinae*⁽³²⁾.

Hospital indoor air contains various range of microorganism. Nosocomial infections also known as hospital acquired infection these infections acquired from healthcare services (hospitals) during treatment. One of the risk factors for such infection is bacterial contamination of hospital wards indoor air by bacteria⁽²³⁾. Airborne microbes attached to dust particles, condense and enter human body directly via inhalation or indirectly via ingestion of contaminated food and water and skin contact resulting in the development of disease. Mostly airborne diseases are caused by pathogenic microbes which are discharged from an infected person via laughing, sneezing, coughing, and close personal contact to the microbes. The microbiological quality assessment of outdoor and indoor air study is one of the most vital investigations to determine the microbial indoor and outdoor air pollution. The bacteria such as *Escherichia coli*, *Staphylococcus aureus* & *Pseudomonas aeruginosa* recorded from indoor air in a hospital Kalyani, West Bengal, India. The highest bacterial concentration was recorded in evening time than morning time⁽⁴⁴⁾. Under study of two major hospitals (chaitainya hospital & district hospital) in Sagar city, various bacteria such as *Staphylococcus* sp., *Bacillus* sp., *streptococcus* sp. & *Escherichia coli*, was recorded. The highest bacterial population was recorded in afternoon than morning & evening⁽³⁾. *Staphylococcus aureus*, *Escherichia coli*, *Bacillus* sp. & *Proteus mirabilis* isolated from accident & emergency ward of University of Benin teaching hospital Benin City, Nigeria⁽¹¹⁾. Some another study has also reported the bacteria species such as *Klebsiella*, *Pseudomonas* species & Coagulase negative *Staphylococci* were carried out from intensive care unit of district hospital Neonatal⁽⁷⁾. The aerobiological survey was carried out in indoor & out door environment at 76 hospital in Amravati. 457 bacteria have been recorded from indoor & 496 from outdoor hospital environment. These bacteria are *staphylococcus aureus* (29.59%), *Pseudomonas aeruginosa* (19.72), *Micrococcus luteus* (16.05%) & *Staphylococcus epidermidis* (15.84%). The occurrence of *Staphylococcus aureus* (13.22%) & *Micrococcus luteus* (6.71%) was less in indoor than in outdoor⁽⁵⁴⁾. The bacterial population was Coagulase – negative *Staphylococci* (32.49%), *Bacillus* spp. (14.75%), *Micrococcus* spp. (13.68%) & *Staphylococcus aureus* (11.34%) carried out from five different educational six ward of a hospital under University of medical science in Hamedan⁽⁹⁾. *S. aureus* (25.4%), *Klebsiella* spp. (24.8%), *Proteus* spp. (11.8%), coagulase negative *streptococci* (10.5%), *Serratia* spp. (9.2%), *Streptococci* spp. (7.2%), *E. coli* (4.6%), *Citrobacter* (4%) & *Enterobacter* spp. (2.6%) bacteria isolated from different wards of Hawassa University teaching & referral hospital, South Ethiopia⁽²³⁾. The seasonal variation of bacteria in two major hospital of Benin city, Nigeria. Show that the highest bacterial load in UBTH compared to central hospital where the bacterial load was high in dry season. *Staphylococcus aureus*, *S. epidermidis*,

Micrococcus sp. bacteria recorded in both dry and wet seasons⁽¹²⁾.

Evaluating density & diversity of microorganisms in the environment of a hospital can be signal of whether such environments are clean or dirty. The microflora of any habitat varies with environmental condition, host type and relations with them. Thus, the diversity of microflora differs from time to time and place to place. In other research seven bacterial species such as *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Proteus mirabilis* & *Klebsiella aerogenes* were isolated from five different wards in the Faith medical center & Central hospital in Benin city. The highest bacterial concentration was recorded in evening compared to the morning & afternoon⁽¹⁰⁾. The high microbial counts recorded for public hospital than private hospital because of subsidizes rate of the public hospital so as to accommodation of more people. The indoor air environment of hospital at greater risk than the outside environment because enclosed space can confine aerosols & allow them to build up to infectious level. Bacteria count was higher in afternoon because of increased human activities in hospital.

Survey of Airborne bacterial load in outdoor environment

In market areas poor sanitary measures also contribute to buildup and spread of various microorganisms. Markets are characterized as a human activity site and also a highly traffic site responsible for generation of higher quantity of bioaerosols. Most of the microbes in outdoor air come from the soil and air. Dwellers, transporters services, domestic animals were found the major contributors in microbial communities⁽⁴²⁾. The aeromicrobial population in outdoor air indicates the presence of dust, smoke, and other pollutant. In Agbowo community area of Ibadan, Nigeria, study was conducted to measurement of the concentration of bacteria in the air of selected shops and metrological condition such as temp, UV radiation, wind speed & relative humidity. Bacteria species as *Pseudomonas* spp., *Bacillus* spp., *Micrococcus* spp. & *staphylococcus* spp. carried out from shops. Bacteria concentration lower in the morning than afternoon⁽⁶⁰⁾. The study was conducted at five traffic location such as K.R. circle, Metropole circle, Fountain circle, Sub-urban bus stand circle and Vijaya bank circle of Mysore city, carried out predominant bacterial types were *Cocci* and *Bacillus*. Air Borne Microorganisms at different traffic locations of Mysore City had 1573 species in all locations, with some Gram-positive *cocci* and rods and some Gram-negative *cocci* and rods⁽²¹⁾. Public Park as an important place associated with the environmental exposure of children. The higher bacterial concentration recorded at traffic circle than public garden due to more traffic & crowded area. In Gwalior city the gram-positive bacteria found at both sided such as *Bacillus*, *Micrococcus*, *Pseudomonas*, *Staphylococcus* & *Acinetobacter* species. *Staphylococcus epidermidis* & *Micrococcus* spp., 11 genera & 19 species identified in a crowded public place in Tokyo⁽²⁹⁾. 11 genera and 19 species of bacteria identified in a crowded, underground public concourse in Tokyo. Most dominant *Micrococcus* sp., and *Staphylococcus epidermidis* were reported⁽⁴⁹⁾.

In study of seasonal bacterial variation in Sardar market, Jodhpur city, Rajasthan, monthly concentrations of isolated airborne bacteria ranged between 173.33 to 287.5 cfu/m higher in September and lowest in February. Gram negative bacilli which are *Enterobacter aerogenes*, *Escherichia coli*, *Pseudomonas* sp. and *Serratia marcescens* were identified as dominant Gram-positive cocci (36.17%). *Staphylococcus aureus*, *Micrococcus luteus* and *Micrococcus kristinae* & endospore forming Gram positive *bacilli* may be isolated from there. The indoor air quality in heavy trafficked buildings is affected by high loads of mesophilic bacteria.⁽⁴⁰⁾ Outdoor airborne bacteria isolated from different four zones of Al-Mafraq Area, Jordan. The highest bacterial level was identified in Al-Mafraq downtown with 2055 CFU m-3 and low level was identified in the open desert with 23 CFU m-3. The identified bacterial species were *Bacillus aerius*, *Bhargavaeacecembensis*, *Bacillus axarquiensis*, *Bacillus amyloliquefaciens*, *Bacillus cereus*, *Bacillus methylotrophicus*, *Bacillus subtilis*, *Bacillus safensis*, *Bacillus pumilus*, *Bacillus licheniformis*, and *Cellulomonas* sp.⁽²⁵⁾.

In comparative analysis show higher concentration of air borne microbes in post monsoon season than in the monsoon season at the indoor environment in comparison to outdoor environment. Gram positive & Gram-negative bacterial concentration is high in post monsoon period than monsoon period⁽³³⁾. 14 bacterial species are

isolated from indoor & outdoor air of two metro station (Imam Khomeini and Sadeghiyeh stations) in Tehran subway system. The dominant bacterial species are *Staphylococcus epidermidis*, *Micrococcus luteus* & *Bacillus* spp. The bacterial concentration in indoor air was higher than the outdoor air⁽³⁸⁾. In Lal Bagh Botanical garden, Bangalore, Karnataka recorded negative coccus as 13% & positive rod as 6%. Bacterial species such as *Aeromonas* sp., *Enterococcus faecalis*, *Mycobacterium* sp., *Pseudomonas* sp., *E. coli*, *Staphylococcus* sp. and *Micrococcus* mostly recorded⁽³⁹⁾. In indoor environment of Visakhapatnam city, 3422 total numbers of bacteria were found from which Gram positive bacteria (73.8%) and Gram negative bacteria (26.2%). *Bacillus* spp., *Klebsiella* spp., *Escherichia* spp., *Micrococcus* spp., *Streptococcus* spp., *Staphylococcus* spp., *Pseudomonas* spp., *Proteus* spp., and *Corynebacterium* spp. were dominantly isolated bacteria⁽²²⁾.

The concentration of airborne Gram positive and Gram-negative bacteria at the Chong Chon border market in Thailand varied at different sites from 1.53 to 9.62 x10¹ and from 0.93 to 7.86x10⁴ CFU m³ respectively were recorded. The recorded airborne bacteria were *Bacillus*, *Corynebacteria*, *Diplococcus*, *Enterobacter* and *Acinetobacter*⁽⁴⁵⁾. The seasonal bacterial concentration was measured in outdoor and indoor environment of public restroom of Korea. The concentration of bioaerosol more in summer than in winter. Overall, the air quality in public restroom was established to be poorer than that in outdoor environment⁽⁵⁾. Bacterial concentration in general tended to peak at sunrise and sunset decrease during the solar noon hours.

CONCLUSION -

This review shall contribute to the knowledge of bacteria load data in various indoor and outdoor environment. A literature study has been performed regarding the level & species of bacteria in various indoors and outdoor environment.

General hospital had pathogenic bacterial flora. In hospital recorded most common contaminants such as *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Micrococcus luteus* & *Pseudomonas aeruginosa*. The microbiological studies confirm that gram-positive bacteria such as *Staphylococcus aureus* & *Staphylococcus epidermidis* are the primary pathogens responsible for wound infection in prosthetic joint surgery. In indoor environment of residential apartment & in educational building mostly *Micrococcus* sp., *Staphylococcus*, *streptococcus* sp., *Pseudomonas* sp. & *Bacillus* sp. bacteria were recorded. The Gram-positive *Cocci* belong to saprophytic micro flora generally associated to human skin and mucosa, suspended in the indoor air derive from human presence⁽²⁰⁾. The presence of moisture damage in school building was a significant risk factor for respiratory symptoms in school students. The high-level *Bacillus* species in the indoor air generally indicate dampness of building & lack of adequate maintenance of the building or house⁽³⁶⁾. This result in dampness within the building envelopes & subsequent health related problems for the occupants.

In outdoor environment mostly *Micrococcus* sp., *Staphylococcus*, *streptococcus* sp., *Pseudomonas* sp. & *Bacillus* sp. *Acinetobacter*, *Enterococcus faecalis*, *E coli* bacteria recorded. As observed in several studies, the high bacterial concentration with in indoor building compared to the observed outdoor air. Air could be associated with various internal sources, including human activities^(35,6). The proportion of pathogenic microorganisms in higher in indoor air than outdoor air. The concentration of gram-negative bacteria was more in indoors than outdoor. That gram-positive bacteria survive longer in the aerosolized state than gram-negative bacteria⁽⁵⁴⁾. Gram positive bacteria have greater resistance & survival ability in more traffic and crowded area⁽⁵¹⁾. Causes of bacterial infection are seen higher during monsoon period as compared to winter season. The possible reason could be higher concentration of pathogenic bacteria in air during monsoon season. Exposure to these bioaerosol can affect on local inhabitants so, it is important to monitor the air in place of increased risk of aerosol contamination, where people spend time every day.

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