INDOOR AIR QUALITY ASSESSMENT: BIOLOGICAL, GASES, AND PARTICULATE MATTER POLLUTION INDICATORS

by

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APPROVAL PAGE

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

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M. S. Thesis – Environmental Engineering
February 2011

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ABSTRACT

In this work, indoor air samples were collected at different places that included two shopping centers, a kindergarten and a house. Indoor air quality parameters such as Carbon Dioxide (CO_2), relative humidity (RH), temperature (ºC), particulate matter (PM), and bioaerosol concentration were monitored. Bacterial and fungal genera were identified by using PCR amplification. Three genera of fungi (*Stachybotrys chartarum, Aspergillus versicolar and Cladosporium Spp.*) and two genera of bacteria (*Micrococcus luteus, Pseudomonas aeruginosa*) were identified and assessed in terms of total numbers and fluctuations in concentration. Correlation tests were performed and discussed for all variables.

Fungi primers were not identified in collected indoor bioaerosol samples after PCR amplification but bacterial genera were found. The results of this study indicated that bioaerosols were increased due to physical activities. Some buildings have a low indoor air quality, which has a negative effect on occupants' health and productivity.

Keywords: Indoor air quality, Shopping center, Kindergarten, Carbon dioxide, Humidity, Temperature, Particulate matter, Bioaerosols.

İÇ ORTAM HAVA KALİTESİ DEĞERLENDİRMESİ: BİYOLOJİK, GAZLAR VE PARTİKÜL MADDE KİRLİLİK GÖSTERGELERİ

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ÖZ

Bu çalışmada, iç hava örnekleri, iki alışveriş merkezi, anaokulu ve ev gibi farklı yerlerde toplanmıştır. Karbon dioksit (CO_2), Bağıl Nem (RH), Sıcaklık (ºC), Partikül Madde (PM), ve biyoaerosol konsantrasyonları gibi iç hava kalitesi parametreleri izlenmiştir. Bakteri ve mantar cinsleri PCR ile belirlenmiştir. Mantarlardan üç cins (*Stachybotrys chartarum, Aspergillus versicolar* ve *Cladosporium Spp*.) ve bakterilerden iki cins (*Micrococcus luteus, Pseudomonas aeruginosa*) tespit edilmiş ve toplam sayı ve konsantrasyonları açısından değerlendirilmiştir. Korelâsyon testleri yapılmış ve tüm değişkenler için tartışılmıştır.

Mantar primerleri PCR amplifikasyonu sonrasında örneklerin içerisinde tanımlanamadı ancak bakteri cinsleri bulunmuştur. Bu çalışmanın sonucunda fiziksel aktiviteler nedeniyle parçacıkların arttığı gözlenmektedir. Bazı binalar sağlık ve verimlilik üzerinde olumsuz bir etkiye sahip olan düşük iç ortam hava kalitesine sahiptir.

Anahtar Kelimeler: İç hava kalitesi, Alışveriş merkezi, Anaokulu, Karbondioksit, Nem, Sıcaklık, Partiküler madde, Biyoaerosoller.

DEDICATION

To my dear, precious, and esteemed family

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Esra TATLI

TABLE OF CONTENTS

LIST OF TABLES

TABLE

LIST OF FIGURES

FIGURE

LIST OF SYMBOLS AND ABBREVATIONS

SYMBOLS/ABBREVATIONS

ANSI	American National Standards Institute
ASHRAE	American Conference of Governmental Industrial Hygienists
BCL	Background Concentration Level
CA	Actual Value
CN	Normalized value
CO	Carbon Monoxide
CO_2	Carbon Dioxide
DNA	Deoxyribonucleic Acid
dNTP	Deoxyribonucleotide Triphosphate
HCHO	Formaldehyde
IAQ	Indoor Air Quality
IAQPs	Indoor Air Quality Parameters
LB	Luria – Bertani
MaxRange	Maximum Value of the Selected Value Range
MEA	Malt Extract Agar
Mluf	*Miccrococcus Luteus*
MinRange	Minimum Value of the Selected Value Range
NaCl	Sodium Chloride
OSHA	Occupational Safety and Health Administration
PCR	Polymerase Chain Reaction
PM	Particulate Matter
PM_{10}	Course Particles
$PM_{2.5}$	Fine Particles
Psaf	*Pseudomonas Aeruginosa*
RH	Relative Humidity
SBS	Sick Building Syndrome

S1	Section 1
S2	Section 2
S3	Section 3
S4	Section 4
T	Temperature
TAE	Tris Acetate EDTA
TBC	Total Microbial Count
TSA	Tryptic Soy Agar
TVOCs	Total Volatile Organic Compounds
UV	Ultra Violet
VOCs	Volatile Organic Compounds
WHO	World Health Organization

CHAPTER 1

LITERATURE REVIEW

1.1 BACKGROUND

1.1.1 Indoor Air Quality

Indoor air quality (IAQ) refers to the environmental characteristics inside a building that may affect human health, comfort, or work performance. The IAQ of a space can be assessed, monitored and indicated for the minimum provision of buildings regarding regulatory control measures. Acceptable IAQ can be ensured by limiting some concerned organic, inorganic and biological air pollutants presented in indoor air. In addition, maintaining an acceptable thermal comfort condition at certain air temperatures, velocities and humidity is desired in some cases (Shan, 2009).

People in the industrialized countries typically spend over 80% of their time in indoor environments rather than outdoors; the majority is in homes and offices or at public places like shopping centers. High rise buildings can be seen everywhere around the cities. Many of them, especially commercial buildings are supplied with mechanical ventilation and air conditioning systems. This type of enclosed structure provides a more spacious and comfortable environment to the occupants, but at the same time, increases the difficulties in controlling and maintaining the air quality perceived by the occupants (Shan, 2009). In addition to that, indoor air pollution might increase the chance of both long and short term health problems for students and staff (Ismail et al., 2010).

Maintaining an acceptable IAQ for a healthy and comfortable environment is of primary concern. Occupants' exposures to levels of a number of chemicals and pollutants, which are higher indoors than outdoors, are driving the health concerns of some specific population groups.

Definition about health problems offers a named Sick Building Syndrome (SBS). SBS is a worldwide and complex problem (Burroughs and Shirley, 2008). It focused on office building. When building's occupants exhibit such symptoms and the complaints persist for more than two weeks, these buildings are deemed as sick. The risk of health problems caused raises the question of sick school syndrome due to poor indoor air quality (Lee et al., 2002). Syndrome is used by the medical profession to indicate a cluster of symptoms occurring together. Common SBS symptoms are established, but their exact causes are unknown (Wong et al., 2009). Although there are air pollutant sources which are shown wide distributions, the concentrations of indoor pollutants can be dominant risk factor in relation to personal exposure. Some SBS signs of disease are eye irritation, nasal manifestations, throat, headaches and skin problems (Burroughs and Shirley, 2008).

Indoor air quality is related to three basic requirements for human occupancy: thermal acceptability, maintenance of normal concentrations of respiratory gases, dilution and removal of contaminants to levels below health or odor discomfort thresholds. Inadequate ventilation can increase indoor pollutant levels. Inadequate air or oxygen is only part of the problems.

The enclosed nature of indoor spaces leads to very high indoor exposures easily when indoor sources are present. Economic growth and urban development change people's lifestyle, and they help increase the use of consumer products containing chemical agents indoors, which may be harmful to the occupants' health. Concurrently, the substantial part of exposures to air pollution from outdoor air occurs indoors as outdoor air enters indoors via infiltration and ventilation. Furthermore, since the energy crisis in the 1970s, policies for promoting energy conservation for sustainable building designs and operations have been applied (Rowe and Leete, 2003).

Being exposed to such elevated pollutant levels may cause health problems and discomfort, and lower the productivity of the staff. However, maintaining a good IAQ is two problems. The pollutant levels should be kept as low as possible in order to minimize the health risks to occupants, but at the same time, there are practical and economical concerns for the industry. It is, therefore, important to keep a balance of the requirements between the two through addressing the performance of IAQ based on proper assessment methodologies and monitoring plans.

1.2 SCOPE and IMPORTANCE OF THE STUDY

1.2.1 Similar Studies Around the World

Lee et al. (2002) measured air pollutants included carbon dioxide (CO_2), respirable suspended particulate matter (PM_{10}), formaldehyde (HCHO), volatile organic compounds (VOCs) and airborne bacteria in domestic kitchens and living rooms in Hong Kong. Their result indicated that the 8-h average concentrations of CO_2 and PM_{10} in the domestic kitchens investigated are 14% and 67% higher than in the living rooms. They found average concentrations of airborne bacteria higher than 500 CFU/m^3.

Green et al. (2003) sampled fungal and bacterial bioaerosol concentrations by using Andersen two-stage viable particle sizing sampler instruments loaded with Malt Extract Agar, Trypicase Soy Agar, Czapek's Cellulose Agar and Corn Meal Agar in the thirty-nine single-family residences in the Greater Cincinnati area, USA. They were incubated the petri dishes and they enumerated the number of colonies from each plate and all colony forming units (per cubic meter of air) were calculated.

Hermann et al. (2007) evaluated indoor air quality in 64 schools in the city of Munich. They collected samples by using parameters such as temperature, relative humidity, carbon dioxide (CO_2) and particle fractions (PM_{10}-$PM_{2.5}$) in winter 2004-2005 in 92 classrooms, and in summer 2005 in 75 classrooms. The CO_2 concentration was 1603 ppm in winter and 405 ppm in summer in a classroom.

Yang et al. (2009) characterized the concentrations of different indoor air pollutants within Korean schools. They compared indoor levels within schools according to the age of school buildings. They obtained carbon monoxide (CO), carbon dioxide (CO_2), particulate matter (PM_{10}), total microbial count (TBC), total volatile organic compounds (TVOCs) and formaldehyde (HCHO) during summer, autumn and winter from classroom, laboratory and computer classroom at 55 different schools. CO_2 concentrations were found to research 1000 ppm and total microbial count concentrations were higher during summer and autumn than during winter. Also they found higher indoor microbial concentrations during summer than winter.

Pastuszka et al. (2000) studied bacterial and fungal bio aerosol in healthy and moldy homes as well as in office rooms in Upper Silesia, Poland. They collected airborne bacteria and fungi using the 6- stage Andersen impactor inside and outside of buildings. The concentration of fungal aerosol and bacterial aerosol were found to be different according to both winter-summer season and healthy homes--moldy buildings.

1.2.2 Similar Studies in Turkey

Aydoğdu (2004) collected bacteria and fungi in kindergartens and day-care centers between January and December 2004, in Edirne, Turkey using a by exposing petri plates which contained Pepton Dextrose Agar with Rose Bengal and Streptomycin for microfungi and Brain Heart Infusion Agar with Sheep Blood 5% for bacteria to air (Petri Plate Gravitational Settling Method). They used 192 petri plates for micro fungi and bacteria isolations and they counted a total of 2071 microfungi (907 of indoor and 1164 of outdoor) and 3120 bacteria colonies (1406 of indoor and 1714 of outdoor) in these plates. Statistical analyses were performed between concentrations of total micro fungi and bacteria. They found some correlations between the monthly outdoor concentrations of most isolated microfungal genus (*Cladosporium*, *Penicillium* and *Alternaria*) and various meteorological factors.

Önoğlu et al. (2008) studied microorganisms such as bacteria and fungi in 15 kindergartens on May 2007, in Istanbul-Fatih, Turkey. They collected indoor air samples in classroom, dining room, kitchen and toilets with Merck Air Sampler Mas

100. The most common cultivable airborne fungi found were *Cladosporium Spp.* and *Aspergillus Spp.*

Bulut (2007) collected particulate matter (PM_1, $PM_{2.5}$, PM_7, PM_{10} and total suspended PM-TSP), carbon dioxide (CO_2), temperature and relative humidity (RH) in classrooms between January and March 2007 on weekdays, in Şanlıurfa, Turkey. They collected samples with portable laser Particulate Matter Counter (Met One Aerocet 531), CO_2 meter (Testo 535) and Temperature and Humidity Counter (Impac Tastotherm-Hum RP2). They performed statistical analyses using MINITAB statistical program to determine samples results. It was found that the PM concentrations in indoor were higher than in outdoor because, smoking rooms have more polluted air. According to their results, when the number of people increases in indoor, the concentrations such as relative humidity, carbon dioxide and particulate matter values increase.

Kuş et al. (2007) measured different parameters such as temperature, relative humidity, carbon dioxide and particulate matters on 2007, at two different campuses in the higher education classrooms in Şanlıurfa, Turkey. Sampling were taken indoor and outdoor spaces at the same time and they were analyzed the results statistically and compared with the international standards related to indoor air quality. It was found that indoor air quality in winter was the most acceptable than in summer. The central heating system was used in winter season. But air quality and comfort conditions in classroom were very poor during the summer season due to the high temperature and lack of any air conditioning system. According to results, relative humidity was in the range of acceptable level during winter, but at low level during summer season. They also observed that the indoor carbon dioxide concentration increased with the student numbers during the winter season and the source of particle matter was based indoor more than outdoor.

1.3 INDOOR AIR QUALITY PARAMETERS (IAQPs)

1.3.1 Particulate matter

Particulate matter (PM) is one of the most important indoor air pollutants. Particles may originate from a wide variety sources that are small enough to be carried by the air and therefore be breathed in by people (Fromme et al., 2007). They can be solid or liquid, or a mixture of both. A source of indoor air pollutants depends on the concentration of aerosol (Estokova et al., 2010). Particle pollution includes course particles (PM_{10}) with diameter larger than 2.5 micrometer and smaller than 10 micrometer and fine particles ($PM_{2.5}$) with diameter 2.5 and smaller. PM_{10} levels are associated with premature deaths and increased mortality of infants and other parts of sensitive population (Heudorf et al., 2009).

There are many activities in indoor places such as cooking, walking, smoking and human activity. In addition to cooking and smoking, some activities such as sweeping and vacuuming lead to an increase in large particle concentration within a home. It is the household cleaning that may cause the re-suspension of indoor particulate matters from domestic floors and furniture which could be deposited on the surfaces of floors and furniture (Lee et al., 2002). They cause the formation of particulate matter in indoor air (Heudorf et al., 2009).

Indoor particulate matter concentration can be influenced by outdoor levels and particulate generation in indoors. The reason why fine particle concentration increase, it is attributed to tobacco smoking and operation of gas stoves for cooking. In addition to that airborne particles levels could be affected by cooking style such as frying (Lee et al., 2002). According to recent study inadequate ventilation could increase the levels of suspended particulate matter in kitchen environments. When particles concentrations exceed recommended maximum limits, it can become contaminated that present different and sometimes more serious risks than related to outdoor exposures (Kalogerakis et al., 2005). These concentrations affect human health. Particulate air pollution associated with decreased lung function, increased respiratory symptoms such as cough, shortness of breath, wheezing and asthma attacks, and lung cancer (WHO, 2002).

1.3.2 Biological Pollutants

Bio aerosols play a significant role in indoor air pollution. They can be pathogenic or cause an allergic reaction following inhalation (Kalogerakis et al., 2005). There are many sources of biological pollutants. Biological contaminants are often found in areas that provide food and moisture or water. The presence of moisture or high relative humidity is a sufficient catalyst for growth of fungal spores (Gravensen et al., 1994). It includes bacteria, viruses, mold, animal dander, house dust and pollen. Allergens are everywhere. Most common allergens are pollen grains and fungal spores (Hess-Kosa, 2001). Bacteria are carried by people, animals and soil and plant debris. Fungal spores can enter the indoor air from outdoor. They are related with health effects (Li and Hou, 2004).

In this study two toxic bacteria, including *Pseudomonas aeruginosa* and *Miccrococcus luteus*, and three fungi, including *Stachybotrys chartarum, Aspergillus versicolar* and *Cladosporium Spp***.** were selected.

Pseudomonas aeruginosa is a common bacterium which can cause disease in an animal and human. It is the epitome of an opportunistic pathogen of humans. It thrives on most surfaces and when some colonies occur in critical body organs, such as the lungs, the urinary tract and kidneys, the results can be fatal. Some diseases cause by *Pseudomonas aeruginosa* (Balcht et al., 1994). *Miccrococcus luteus* is found in indoor air, soil and water. Some studies have showed that *Miccroccus spp*. had the highest count in all homes (Pastuszka et al., 2000).

Molds are very common in buildings and homes and will grow anywhere indoors where there is moisture. According to literature, the most common indoor molds are *Cladosporium*, *Penicillium*, *Aspergillus*, *Stachybotrys,* and *Alternaria*. *Stachybotrys chartarum* and *Aspergillus versicolor* produced the mycotoxins, or fungal toxins. Mycotoxins may cause DNA damage (Ismail et al., 2010).

They are a serious concern in health care because of their infection potential. Some of these fungi can cause allergic or toxic reactions, while a few may cause infections in susceptible individuals (Green et al., 2003). *Cladosporium Spp*. is a large

fungal genus indoor and is related to allergenic respiratory disease, especially asthma (Storey et al., 2004).

1.3.3 Carbon Dioxide

Carbon dioxide (CO_2) is a surrogate for indoor pollutants emitted by humans and correlates with human metabolic activity. Carbon dioxide at levels that are unusually high indoors may cause occupants to grow drowsy, get headaches, or function at lower activity levels. Humans are the main indoor source of carbon dioxide. Indoor levels are an indicator of the adequacy of outdoor air ventilation relative to indoor occupant density and metabolic activity.

To eliminate most Indoor Air Quality complaints, total indoor carbon dioxide should be reduced a difference of less than 600 ppm above outdoor levels. NIOSH considers that indoor air concentrations of carbon dioxide that exceed 1,000 ppm are a marker suggesting inadequate ventilation. ASHRAE recommends that carbon dioxide levels not exceed 700 ppm above outdoor ambient levels (ASHRAE, 1989). The UK standards for schools state that carbon dioxide in all teaching and learning spaces, when measured at seated head height and averaged over the whole day should not exceed 1,500 ppm. The whole day refers to normal school hours (i.e. 9.00am to 3.30pm) and includes unoccupied periods such as lunch breaks. Canadian standards limit carbon dioxide to 3500 ppm. OSHA limits carbon dioxide concentration in the workplace to 5.000 ppm for prolonged periods, and 35.000 ppm for 15 minutes. Exhaust gas leakages can occur from furnace metal exhaust pipes that lead to the chimney when there are leaks in the pipe and the pipe gas flow area diameter has been reduced.

1.3.4 Temperature and Humidity

Temperature is the most important indicators of thermal comfort and humidity another key parameter. Temperature, humidity and fresh air can be defined in indoor places as comfortable environment. They are related to contaminants that may affect health and nature of indoor environment (Burroughs and Shirley, 2008). Actually there are complaints building's occupants which are related to thermal discomfort.

The activity level, age, and physiology of each person affect the thermal comfort requirements of that individual. They can affect human health and perceived air quality. Relative Humidity (RH) is related to amount of water vapor in the indoor air. It affects temperature range. When moisture is available in indoor environment, it consists of hundreds of species of bacteria and fungi. Moisture and mold are related to illnesses such as headache, drowsiness, occasionally cough, dermatitis, and most often burning and irritation of the eyes, nose, and throat. Especially it is associated with asthma in children and adults in buildings (WHO, 2002).

1.3.5 Effects of IAQPs on Human Health and Structures

Indoor air quality for Human comfort should primary focus of the design and operation of ventilation systems for buildings because comfort factors include temperature, humidity, noise, odors and lighting. Health risks from indoor pollution depend on both indoor concentrations and human activities. Air pollutants include organic, inorganic and biological types. Bacteria can cause disease such as influenza or asthma symptoms. Also fungi and pollen can cause allergies (Samet and Spengler, 1991).

1.4 THE PURPOSE OF THIS STUDY

People spend most of their life time (almost they spend 90% of their time indoors) either at home, at work or at public places like shopping centers. Indoor exposure to biogenic aerosol air pollutants may pose harmful health effects especially in children.

The main objectives of this study are to:

1. Assess biogenic aerosols in different indoor environments by using polymerase chain reaction (PCR) method.
2. Examine the impact of indoor air pollution on human health daily activities.
3. Find the possible relationship and effects between indoor and outdoor air quality.
4. Assessment of the amount of pollutants.

In order to fulfill the above mentioned aims, the scope of this study is conducted to estimate airborne microorganisms in indoor environments. Mainly this study focused on sampling and analysis. Indoor air quality parameters particle number concentration at six different size fractions, biogenic aerosols number and type, humidity and temperature for indoor environments, meteorological parameters of adjacent outdoor environments and in public places like, kindergarten, classroom and shopping centers.

Viable aerosol samplers were used to collect biogenic aerosols onto suitable media. An impaction based viable microbial particle sampler was used during the sampling of biological aerosols.

In addition to that, this study particularly focused on identifying the indoor air pollution problems caused by lack of ventilation, heating and air conditioning systems especially in children schools, classrooms and shopping centers.

Concentration of the collected particulate matter, carbon dioxide, humidity-temperature, bacteria and fungi were calculated. The calculated sample levels were then compared with the natural and international limit values. Bacteria and fungi samples were analyzed with PCR. This technique is the availableness for the identification of species of bacteria and fungi in air (Alvarez et. al., 1994). A large group of microorganisms can be assessed by using PCR method.

CHAPTER 2

EXPERIMENTAL WORK

2.1 SAMPLING

2.1.1 Sampling Site and Selection

Site selection is very important step in determining indoor air quality. The aim and expected outcomes of the study is mainly the main guide for the targeted site. There are no governmental requirements for indoor biological monitoring nor are there clearly defined methodologies. There are a few accepted methodologies and guidelines worldwide such as American Conference of Governmental Industrial Hygienists (ACGIH). As a matter of fact the pollutant concentration can change depends on the collection time and place. Furthermore, those variations have been observed in locations close to emission sources.

The site selection criteria for indoor air quality fall into four categories which are listed below: (Hess-Kosa, 2001).

- Time of day, occupancy, different activities near the sampling areas, enclosed office spaces and occupied and non-occupied spaces.
- The sites should be selected according to high exposure area (if there are health complaints) or low exposure area (it can be identified and confirmed minimum health complaints)
- Samples from the roof or along the side of the building where fresh air is taken to supply the indoor areas should be collected.

- If potential sources of bio aerosols are close to the outdoors, pollutant may enter into buildings. Consequently, outdoor sampling could be necessary.

According to the above criteria, indoor air quality investigation was conducted to characterize the air quality of selected indoor environments in Turkey-Istanbul. People spend lots of their times inside closed buildings so according to sampling strategy, sampling sites were chosen to present the whole occupied areas of the building. The sampling locations for this study were chosen to be different work and living places. Indoor air quality places evaluated included: kindergarten, home and two shopping centers (Shopping Center_1 and Shopping Center_2). Samples were collected in according with standard method, Bioaerosol sampling (Indoor Air) Method: 0800. This Method written by: Miriam K. Lonon, Ph.D., NIOSH/DPSE.

2.1.2 Sampling Locations

Representative air samples from kindergarten, shopping centers and home were collected.

Kindergarten: During the first part of kindergarten bioaerosol sampling the eight rooms (Kitchen, Rooms 1, 2, 3, 4, 5, playing room and sleeping room) were selected to collect microbes and other particles for this study. There were children in different age in the kindergarten. Four of the kindergartens rooms were infants' rooms whose age ranges from 0 to 2 years. Rooms were ventilated with door and windows. The measurements were conducted from April to May 2010. The bioaerosol and particle characteristics were sampled at a height of 1 m to simulate for each room. Furthermore, temperature, carbon dioxide, humidity were recorded.

The bioaerosol sampling time was in the range of 5-10 min to obtain statistically sufficient colony numbers. There were children in each room during sampling. There was no ventilation in the rooms during sampling time. Room occupancy conditions were different. Some rooms were crowded and small but some of them are big and empty.

Shopping Center_1: One of the popular shopping malls in Istanbul were selected for this study. The temperature, carbon dioxide, humidity and biological pollutants were recorded during the Shopping Center _1 from the different floors (Floor 1, 2, 3 and Fast food) for different days (Weekday and weekend). Each sampling was performed at different places on the floor. Ten points were selected in total. Height of the sampling point was from 1 to 1.5 m. This shopping center_1 was ventilated using mechanical ventilation and air-conditioning systems. Anti-smoking policy was in process in this monitoring site.

Shopping Center_2: Four floors were evaluated at Shopping Center_2 for different days (Weekday and weekend). During sampling, all units were recorded. 14 points were selected in total. Height of the sampling point was from 1 to 1.5 m.

These shopping centers were located in major commercial and residential districts where population and vehicle densities were relatively high in Istanbul-Turkey. The shopping center_1, 2 were very crowded on weekend due to the weekend vacation, so sample results were assessed according to this condition. All shopping malls were multi-storied and ventilated with central air-conditioning systems.

Home: Indoor air samples were collected and characterized at a residential place in Istanbul. The site was located in an urban area of Istanbul with poor outdoor air quality. Indoor quality parameters were measured including temperature, humidity and CO_2. The same is used to monitor relative humidity and temperature during all sampling periods. Air samples were collected at the same time between 11:00-15:00, in every room. Before sampling the rooms windows were closed for two hours. After applying this procedure, samplings were done in each room.

2.2 MEASURING EQUIPMENT and ANALYSIS METHODS

Indoor air quality (IAQ) studies are of great importance simply because it directly affects our health and performance. In the literature, limited parameters and techniques have directly been used to measure sample indoor air pollutants indicators. In this study,

airborne biogenic aerosols were collected using HRTECH® viable aerosol sampler. Details of used sampler and other equipments are discussed in the following parts.

In the first phase of this work, planning of the sampling part has been carried out. The necessary equipment, materials and laboratory infrastructure were bought and/or had been established. For this purpose; purchasing of the necessary chemical and biological materials took place.

2.2.1 Materials and Chemical

The following equipments, cultural media and chemicals were used in the study:

- Airborne Particle Counter: CLJ-H603®
- CO_2 Meter and Humidity / Thermometer: EXTECH® instruments
- Biological Air sampler: HRTECH® model FSC-IV
- Incubator: Incu Cell® model 55
- Autoclave: Nuve®, model OT 012
- Hot Plate: Heidolph®
- Refrigerator: Vestel®, model GT 540 A
- Colony Counter: Comecta SA®
- PCR
- Gel Electrophoresis
- Spectrophotometer: Shimadzu®
- Malt Extract Agar (MEA)
- Tryptic Soy Agar (TSA)
- Ethyl alcohol, 95%

2.2.2 Sampling Equipments

2.2.2.1 Airborne Particulate Matter Counter Measurement

Online particle counter CLJ-H6003® with data logger was used to monitor the number particle concentration at 6 different stages in the range of 0.3, 0.5, 1.0, 2.0, 3.0 and 5.0 micrometer in size (Figure 2.1). Airborne particles belonging to each of the

particle size fractions were assumed as spherical particles with an average diameter of related stage range indication (e.g., 0.3, 0.5, 1.0, 2.0, 3.0 and 5.0). Then, mass concentrations of each stage were calculated by arithmetically and the densities of the particles during these calculations were assumed to be 2.0 g/cm^3. In the results and discussions part, particulate matter (PM) counts in mass concentrations were generally reported. Typical volume of the equipment is 0.1 cfm.

Figure 2.1 Picture of Airborne Particulate Matter Counter.

2.2.2.2 CO_2, Humidity, and Temperature Meter

Air quality parameters such as carbon dioxide, humidity and temperature were monitored with using equipment, EXTECH® CO250: Portable Indoor Air Quality CO_2 Meter/Data logger (Figure 2.2). It can be measure those specifications with ranges;

CO_2: 0 to 5.000 ppm,

Temperature: -10 to +60°C

Humidity: 0.0 to 99.9%

This device is a portable type and user friendly. Furthermore, it is equipped with an RS-232 PC interface for connection to a PC. It is an ideal instrument for indoor air quality diagnosis for the ease of use and sampling.

Figure 2.2 Picture of Temperature, Humidity and CO_2 Metter device.

2.2.2.3 Biological Air Sampler

This HRTECH® (FSC-IV model) biological sampler works according to the principle of multi jet holes particle impact and isokinetic sampling (Figure 2.3). It is a kind of high effective air biological sampler. During sampling, airborne particles impact on agar surface of substrate, following to sucked through tiny holes. The collection is not enough itself for quantification for bio aerosols, so it should be followed by incubation of the agar plate, and then colonies can be counted and identified.

This instrument is designed in two parts. The upside part consists of sampling jet holes; pedestal and gas pump. The other part (downside) includes controller and batteries. This equipment is made of high quality aviation aluminum. In the case of redundancy or unused times, surface holes should be kept closed for being ready to work in convenient and sterile before using. This instrument is of large sampling volume, stable performance, and easy-to-use and reaches international standard of similar product.

Figure 2.3 Picture of experimental biologic air sampler.

The studies were carried out in two phases: i) in the first phase samples and air quality monitors were carried out in laboratories and classrooms. This phase contains the preparation and testing operations, ii) in the second phase, more detailed and complete sampling campaigns were performed in shopping centers, classrooms, laboratories and kindergartens.

The results were summarized in chronicle order in the following parts. Then it was concluded by discussions on the findings and related results.

2.2.3 Preparation of Media

2.2.3.1 Media for the Growth of Fungi

Malt Extract Agar (MEA) was used to grow Fungi from the collected samples. The composition of the growth medium for Fungi was shown in Table 2.1.

Table 2.1 The composition of the growth medium for Fungi

Malt Extract Agar (MEA) medium: (per liter)	
Maltose, Technical	12.75 g
Dextrin	2.75 g
Glycerol	2.35 g
Peptone	0.78 g
Agar	15.0 g

Appropriate amount of MEA medium was weighted and dissolved in 500 ml distilled water to be used for cultivation of fungus. The suspension was heated to boiling while stirring to dissolve all ingredients completely. The media were autoclaved at 121^{o}C for 15 minutes, and then cooled to 50^{o}C. Furthermore, the sterile media were poured into sterile Petri dishes. The dishes were cooled in order to solidify the media under aseptic conditions, and then sealed with stretch film and stored at 4^{o}C until use.

2.2.3.2 Media for the Growth of Bacteria

Tryptic Soy Agar (TSA) was used to grow Bacteria. The composition of the growth medium for Bacteria was shown in Table 2.2.

Table 2.2 The composition of the growth medium for Bacteria

Tryptic Soy Agar (TSA) medium: (per litre)	
Pepton from casein	15.0 g
Pepton from soymeal	5.0 g
Sodium Chloride	5.0 g
Agar	15.0 g

Appropriate amount of TSA medium was weighted and dissolved in 500 ml distilled water used for cultivation for bacteria. The suspension was heated to boiling while stirring to dissolve all ingredients completely. The media were autoclaved at 121^{o}C for 15 minutes, and then cooled to 50^{o}C. Then, the sterile media were poured into sterile Petri dishes. Petri dishes were cooled in order to solidify the media under aseptic conditions, and then sealed with stretch film and stored at 4^{o}C until use.

2.2.4 Culture Medium

Luria – Bertani (LB) broth (Merck) were used for the cultivation of Bacteria and Fungi. The composition of the growth media for *Bacteria and Fungi were* shown in Table 2.3.

Table 2.3 The composition of the growth media for Bacteria and Fungi.

Luria-Bertani (LB) broth medium: (per litre)

Tryptone (pancreatic digest of casein)	10 g
Yeast extracts	5 g
NaCl	5 g

For the preparation of 500 mL LB broth medium, 10 g powder was added to 500 mL of distilled water to form a suspension. The media were autoclaved at 121^{o}C for 15 minutes, then cooled to 50^{o}C, and stored at 4^{o}C until use.

After collecting of samples, agar mediums were mixed in culture media, waited at 37 ^{o}C for 1 day, and then stored at -20 ^{o}C until use.

2.2.5 Molecular methods

2.2.5.1 Isolation of genomic DNA from fungi

The Fungi DNA was extracted using a high purity Pure PCR Template Preparation kit (Roche®) but with a modification of the manufacturer's protocol.

Approximately 200 mg mycelia was added to a 1.5 ml microcentrifuge tube and mixed with 200 µl sterile PBS. 10 µl lysozyme (5mg/ml) was added into the solution and the microcentrifuge tube was incubated at 37^{o}C for 30 min in order to lysis the cells. Then 200 µl Tissue Lysis Buffer and 40 µl reconstituted Proteinase K solution were added to lysed cells and mixed the contents of the tube immediately. The tube was incubated for 10 min at 70^{o}C. After the incubation, sample was mixed with 100 µl isopropanol. One high pure fitler tube was inserted into one collection tube. The entire sample was pipetted into upper buffer reservoir of the Filter Tube. The entire High Pure Tube assembly a standard tabletop microcentrifuge, then the tube assembly was centrifuged for 1 min at 8000 x g.

After centrifugation, the Filter Tube was removed from the Collection Tube and the liquid and the Collection tube were discarded. 500 µl Inhibitor Removal Buffer was added to the upper reservoir of the Filter Tube assembly. The centrifugation step was repeated (1min at 8000 g) and the liquid and Collection Tube were discarded. The Filter Tube was reinserted in a new Collection Tube. 500 µl Wash Buffer was added to the upper reservoir of the Filter Tube. The centrifugation was repeated again. After the centrifugation, the Filter Tube was removed from the Collection Tube and the liquid and the Collection tube were discarded again. The wash step and centrifugation were repeated. Flowthrough was discarded. The Filter Tube-Collection Tube assembly was spinned for 10 s at maximum speed (approx. 13,000 x g) to remove residual Wash Buffer. The Collection Tube was discarded and the Filter Tube was inserted in a clean, sterile 1.5 ml microcentrifuge tube. 200 µl of prewarmed (70^{o}C) Elution Buffer was added to the Filter Tube. The tube assembly was centrifuged for 1 min at 8000 x g.

The eluted DNA was checked by %1 agarose gel electrophoresis under the UV-transilluminator (Gel-Doc, Biorad - USA) and single band was observed near under the loaded well.

Quantification of total DNA was carried out by absorbance at 260 and 280 nm using a Shimadzu® UV-VIS spectrophotometer. The absorbance at 260 and 280 nm ratio (260/280) was used to assess the purity of the DNA.

2.2.5.2 Isolation of Genomic DNA from Bacteria

The bacteria DNA was extracted using a High Pure PCR Template Preparation kit (Roche®. Approximately 200 mg bacteria culture was added aseptically to a 1.5 ml microcentrifuge tube and mixed with 200 µl sterile PBS. 200 µl Tissue Lysis Buffer and 40 µl reconstituted Proteinase K solution were added to lysed cells and mixed the contents of the tube immediately. The tube was incubated for 10 min at 70^{O}C.

The previous procedure was followed in the same manner for the bacteria DNA separation.

2.2.5.3 Design of Primers

Particularly special primers were used in this study, namely Primer 3 and details are given in Table 2.4 and Tabe 2.5. Both primers were obtained from Iontek A.S. (Istanbul, TR). Specific detection of Fungi and Bacteria culture were design from indoor air by PCR. Three fungi primers and two bacteria primers were designed according to toxic influence.

Table 2.4. Nucleotide primers used for PCR of Fungi.

Primer	Sequences	Lenght of Primers	T_M (^{o}C)	Lenght of PCR product (bp)
ST5	Forward: 5-GTGGCAACCCGCAAAAGC-3	18	55 °C	250 bp
	Reverse: 5- TTGCTCTTTCTTGGAATATTTTGG-3	24	55 °C	255 Bp
AspBT	Forward: 5-CATCCATTTCAGATGGTATTTCCT-3	24	56 °C	385 bp
	Reverse: 5-TGTTTTGATCGAGTCTTGGACG-3	22	56 °C	380 Bp
CLAD	Forward: 5-CCKGGATGTTCATAACCCTTTG-3	22	55 °C	155 Bp
	Reverse: 5-CCCGAACACCCTTTAGCG-3	18	55 °C	150 bp

ST5: Staphbotrys charatum, AspBT: Aspergillus versicolor, CLAD: Cladosporium Spp.

Table 2.5. Nucleotide primers used for PCR of Bacteria.

Primer	Sequences	Lenght of Primers	TM (^{o}C)	Lenght of PCR product (bp)
MLU	Forward: 5-TCTCGATCGCCGTAGAGATACGGT-3	24	57 °C	150 Bp
	Reverse: 5-ATGGAACGAGGGTTGCGCTCG-3	21	57 °C	155 Bp
PSA	Forward: 5-ACGTCCTACGGGAGAAAGCAGGG-3	23	56 °C	250 Bp
	Reverse: 5-TCTTCACACACGCGGCATGGC-3	21	56 °C	255 Bp

MLU: Miccrococcus luteus, PSA: Pseudomonas aeuroginosa.

2.2.6 PCR Conditions

The first PCR protocol was as follows: 1,5 µl (~150-250 ng) of gDNA was added to a 25 µl reaction containing 2 µl dNTPs (5µM) (Fermentas), 2.5 µl (0.5 µM) forward (F1) and reverse primers (R1) (Iontek, Turkey), 0.2 µl Ex Taq HS DNA polymerase (Takara), and 4µl 10X Ex Taq HS DNA polymerase buffer with Mg^{++} (Takara), 14,7 µl PCR graded H_2O. The reaction mixture was spin down for 10 s and performed for the First PCR reaction.

First PCR amplification reactions were as described below:

94°C, 2 min for initial denaturation

94°C, 30 sec for denaturation
62°C, 30 sec for annealing } x 30 cycle
72°C, 2.5 min for extension

72°C, 5 min for final extension

The expected PCR product size was 2000 bp. First PCR product was run on a 1% TAE gel stained with ethidium bromide (5 mg/ml) to confirm successful amplification. A 1: 100 dilution of first round reaction was made to be used as template for the second round of PCR. This reaction mixture contains 5 µl 10 X buffer (Takara), 2 µl 0,2 µM of all four dNTPs, 1,5 µl (10 µM) second set of primers, F2 and R2, 0,2 µl Prime Star

DNA polymerase, 1 µl of template DNA and 13,3 µl PCR graded H_2O in a 50 µl reaction volume. Totally 5 tubes (250 µl) were prepared by the same way. A second round was performed for 30 cycles. Before 30 cycles of second PCR, initial denaturation (1,5 min at 94^oC) step was performed. After this step, a 30 cycles of melting (30 s at 94^oC), annealing (20 s at 63^oC), extention (2 min at 72^oC) was performed. The reaction was ended with a final extension 10 min at 72^oC and cooled to 4^oC for storage.

Amplification products were fractionated by electrophoresis in 1% agarosa/TAE gels and appropriate bands excides. The DNA was extracted with a commercial kit.

2.2.7 Gel Electrophoresis

Agarose gel (1%) was prepared to visualize the PCR products. 0,4 g powdered agarose (AppliChem, Germany) was dissolved in 40 ml 1 x Tris Acetate EDTA (TAE) buffer by using microwave oven. It was heated on nearly 45 second until boiling by pulse and stirred with 15 second intervals. The gel was cooled to 50°C and 2,5 µl safeviewDNA staining was added. The gel was then poured into horizontal agarose gel platform and and a comb was placed in the gel before polymerization. Afterwards, totally 25 µl of PCR product with approximately 20 µl of 6x DNA Loading Dye (Fermentas) were mixed and loaded on to a large well that is illustrated in Figure 2.5 and Figure 2.6. Then, 1 µl DNA size marker from Fermentas (GeneRuler^{TM} 1kb DNA Ladder) with 2 µl of Loading Dye and 6 µl of ddH_2O mixture were loaded into the other well. The electrophoresis tank was filled with 1X TAE running buffer and the gel was run for 45 minutes at 100 volts. After running, the gel was placed in Gel Doc 2000 (Biorad, Milan, Italy) apparatus and the band was visualised and photographed on a UV transilluminator.

The gel was examined under UV light in order to determine whether DNA band of interest was present on the appropriate place on the gel according to molecular size marker or not. Only a band was detected.

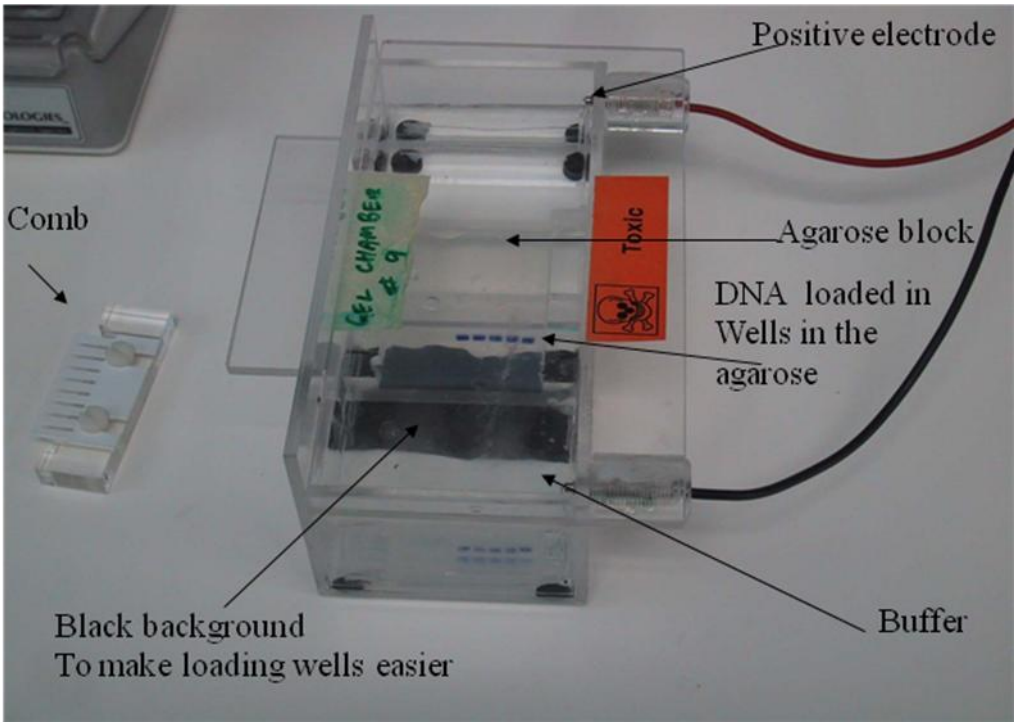

Figure 2.4 Schematic illustration of gel before running.

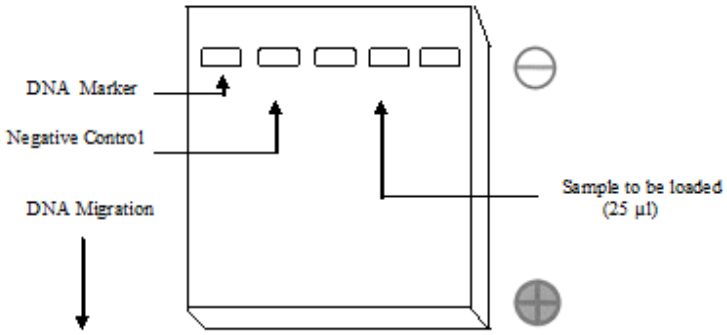

Figure 2.5 Schematic illustration of an agarose gel well preparation before loading.

CHAPTER 3

RESULTS AND DISCUSSION

3.1 EVALUATION OF COLLECTED and MEASURED PARAMETERS

During this study air samples were collected and analysis of indoor air quality parameters was performed. Tested parameters included, Particulate matter concentration (PM), Temperature (^{o}C), Relative humidity (RH), Carbon dioxide (CO_2) and bio aerosol sampling and analysis were done in different rooms and classes of a school, in two shopping centers, a kindergarten and a house. Period of taken concentrations is during autumn.

3.1.1 AIR QUALITY MONITORING ON PLACES

3.1.1.1 Air quality monitoring (all parameters) in Fatih University Kindergarten (May 2010).

The sampling of air quality parameters were measured on 21 of April 2010. All parameters were measured during working day hours of the Kindergarten. The concentration of 0.3 μm and 0.5 μm sized particles remained fairly close in the kindergarten atmosphere during all the period and any significant changes were not observed. It is clear that their concentrations remained on the level of background concentration level (BCL). On the other hand the particles having diameter of >1.0 μm were steadily increased during the study period. This situation is clearer in higher sized particles, due to physical activities.

There was a significant difference variation in CO_2 concentration between the rooms from 1400 to 2200 ppm (Table 3.1). At that time, the door of the room was closed. When the sampling moved to the next, carbon dioxide concentration was

changed. Furthermore, when the window was opened outside air mix with the room air, as a result of this action, a significant turbulence in indoor environment was observed which resulted in a decrease of CO_2 concentration. Collected samples results were shown in Figure 3.1, 3.2, 3.3.

Table 3.1 Air quality monitoring results (average values of all parameters) in Fatih University Kindergarten.

Location	Bioaerosols (cfu/mL)		PM Mass (µg/m³)						CO	Temperature	Humidity
	Fungi	Bacteria	0.3	0.5	1	2	3	5	(ppm)	(°C)	(%)
kitchen	4	18	4.13	16.12	40.31	108.49	129.97	66.96	1814	26	54
first room	40	90	1.47	4.08	6.82	23.20	41.83	56.19	2058	26	51
second room	16	50	1.05	2.70	3.98	12.75	22.01	27.53	1834	26	50
third room	0	132	1.18	3.05	4.29	13.34	23.21	30.27	2203	27	51
fourth room	318	402	0.92	2.40	4.40	16.01	30.30	44.37	2186	27	51
playing room	58	178	0.62	1.61	3.68	14.32	26.91	37.58	2009	22	59
fifth room	4	12	0.53	1.23	2.16	7.51	13.53	18.52	1400	23	51
sleeping room	60	254	0.78	2.09	4.50	16.34	28.95	36.05	3365	24	63

ASRAE CO_2 Standard: 1000 ppm, Humidity: 30-60 %, Temperature (at summer): 22,7-26,1 ºC.

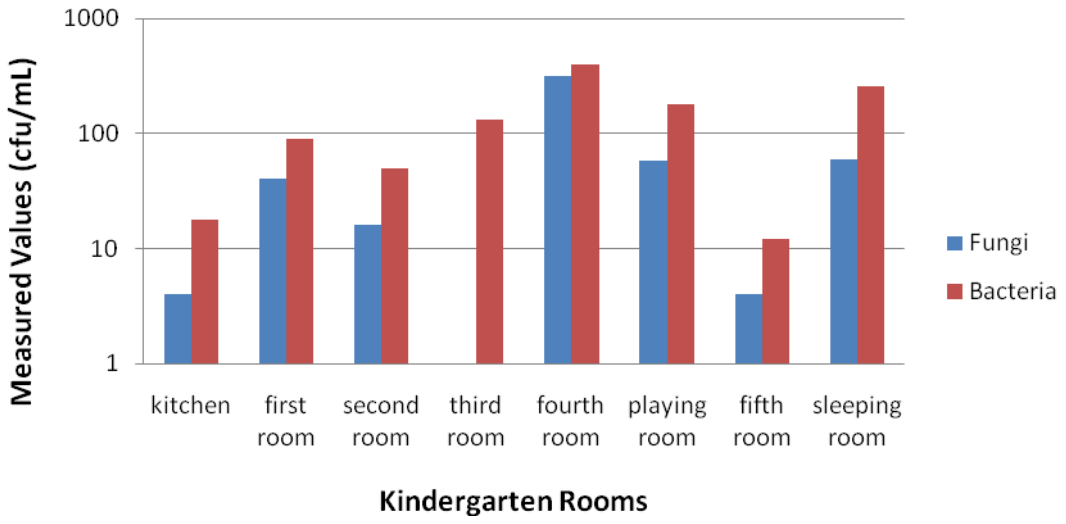

Figure 3.1 Bioaerosol Concentration of Kindergarten samples.

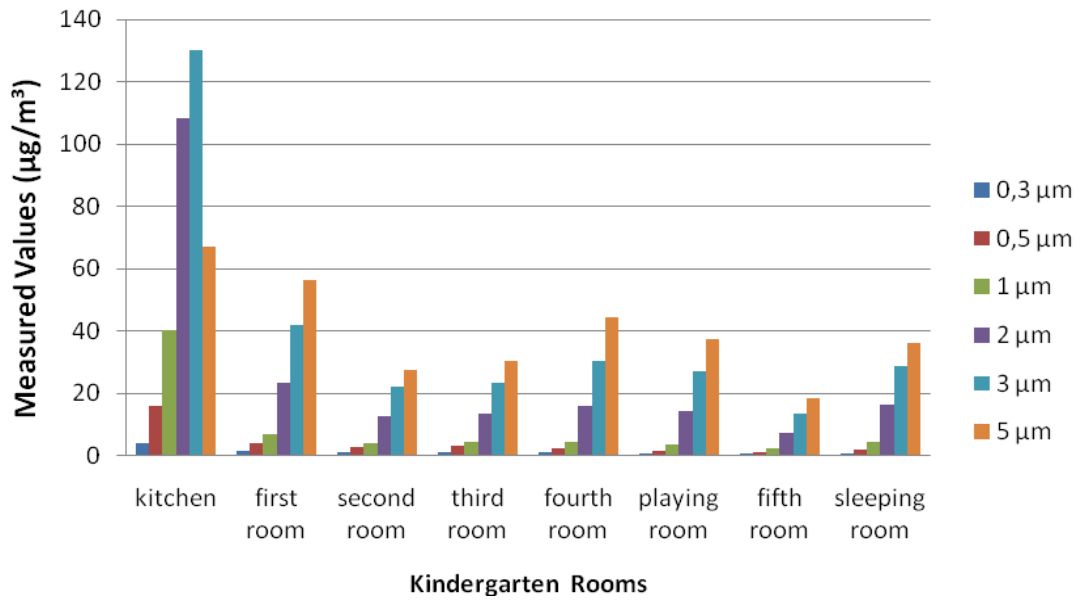

Figure 3.2 Particulate Matter Concentration of Kindergarten samples.

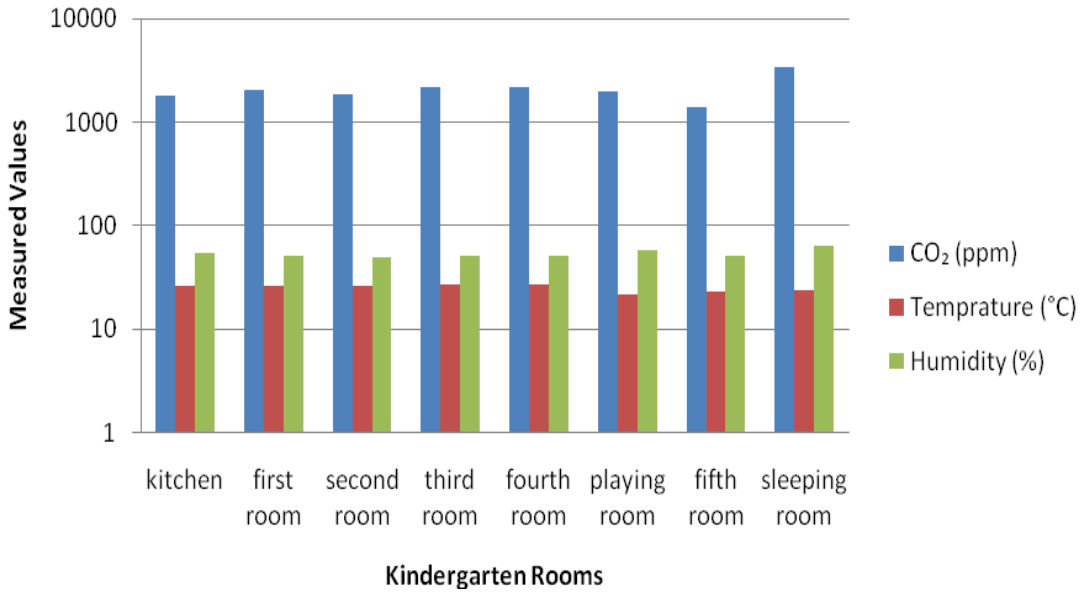

Figure 3.3 Particulate Matter Concentration of Kindergarten samples.

3.1.1.2 Air quality monitoring in shopping center_1

The air quality parameters in the shopping mall were measured on second of May 2010. The temperature, carbon dioxide, humidity and biological pollutants were recorded in a shopping center (Shopping Center _1) at several places (Floor 1, 2, 3 and Fast food) during a weekday and a weekend (Weekday and weekend). Each sampling was performed in different regions on the same floor. Ten points were selected in total. This shopping center_1 was ventilated using mechanical ventilation and air-conditioning systems. Anti-smoking policy was in progress in this monitoring site. There were people activities in all floors. This shopping centre is a very big and crowded one and maybe one of the biggest in Istanbul. So for this reason the different locations were chosen e.g., in first floor two different points, and in fast food floor four different points. Collected samples results were shown in from Figure 3.4 to 3.9 for weekday and weekend day measurements, respectively. The results of microorganism culture were different from our place to another and fast food floor environment had the highest contamination by bacteria and fungi. There was a different change in characteristics for CO_2 levels between the rooms ranging from 710 to 985 ppm. When the ventilation was opened, carbon dioxide concentration in floors was changed and outside air entered the shop very fast. As a result of this action, a significant turbulence in indoor environment was achieved and that resulted in a decreased CO_2 concentration. Results are summarized in Table 3.2 and Table 3.3 for weekday and weekend day measurements, respectively.

Table 3.2 Air quality monitoring results (average values of all parameters) in shopping center_1 (Weekend-02.05.2010).

Location	Bioaerosols (cfu/mL)		PM Mass (µg/m³)						CO	Temperature	Humidity
	Fungi	Bacteria	0.3	0.5	1	2	3	5	(ppm)	(°C)	(%)
1.Floor S1	6	12	1.1	1.62	1.4	5.1	9.54	12.86	749	21	38
1.Floor S2	28	34	0.9	1.35	1.39	5.11	9.61	13.99	774	21	37
2.Floor S1	8	32	1.28	2.08	2.01	7.2	13.29	18.07	716	22	35
2.Floor S2	16	12	0.76	1.26	1.71	6.8	13.47	20.72	861	23	34
Fast food S1	26	8	0.65	0.97	1.06	4.06	7.86	12.68	809	23	33
Fast food S2	6	40	0.68	1.1	1.43	5.5	10.54	16.05	983	24	33
Fast food S3	22	36	0.97	1.64	2.16	8.42	16.5	25.78	960	25	31
Fast food S4	2	38	0.72	1.14	1.44	5.62	10.87	16.67	929	23	36
3.Floor S1	10	52	0.64	1.01	1.33	5.22	10.21	16.31	896	25	30
3.Floor S2	10	22	0.58	0.95	1.28	4.98	9.71	14.49	896	25	30

S1: Section 1, S2: Section 2, S3: Section 3, S4: Section 4

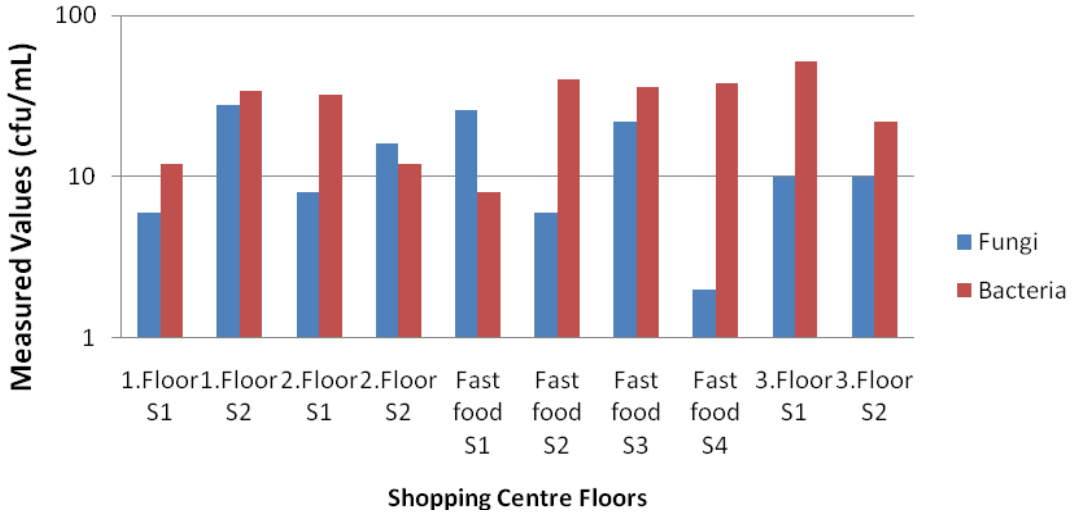

Figure 3.4 Bioaerosol Concentration of Shopping Center_1 samples on weekend.

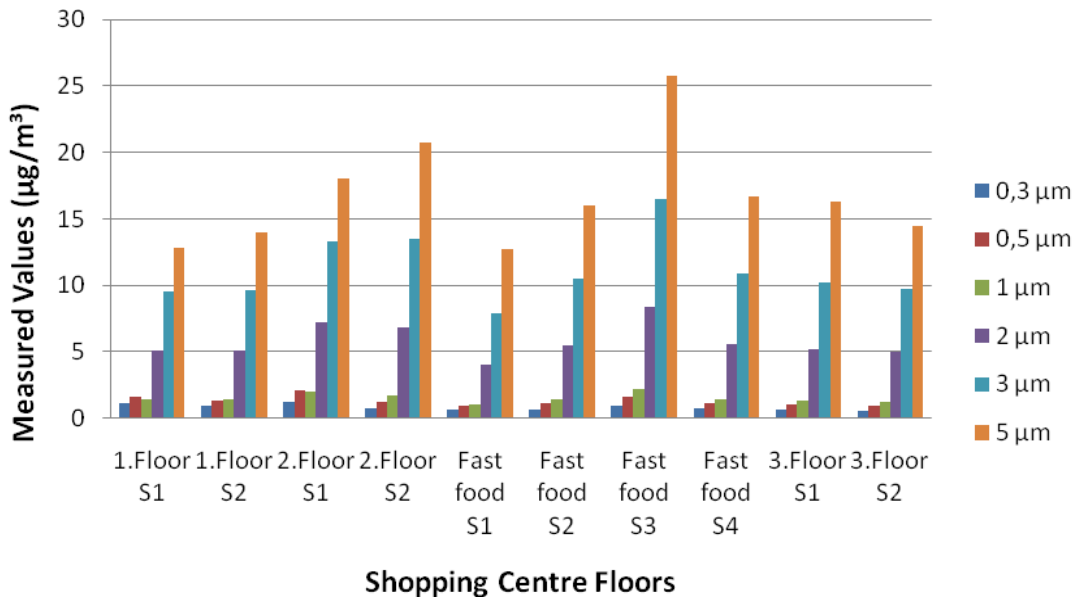

Figure 3.5 Particulate Matter Concentration of Shopping Center_1 samples on weekend.

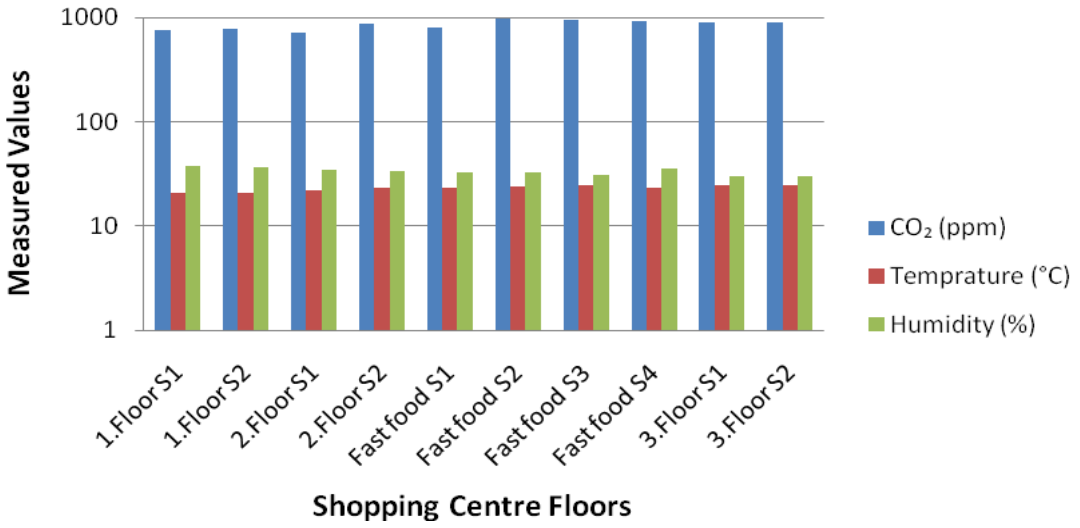

Figure 3.6 Carbon Dioxide, Temperature and Humidity Concentration of Shopping Center_1 samples on weekend.

ASRAE CO_2 Standard: 1000 ppm, Humidity: 30-60 %, Temperature (at summer): 22,7-26,1 ºC.

Table 3.3 Air quality monitoring results (average values of all parameters) in shopping center_1 (Weekday-05.05.2010).

Location	Bioaerosols (cfu/mL)		PM Mass (µg/m³)						CO	Temperature	Humidity
	Fungi	Bacteria	0.3	0.5	1	2	3	5	(ppm)	(°C)	(%)
1.Floor S1	8	14	1.16	1.66	1.27	4.13	7.21	9.47	737	21	49
1.Floor S2	14	4	1.01	1.42	1.09	3.65	6.42	7.66	710	21	49
2.Floor S1	6	74	0.82	1.21	1.25	4.41	8.04	10.69	743	22	46
2.Floor S2	4	32	1.36	2.04	2.15	7.77	13.99	18.00	739	22	45
Fast food S1	6	10	0.63	0.85	0.59	1.95	3.42	4.51	774	21	45
Fast food S2	6	22	0.58	0.82	0.75	2.65	5.03	8.14	858	23	43
Fast food S3	6	10	0.89	1.27	0.85	2.67	4.85	6.51	833	22	43
Fast food S4	6	14	0.71	1.01	0.81	2.71	5.05	7.00	794	22	43
3.Floor S1	8	10	0.73	1.04	0.82	2.79	4.94	6.75	798	24	38
3.Floor S2	8	10	0.88	1.27	0.81	2.68	4.83	6.82	802	23	41

S1: Section 1, S2: Section 2, S3: Section 3, S4: Section 4.

ASRAE CO_2 Standard: 1000 ppm, Humidity: 30-60 %, Temperature (at summer): 22,7-26,1 ºC.

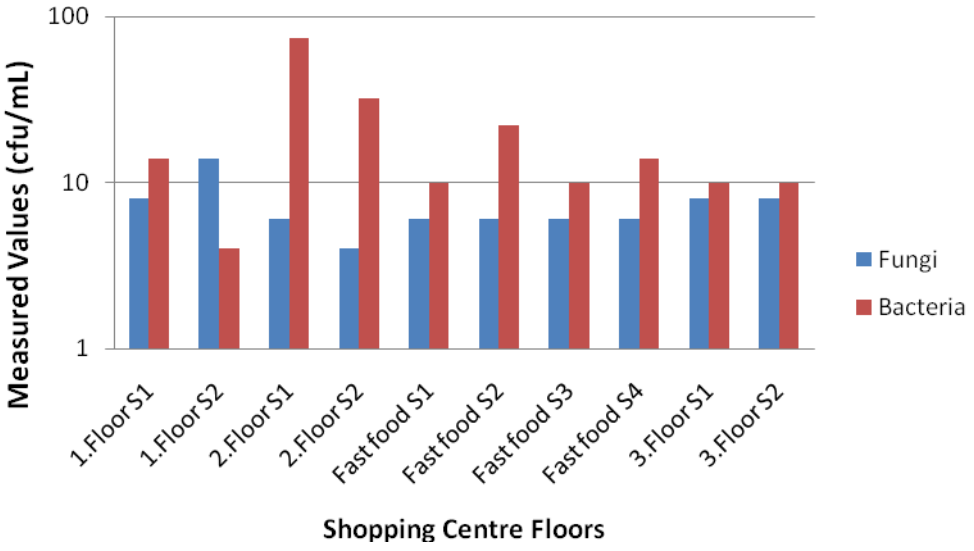

Figure 3.7 Bioaerosol Concentration of Shopping Center_1 samples on weekday.

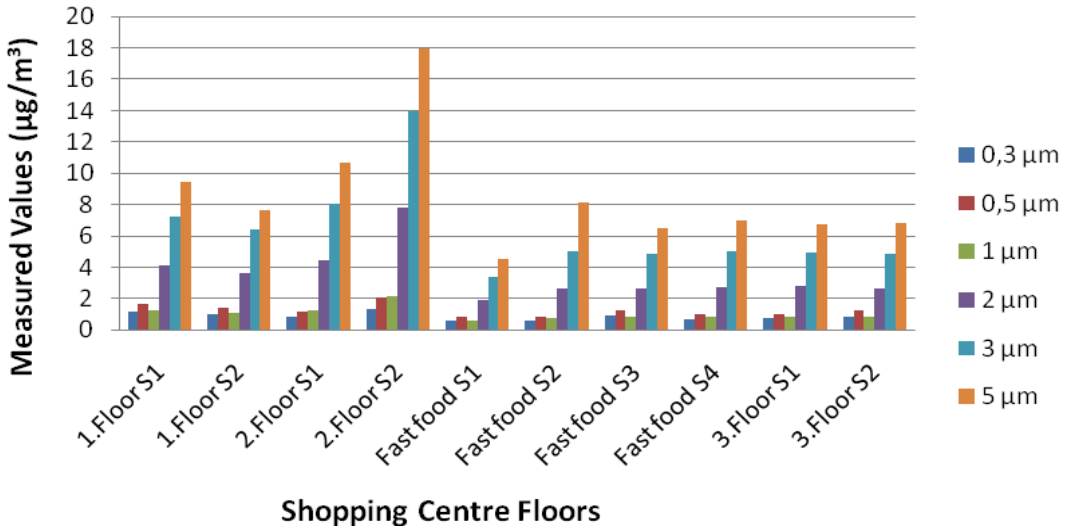

Figure 3.8 Particulate Matter Concentration of Shopping Center_1 samples on weekday.

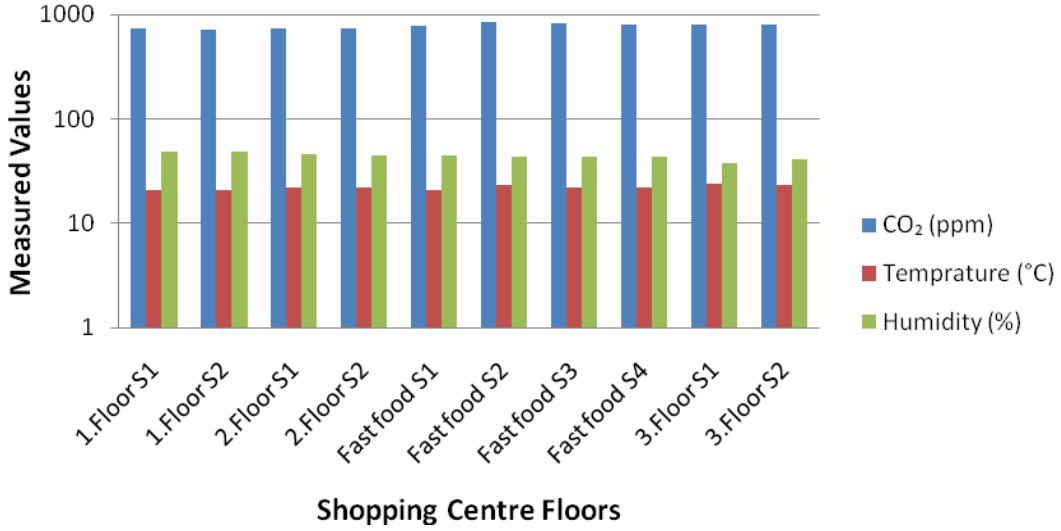

Figure 3.9 Carbon Dioxide, Temperature and Humidity Concentration of Shopping Center_1 samples on weekday.

3.1.1.3 Air quality monitoring (all parameters) in shopping center_2 (12/16.05.2010).

All parameters were applied with same protocol to another shopping center (Shopping Center _2). Each sampling was performed at different regions on the same

floor. Fourteen points were selected in total. This shopping center_2 was ventilated using mechanical ventilation and air-conditioning systems. This shopping centre is very big and crowded, too. CO_2 level was changed from 840 to 1115 ppm. Results are summarized in Table 3.4 and Table 3.5 for weekday and weekend day measurements, respectively.

Table 3.4 Air quality monitoring results (average values of all parameters) in shopping center_2 (Weekday-12.05.2010).

Location	Bioaerosols (cfu/mL)		PM Mass (µg/m^3)						CO_2	Temperature	Humidity
	Fungi	Bacteria	0.3	0.5	1	2	3	5	(ppm)	(°C)	(%)
1.Floor S1	54	28	0.45	0.72	1.21	5.2	10.5	15.2	891	26	39
1.Floor S2	32	102	0.38	0.57	0.56	2.16	4.26	6.97	934	26	39
1.Floor S3	10	244	0.37	0.58	0.87	3.74	7.59	12.3	952	26	40
2.Floor S1	16	168	0.38	0.57	0.82	3.43	6.9	11.1	969	26	36
2.Floor S2	10	222	0.43	0.7	1.07	4.57	9.5	15.5	1011	27	35
2.Floor S3	28	194	0.41	0.61	0.69	2.75	5.49	9.07	939	26	37
3.Floor S1	48	208	0.41	0.63	0.94	4.02	8.37	15.6	891	26	36
3.Floor S2	106	38	0.37	0.5	0.52	2.13	4.43	7.31	890	26	35
3.Floor S3	38	152	0.51	0.74	0.87	3.57	7.22	11.7	842	25	38
3.Floor S4	42	156	0.62	0.93	0.98	3.84	7.67	12.8	897	26	35
Fast Food S1	26	120	0.5	0.66	0.66	0.56	2.08	4.08	867	25	37
Fast Food S2	36	112	0.73	1.12	0.87	3.07	5.95	9.49	844	26	34
Fast Food S3	152	94	0.46	0.64	0.72	2.82	5.37	8.4	1115	27	35
Fast Food S4	48	52	0.5	0.7	0.78	3.1	6.29	10.9	910	27	33

S1: Section 1, S2: Section 2, S3: Section 3, S4: Section 4

In Table 3.4, it is observed that there were changes in the concentration of parameters in the shopping centers_2 (Weekend). Shopping center_2 results were shown on Figures.

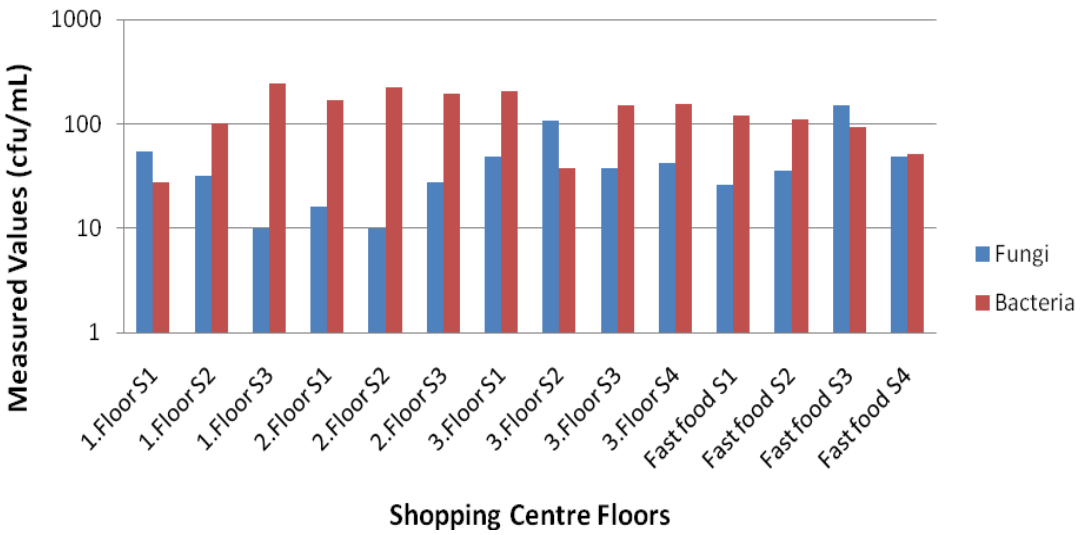

Figure 3.10 Bioaerosol Concentration of Shopping Center_2 samples on weekday.

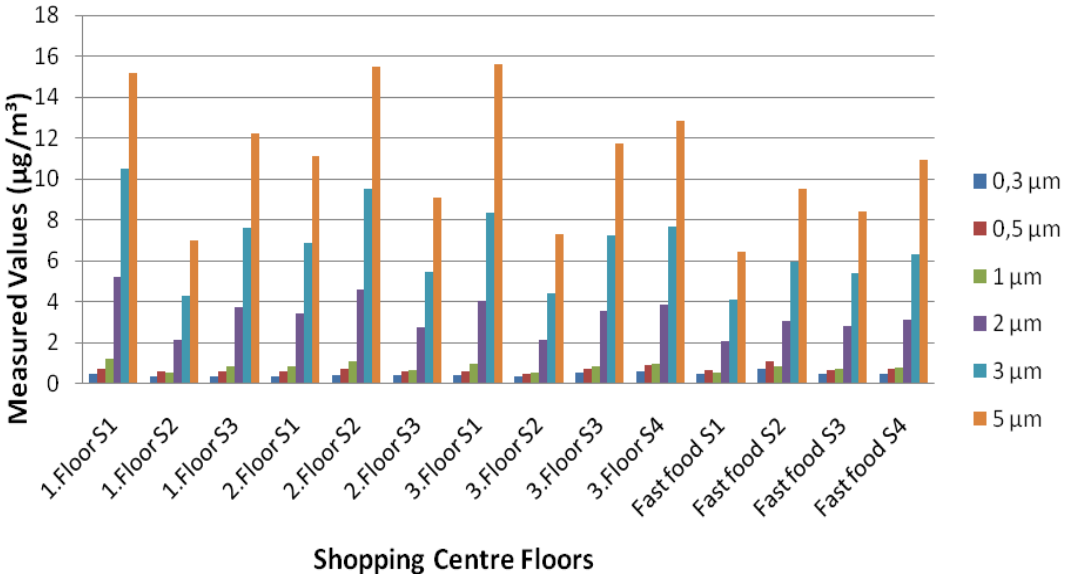

Figure 3.11 Particulate Matter Concentration of Shopping Center_2 samples on weekday.

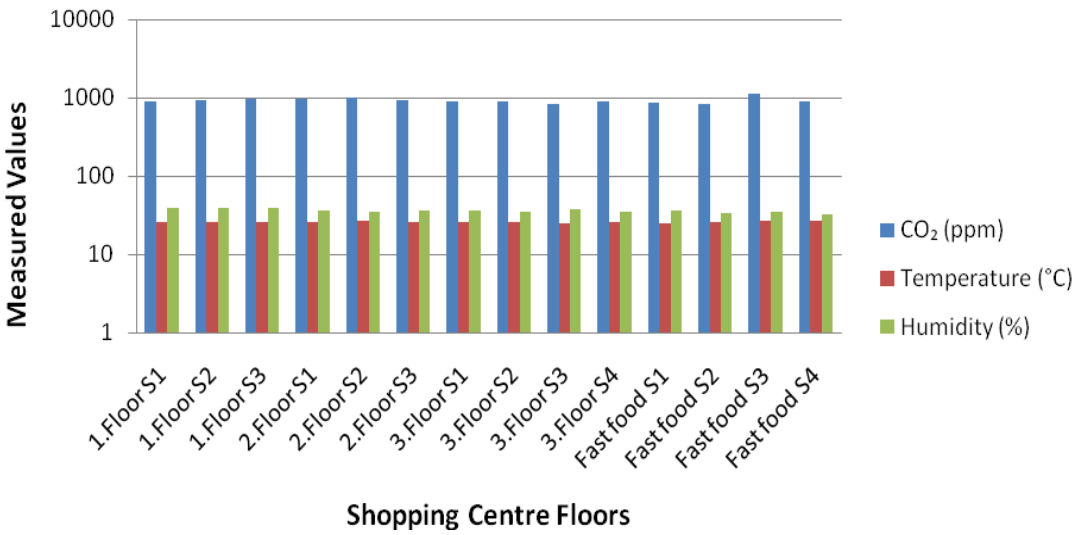

Figure 3.12 Carbon Dioxide, Temperature and Humidity Concentration of Shopping Center_2 samples on weekday.

ASRAE CO_2 Standard: 1000 ppm, Humidity: 30-60 %, Temperature (at summer): 22,7-26,1 ºC.

Table 3.5 Air quality monitoring results (average values of all parameters) in shopping center_2 (Weekend-16.05.2010).

Location	Bioaerosols (cfu/mL)		PM Mass (µg/m^3)						CO_2	Temperature	Humidity
	Fungi	Bacteria	0.3	0.5	1.0	2.0	3.0	5.0	(ppm)	(°C)	(%)
1.Floor S1	20	202	0.25	0.50	1.02	4.46	9.19	14.72	859	25	37
1.Floor S2	42	106	0.20	0.33	0.44	1.77	3.48	5.73	854	25	35
1.Floor S3	34	238	0.41	0.63	0.67	2.68	5.39	9.50	860	25	37
2.Floor S1	16	38	0.24	0.41	0.58	2.40	4.75	7.85	850	24	37
2.Floor S2	46	252	0.32	0.57	0.97	4.20	8.85	16.01	846	26	36
2.Floor S3	20	150	0.34	0.65	1.25	5.40	10.88	18.11	946	26	35
3.Floor S1	26	60	0.36	0.66	1.10	4.53	9.00	14.70	1069	26	35
3.Floor S2	6	24	0.30	0.59	1.03	4.34	8.71	14.80	924	25	34
3.Floor S3	42	322	0.19	0.43	1.06	4.74	9.65	15.95	945	24	38
3.Floor S4	26	320	0.30	0.61	1.27	5.42	11.02	18.24	982	26	36
Fast food S1	22	296	0.29	0.57	1.07	4.55	9.17	14.85	964	25	36
Fast food S2	92	340	0.38	0.71	1.20	4.95	10.08	16.26	1125	27	36
Fast food S3	78	378	0.34	0.73	1.54	6.53	13.45	22.34	1147	26	36
Fast food S4	76	254	0.39	0.82	1.59	6.70	13.41	22.78	1127	26	36

S1: Section 1, S2: Section 2, S3: Section 3, S4: Section 4

ASRAE CO_2 Standard: 1000 ppm, Humidity: 30-60 %, Temperature (at summer): 22,7-26,1 ºC.

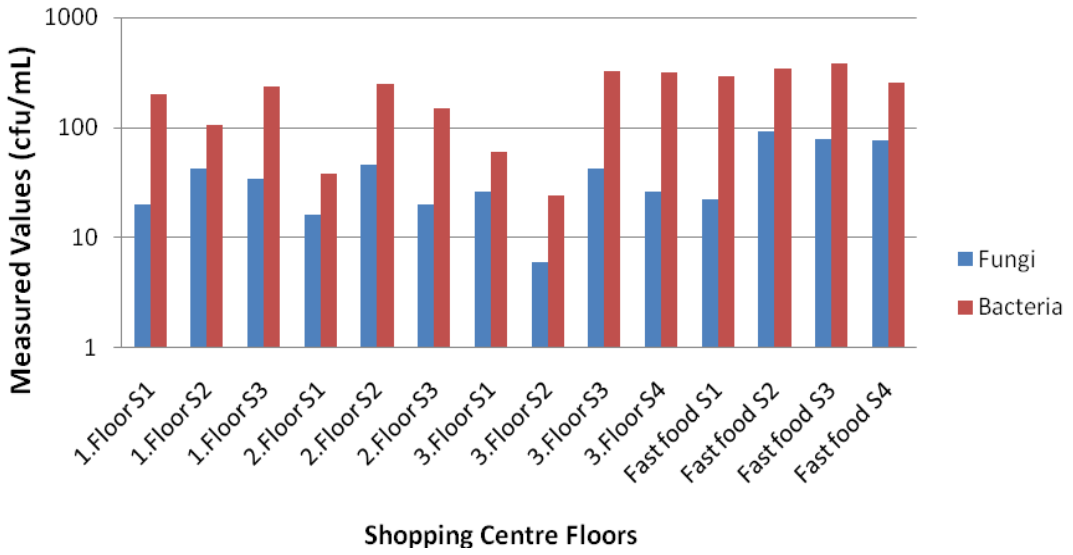

Figure 3.13 Bio aerosol Concentration of Shopping Center_2 samples on weekend.

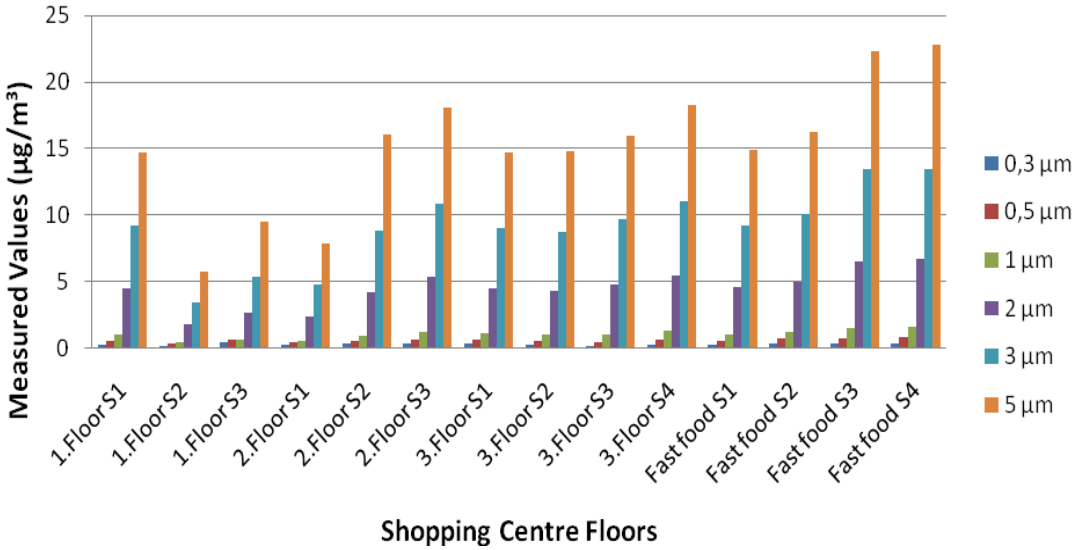

Figure 3.14 Particulate Matter Concentration of Shopping Center_2 samples on weekend.

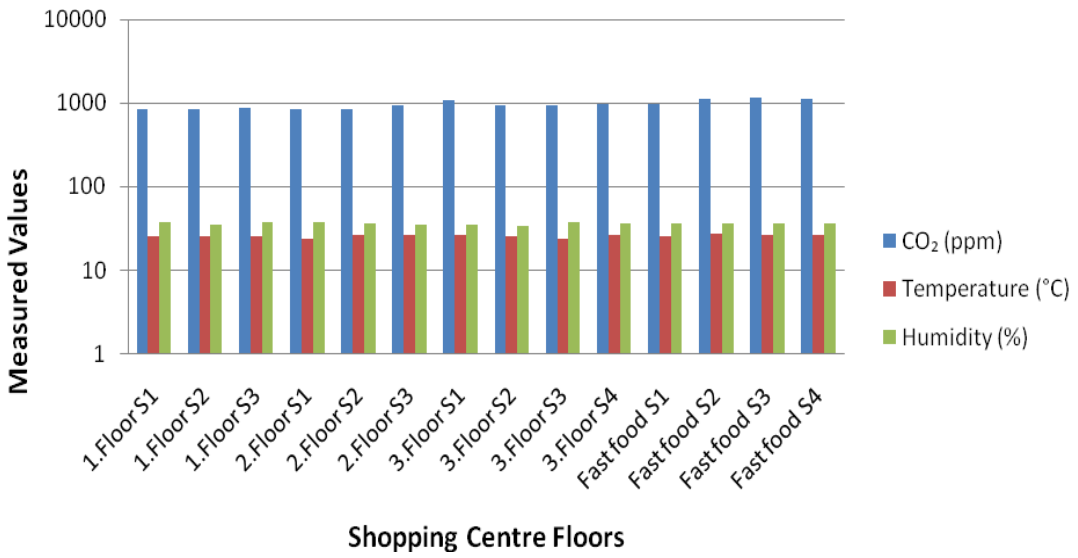

Figure 3.15 Carbon Dioxide, Temperature and Humidity Concentration Shopping Center_2 samples on weekend.

3.1.1.4 Air quality monitoring (all parameters) in a selected house in Istanbul (12/16.05.2010).

All parameters were collected in the house. Each sampling was performed in different regions in the rooms. Fourteen points were selected in total. This home was ventilated with fresh air. This home has 4 rooms. CO_2 level was changed from 873 to 2124 ppm. Results are summarized in Table 3.6 for weekday measurements.

Table 3.6 Air quality monitoring results (average values of all parameters) in Home.

Location	Bioaerosols (cfu/mL)		PM Mass (µg/m^3)						CO_2	Temperature	Humidity
	Fungi	Bacteria	0.3	0.5	1	2	3	5	(ppm)	(°C)	(%)
Kitchen S1	68	400	2.90	3.92	2.26	6.32	10.10	12.47	2124	29.1	67.4
Kitchen S2	48	100	2.41	3.64	1.83	4.82	7.25	7.32	1714	29.2	67.4
Kitchen S3	90	196	1.91	3.04	2.49	6.95	10.30	10.26	1906	29.1	69.1
Entrance S1	194	420	1.47	1.99	1.97	7.09	13.26	20.10	1063	27.7	62.7
Entrance S2	124	500	1.38	1.79	1.42	4.52	7.63	9.13	1358	28	64
Living Room S1	158	594	1.46	1.99	1.63	5.40	9.39	13.38	873	27.8	62.4
Living Room S2	98	326	1.65	2.30	2.07	7.01	12.44	16.47	1156	28.1	63.1
Bed Room S1	164	218	1.87	2.53	1.51	4.47	7.44	9.22	908	27.5	60.6
Bed Room S2	238	486	1.71	2.40	1.90	6.43	11.45	16.11	1028	27.5	60.9

S1: Section 1, S2: Section 2.

ASRAE CO_2 Standard: 1000 ppm, Humidity: 30-60 %, Temperature (at summer): 22,7-26,1 ºC.

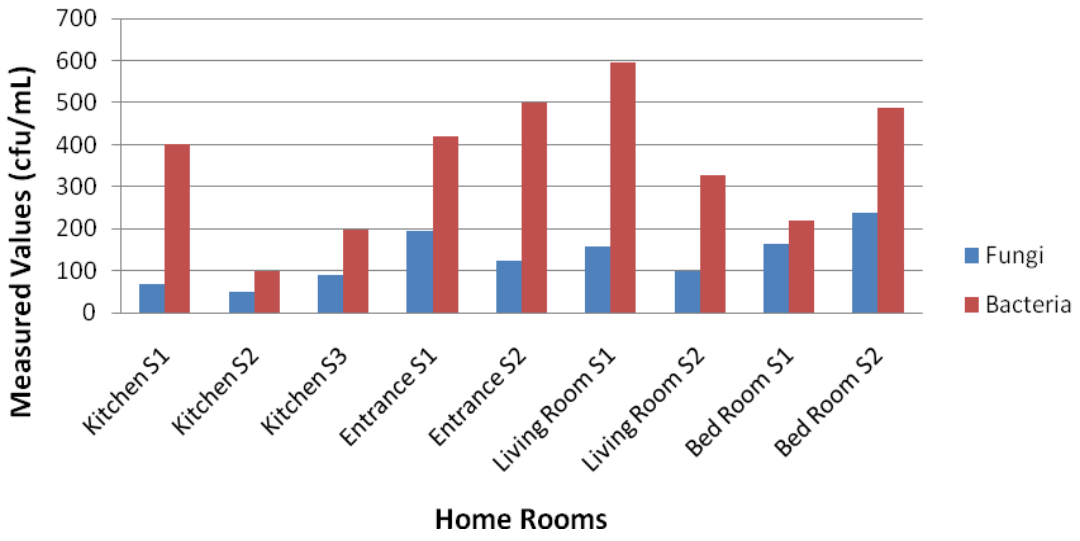

Figure 3.16 Bio aerosol Concentration of Homes samples.

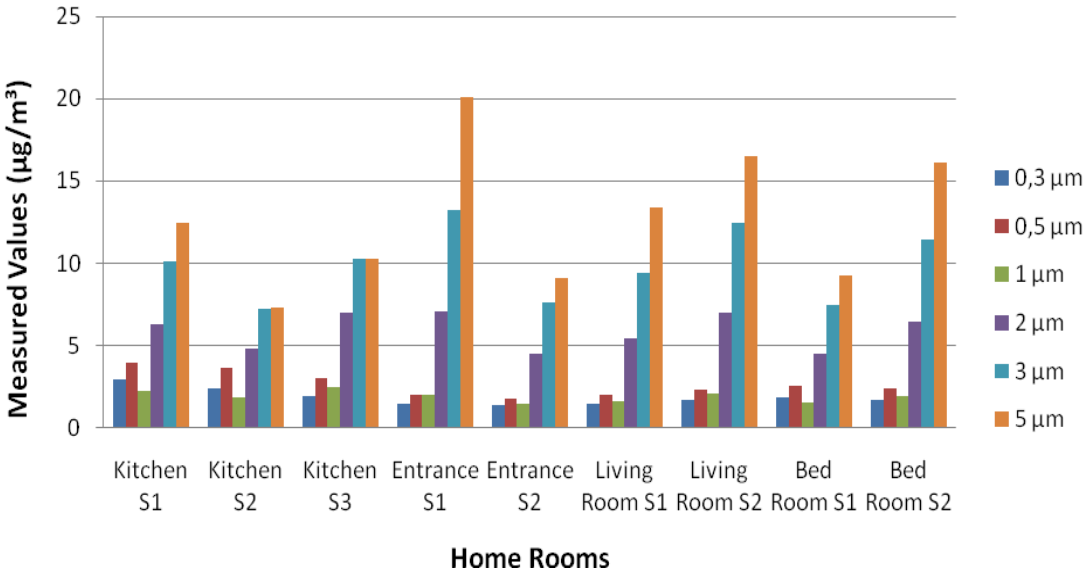

Figure 3.17 Particulate Matter Concentration of Shopping Center_2 samples on weekend.

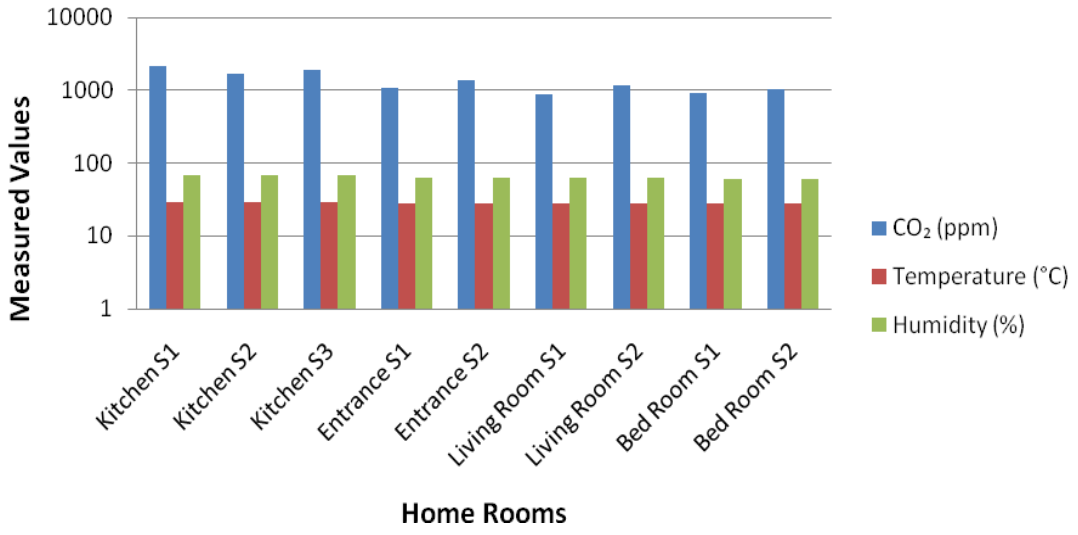

Figure 3.18 Carbon Dioxide, Temperature and Humidity Concentration at Home.

3.2 STATISTICAL ANALYSIS

3.2.1 Correlation Statistics of IAQPs

In this part, correlation analysis we are performed to explain the relationships between the measured parameters in the rooms and living areas within the same and all the studied buildings.

These analyses can be used to quantify not only the relations between the places but also the relations within the quality indicators. In the former parts of each discussion topics the results related to places and their connections with regard to indoor air quality subjects are discussed in detail. After that, cause and effects of air quality indicators with respect to their quantities and their inter correlations followed.

In order to perform a reliable correlation analysis all measured/monitored parameters were normalized to [0, 1] scale. A basic normalization equation was applied in the normalization process and that equation can be given as follows:

CN = [(CA)-(MinRange)]/[(MaxRange)-(MinRange)]
Where;
CN = normalized value,
CA = actual value,
MinRange = minimum value of the selected value range
MaxRange = maximum value of the selected value range

3.2.1.1. Kindergarten

Firstly, correlation analysis we are applied to kindergarten data set. This data set consist of eight different places/rooms, namely; Kitchen, First room, Second room, Third room, Fourth room, Playing room, Fifth room, and Sleeping room. Details of the places were previously discussed. Obtained correlation results are given in Table 3.7. One of the most interesting results indicated by negative correlations was obtained between kitchen and some rooms. This result was obtained due to low level of bioaerosols accompanied by high level of other type of particulate matters in kitchen.

This situation was completely different in the rooms which have negative correlation with kitchen. It is surprising that bio-aerosols are in low level in the kitchen, but due to indoor burning activities carried out by kitchen oven can be the main factor stimulating the high level of PM. Fourth, playing and sleeping rooms are enriched by bio aerosols and carbon dioxide which is a typical air quality indication of being deficient in good ventilation for biologically active environments. Another significant result obtained as high level of positive correlations. These types of positive correlations were observed between living and activity rooms. The most significant one was second and third rooms. These rooms have similar physical properties (volume, amount of people in, side of building and ventilation characteristics) and they are connected to each other.

Table 3.7 Correlation table for rooms in kindergarten with regard to air quality indicators.

	kitchen	*first room*	*second room*	*third room*	*fourth room*	*playing room*	*fifth room*	*sleeping room*
Kitchen	1.00							
first room	0.31	1.00						
second room	0.18	0.83	1.00					
third room	0.03	0.80	0.96	1.00				
fourth room	-0.55	0.46	0.50	0.54	1.00			
playing room	-0.60	-0.14	-0.31	-0.14	0.09	1.00		
fifth room	0.06	0.61	0.89	0.82	0.43	-0.11	1.00	
sleeping room	-0.64	0.07	0.13	0.33	0.21	0.79	0.23	1.00

Above mentioned values gave very indicative results to understand the behavior of air quality within a certain type of living area. In addition to those analyses an additional correlation test was performed between the parameters for studied kindergarten and the results are summarized in Table 3.8. Firstly, a high level of positive correlation was observed between fungi and bacteria counts. This can be related to similar behavior of bioaerosols in living aerosols. It means that under similar environmental conditions, fungi and bacteria can grow in similar or in a correlation. On the other hand, while a positive correlation was being observed between carbon dioxide and bacteria the relationship between carbon dioxide and fungi was not the same level. This can be related by the common sources of bacteria and carbon dioxide than can human inhalation. An appropriate conclusion is that a bacterium has similar growth characteristics as fungi but different sources. As a final point, all the stages of PM gave

very high correlations indication similar origins. But the level of correlations has a tendency to decrease while the aerodynamic diameters of particulates are increased. A perfect correlation (R^2=1) between 0.3 and 0.5 micron sized particles was obtained while the level was decreased to 0,79 for 0.3 and 5.0 micron sized groups. This is an indication of contribution of physical activity related dust generation to higher level of PM ranges which have altering affects on the typical behavior of PM levels.

Table 3.8 Correlation table for air quality indicators observed in kindergarten rooms.

	Fungi	*Bacteria*	*1st stage*	*2nd stage*	*3rd stage*	*4th stage*	*5th stage*	*6th stage*	*CO_2*	*Temperature*	*Humidity*
Fungi	1.00										
Bacteria	0.88	1.00									
1st stage	-0.23	-0.38	1.00								
2nd stage	-0.23	-0.38	1.00	1.00							
3rd stage	-0.21	-0.36	0.98	1.00	1.00						
4th stage	-0.19	-0.33	0.98	0.99	1.00	1.00					
5th stage	-0.15	-0.29	0.98	0.99	0.99	1.00	1.00				
6th stage	0.14	0.03	0.79	0.77	0.76	0.78	0.83	1.00			
CO_2	0.20	0.59	-0.18	-0.19	-0.17	-0.15	-0.12	0.07	1.00		
Temperature	0.23	0.10	0.44	0.38	0.30	0.30	0.32	0.43	0.04	1.00	
Humidity	-0.09	0.28	-0.05	-0.01	0.06	0.07	0.08	0.08	0.72	-0.53	1.00

3.2.1.2 Shopping Center_1

Secondly, correlation analysis was applied to shopping center_1 data sets. These data sets consist of three different floors which included fast food part. They were namely; first floor, second floor, and third floor. Third Floor was included Fast food part. Details of the places were previously discussed. Correlation matrices were calculated based on floors, parameters and obtained correlation results were given in Table 3.9. Daily correlation of measured parameters showed discrepancy. One of the most interesting results indicated by negative correlations was obtained between first floor and some floor. This result was obtained due to low level of bio aerosols accompanied by high level of other type of particulate matters in first. This situation was completely different in the floors which have negative correlation with first floor section_1. First floor Section_2 has significant correlation only with Fast food section three. It is surprising that bio-aerosols are in low level in first floor, but due to indoor

burning activities carried out by fast food part oven can be the main factor stimulating the high level of PM. Another significant result was obtained as high level of positive correlations. These types of positive correlations were observed between living and activity floors. The most significant one was fast food floors. This floor has similar physical properties (volume, amount of people in, side of building and ventilation characteristics) and they are connected to each other.

Table 3.9 Correlation table in shopping center_1 floors on weekend with regard to air quality indicators.

	1. Floor S1	**1. Floor S2**	**2.Floor S1**	**2. Floor S2**	**Fast food S1**	**Fast food S2**	**Fast food S3**	**Fast food S4**	**3.Floor S1**	**3. Floor S2**
1. Floor S1	1.00									
1. Floor S2	0.45	1.00								
2. Floor S1	0.60	0.03	1.00							
2. Floor S2	-0.28	-0.31	-0.30	1.00						
Fast food S1	-0.04	0.58	-0.62	0.13	1.00					
Fast food S2	-0.45	-0.30	-0.67	-0.09	0.08	1.00				
Fast food S3	-0.81	-0.66	-0.24	0.57	-0.23	0.16	1.00			
Fast food S4	-0.03	-0.17	-0.42	-0.12	-0.09	0.84	-0.20	1.00		
3. Floor S1	-0.69	-0.23	-0.63	-0.25	0.13	0.83	0.26	0.55	1.00	
3. Floor S2	-0.65	-0.36	-0.78	0.14	0.39	0.77	0.38	0.43	0.82	1.00

Above mentioned values gave very indicative results to understand the behavior of air quality within a curtain type of living area. In addition to those analyses an additional correlation test was performed between the parameters for studied shopping center_1 and the results are summarized in Table 3.10. Firstly, negative correlation was observed between fungi and bacteria counts. This can be related to similar behavior of bio aerosols in living aerosols. It means that under similar environmental conditions, fungi and bacteria can grow in similar or in a correlation. On the other hand, while a positive correlation was being observed between carbon dioxide and bacteria the relationship between carbon dioxide and fungi was not the same level. This can be related by the common sources of bacteria and carbon dioxide than can be human inhalation. Our conclusion is a bacterium has a similar grown in characteristics by fungi but different sources. As a final point, all the stages of PM gave very high correlations indication similar origins. But the level of correlations has a tendency to decrease while the aerodynamic diameters of particulates are increased. A perfect correlation (R^2=1) between 0.3 and 0.5 micron sized particles was obtained while the level was decreased

to 0,79 for 0.3 and 5.0 micron sized groups. This is the indication of contribution of physical activity related dust generation to higher level of PM ranges which have altering affects on the typical behavior of PM levels.

Table 3.10 Correlation table for air quality indicators observed in shopping center_1 floors on weekend.

	Fungi	Bacteria	1st stage	2nd stage	3rd stage	4th stage	5th stage	6th stage	CO_2	Temperature	Humidity
Fungi	1.00										
Bacteria	-0.26	1.00									
1st stage	-0.05	-0.07	1.00								
2nd stage	-0.05	-0.01	0.98	1.00							
3rd stage	-0.02	0.21	0.65	0.77	1.00						
4th stage	0.00	0.23	0.52	0.66	0.98	1.00					
5th stage	0.02	0.22	0.43	0.58	0.96	0.99	1.00				
6th stage	0.10	0.26	0.22	0.37	0.86	0.94	0.97	1.00			
CO_2	-0.18	0.45	-0.63	-0.53	0.03	0.18	0.25	0.43	1.00		
Temperature	-0.12	0.40	-0.69	-0.57	-0.05	0.09	0.16	0.34	0.83	1.00	
Humidity	-0.06	-0.32	0.56	0.43	-0.04	-0.14	-0.20	-0.35	-0.61	-0.93	1.00

Thirdly, correlation analysis was applied to shopping center_1 data sets. These data sets consist of three different floors, namely; first floor, second floor, third floor and fast food floor. Details of the places were previously discussed. Obtained correlation results are given in Table 3.11. An interesting point of parameter the weekday correlations are observed for fast food floors. The most interesting results indicated by negative correlations were obtained between second floors sections and some floor. This result was obtained due to low level of bio aerosols accompanied by high level of other type of particulate matters in first. This situation was completely different in the floors which have negative correlation with first floor. It is surprising that bio-aerosols are in low level in second floor section_2, but due to indoor burning activities carried out by fast food part oven can be the main factor stimulating the high level of PM. Another significant result was obtained as high level of positive correlations. These types of positive correlations were observed between living and activity floors. The most significant one was fast food floors sections, between fast food section_2 to fast food section_4.

Table 3.11 Correlation table in shopping center_1 floors on weekday with regard to air quality indicators.

	1.Floor S1	1.Floor S2	2.Floor S1	2.Floor S2	Fast food S1	Fast food S2	Fast food S3	Fast food S4	3.Floor S1	3.Floor S2
1.Floor S1	1.00									
1.Floor S2	0.77	1.00								
2.Floor S1	0.04	-0.08	1.00							
2.Floor S2	0.39	-0.05	0.06	1.00						
Fast food S1	0.30	0.34	0.12	-0.57	1.00					
Fast food S2	-0.37	-0.33	-0.09	-0.64	0.70	1.00				
Fast food S3	0.16	-0.01	-0.35	-0.37	0.71	0.74	1.00			
Fast food S4	-0.04	-0.08	-0.16	-0.58	0.86	0.93	0.86	1.00		
3.floor S1	-0.51	-0.38	-0.54	-0.58	0.19	0.58	0.42	0.57	1.00	
3.floor S2	-0.13	-0.10	-0.59	-0.56	0.45	0.61	0.73	0.72	0.88	1.00

Above mentioned values gave very indicative results to understand the behavior of air quality within a curtain type of living area. In addition to those analyses additional correlation test was performed on between the parameters for studied shopping center_1 and the results are summarized in Table 3.12. Firstly, negative correlation was observed between fungi and bacteria counts. This can be related to similar behavior of bio aerosols in living aerosols. It means that under similar environmental conditions, fungi and bacteria can grow in similar or in a correlation. On the other hand, while a negative correlation was being observed between carbon dioxide and bacteria the relationship between carbon dioxide and fungi was the same level. This can be related by the common sources of bacteria and carbon dioxide than can be working area situation. Our conclusion is a bacterium has a similar grown in characteristics by fungi. As a final point, all the stages of PM gave very high correlations indication similar origins. But the level of correlations has a tendency to decrease while the aerodynamic diameters of particulates are increased. A perfect correlation (R^2=1) between 0.3 and 0.5 micron sized particles was obtained while the level was decreased to 0,79 for 0.3 and 5.0 micron sized groups. This is the indication of contribution of physical activity related dust generation to higher level of PM ranges which have altering affects on the typical behavior of PM levels.

Table 3.12 Correlation table for air quality indicators observed shopping center_1 floors on weekday.

	Fungi	*Bacteria*	*1st stage*	*2nd stage*	*3rd stage*	*4th stage*	*5th stage*	*6th stage*	*CO_2*	*Temperature*	*Humidity*
Fungi	1.00										
Bacteria	-0.41	1.00									
1st stage	0.06	0.07	1.00								
2nd stage	0.01	0.12	1.00	1.00							
3rd stage	-0.21	0.41	0.88	0.91	1.00						
4th stage	-0.24	0.44	0.84	0.87	1.00	1.00					
5th stage	-0.26	0.46	0.82	0.85	0.99	1.00	1.00				
6th stage	-0.35	0.50	0.76	0.80	0.97	0.98	0.99	1.00			
CO_2	-0.41	-0.22	-0.63	-0.61	-0.58	-0.55	-0.52	-0.42	1.00		
Temperature	-0.25	-0.12	-0.38	-0.35	-0.31	-0.28	-0.27	-0.20	0.63	1.00	
Humidity	0.34	0.17	0.44	0.41	0.35	0.31	0.29	0.23	-0.68	-0.96	1.00

3.2.1.3 Shopping Center_2

Correlation analysis data sets were calculated to shopping center_2. These data sets consist of four different floors, namely; first floor, second floor, third floor and fast food floor. Details of the places were previously discussed. Obtained correlation results are given in Table 3.13. An interesting point of parameter the weekday correlations are observed for fast food floors. The most interesting results indicated by negative correlations were obtained between third floors section_3 and fast food section_3. This result was obtained due to low level of bio aerosols accompanied by high level of other type of particulate matters in first. This situation was completely different in the floors which have negative correlation with third floor. It is surprising that bio-aerosols are in low level in third floor section_3, but due to indoor burning activities carried out by fast food part oven can be the main factor stimulating the high level of PM. Another significant result was obtained as high level of positive correlations. These types of positive correlations were observed between living and activity floors.

Table 3.13 Correlation table in shopping center_2 floors on weekday with regard to air quality indicators.

	1.Floor S1	1.Floor S2	1.Floor S3	2.Floor S1	2.Floor S2	2.Floor S3	3.Floor S1	3.Floor S2	3.Floor S3	3.Floor S4	Fast food S1	Fast food S2	Fast food S3	Fast food S4
1.Floor S1	1.00													
1.Floor S2	-0.12	1.00												
1.Floor S3	0.29	0.54	1.00											
2.Floor S1	0.26	0.31	0.87	1.00										
2.Floor S2	0.36	-0.13	0.58	0.86	1.00									
2.Floor S3	-0.22	0.74	0.81	0.73	0.40	1.00								
3.Floor S1	0.45	-0.15	0.65	0.73	0.81	0.36	1.00							
3.Floor S2	-0.21	0.38	-0.21	-0.14	-0.24	0.15	-0.19	1.00						
3.Floor S3	0.49	0.02	0.55	0.21	0.13	0.14	0.49	-0.60	1.00					
3.Floor S4	0.18	-0.41	-0.03	0.07	0.45	-0.06	0.39	-0.35	0.25	1.00				
Fast food S1	-0.45	0.74	0.27	-0.02	-0.31	0.63	-0.28	0.19	0.11	0.02	1.00			
Fast food S2	-0.23	-0.30	-0.47	-0.48	-0.17	-0.25	-0.26	-0.19	-0.02	0.77	0.31	1.00		
Fast food S3	-0.47	0.26	-0.33	-0.12	-0.24	0.07	-0.41	0.80	-0.87	-0.58	0.01	-0.32	1.00	
Fast food S4	0.05	-0.25	-0.34	0.00	0.36	-0.13	0.12	0.41	-0.54	0.55	-0.16	0.43	0.28	1.00

In addition to those analyses an additional correlation test was performed between the parameters for studied shopping center_2 and the results are summarized in Table 3.14. Firstly, positive correlation was observed between fungi and bacteria counts. This can be related to similar behavior of bio aerosols in living aerosols. It means that under similar environmental conditions, fungi and bacteria can grow in similar or in a correlation. On the other hand, while a positive correlation was being observed between carbon dioxide and bacteria the relationship between carbon dioxide and fungi was the same level. This can be related by the common sources of bacteria and carbon dioxide than can be working area situation. Our conclusion is a bacterium has a similar grown in characteristics by fungi. As a final point, all the stages of PM gave very high correlations indication similar origins. A perfect correlation (R^2=1) between 0.3 and 0.5 micron sized particles was obtained for 0.3 and 5.0 micron sized groups. This is the indication of contribution of physical activity related dust generation to higher level of PM ranges which have altering affects on the typical behavior of PM levels. Weekend results were shown in Table 3.15 and 3.16.

Table 3.14 Correlation table for air quality indicators observed in shopping center_2 floors on weekday.

	Fungi	*Bacteria*	*1st stage*	*2nd stage*	*3rd stage*	*4th stage*	*5th stage*	*6th stage*	*CO_2*	*Temperature*	*Humidity*
Fungi	1.00										
Bacteria	0.64	1.00									
1st stage	0.40	0.20	1.00								
2nd stage	0.50	0.37	0.90	1.00							
3rd stage	0.46	0.53	0.48	0.81	1.00						
4th stage	0.43	0.54	0.43	0.77	1.00	1.00					
5th stage	0.44	0.56	0.42	0.76	0.99	1.00	1.00				
6th stage	0.45	0.56	0.45	0.77	0.99	0.99	0.99	1.00			
CO_2	0.68	0.44	0.53	0.77	0.81	0.77	0.76	0.73	1.00		
Temperature	0.48	0.29	0.60	0.71	0.65	0.62	0.62	0.62	0.67	1.00	
Humidity	0.06	0.44	-0.33	-0.33	-0.19	-0.15	-0.14	-0.15	-0.27	-0.64	1.00

Table 3.15 Correlation table for air quality indicators observed in shopping center_2 floors on weekend.

	1.Floor S1	**1.Floor S2**	**1.Floor S3**	**2.Floor S1**	**2.Floor S2**	**2.Floor S3**	**3.Floor S1**	**3.Floor S2**	**3.Floor S3**	**3.Floor S4**	**Fast food S1**	**Fast food S2**	**Fast food S3**	**Fast food S4**
1.Floor S1	1.00													
1.Floor S2	-0.12	1.00												
1.Floor S3	0.11	0.13	1.00											
2.Floor S1	0.46	0.10	0.60	1.00										
2.Floor S2	0.49	0.19	0.32	-0.06	1.00									
2.Floor S3	0.28	-0.54	-0.18	-0.32	0.48	1.00								
3.Floor S1	-0.40	-0.48	-0.27	-0.46	-0.10	0.71	1.00							
3.Floor S2	0.09	-0.75	-0.21	-0.28	0.21	0.92	0.80	1.00						
3.Floor S3	0.65	0.03	-0.02	0.45	-0.06	-0.43	-0.82	-0.48	1.00					
3.Floor S4	0.49	-0.42	-0.26	-0.46	0.50	0.70	0.23	0.50	0.08	1.00				
Fast food S1	0.70	-0.38	0.18	0.09	0.32	0.25	-0.26	0.09	0.54	0.74	1.00			
Fast food S2	-0.78	0.36	-0.13	-0.74	0.04	-0.05	0.34	-0.09	-0.68	-0.06	-0.45	1.00		
Fast food S3	-0.19	-0.41	-0.67	-0.86	-0.03	0.30	0.27	0.33	-0.05	0.58	0.19	0.36	1.00	
Fast food S4	-0.28	-0.75	-0.36	-0.53	-0.07	0.54	0.61	0.76	-0.39	0.28	-0.11	0.15	0.67	1.00

Table 3.16 Correlation table for air quality indicators observed in shopping center_2 floors on weekend.

	Fungi	Bacteria	1st stage	2nd stage	3rd stage	4th stage	5th stage	6th stage	CO_2	Temperature	Humidity
Fungi	1.00										
Bacteria	-0.56	1.00									
1st stage	-0.04	-0.16	1.00								
2nd stage	-0.13	-0.06	0.97	1.00							
3rd stage	-0.26	0.22	0.24	0.41	1.00						
4th stage	-0.26	0.25	0.06	0.24	0.98	1.00					
5th stage	-0.28	0.27	0.02	0.20	0.97	1.00	1.00				
6th stage	-0.30	0.38	0.01	0.18	0.92	0.95	0.97	1.00			
CO_2	0.40	0.17	-0.40	-0.36	-0.02	0.03	0.01	-0.01	1.00		
Temperature	0.36	-0.20	0.20	0.20	0.07	0.03	0.02	0.06	0.48	1.00	
Humidity	-0.31	0.22	-0.45	-0.36	0.11	0.18	0.17	0.06	-0.03	-0.71	1.00

3.3 MICROBIOLOGICAL AIR QUALITY DETERMINATION

Indoor air Samples were collected from 4 sampling sites including; two sampling sites of shopping centers, one sampling site of kindergarten and one sampling site of a selected house. The results of bacterial and fungal culture in plate count agar of air samples showed contamination in indoor air. The relative humidity an effect in increasing number of bacteria in air. The high number of bacteria in air might occur from people activities. Human activities provided a major source of bioaerosol such as aerosol treatment and pathogens.

5 Primer pairs were tested on samples. Bacterial primers were *Micrococcus luteus, Pseudomonas aeruginosa,* and fungal primers were *Stachybotrys chartarum, Aspergillus versicolar and Cladosporium Spp.* 130 points sampled for microorganisms, 65 points for bacteria and points for fungi. Fungi primers were not found in samples after PCR amplification. Only 18S rRNA gen was in samples.

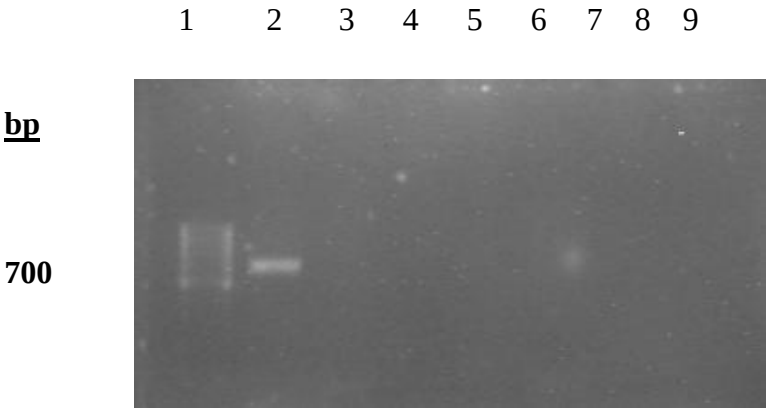

Figure 3.19 Agarose gel (%1) electrophoresis of eight well-isolated fungi colonies amplification by universal primer PCR.

1. line size is a marker. 2. line size is an universal primer and we were showed this primer. Some of our samples are there from 3 to 9 line size. Length of PCR product (bp) is approximately 700 bp. There are eight samples for fungi in Figure 3.19. In each fungi sample, selected fungi genus did not find. Every fungus has 18S rRNA genes but all locations have not our selected fungi.

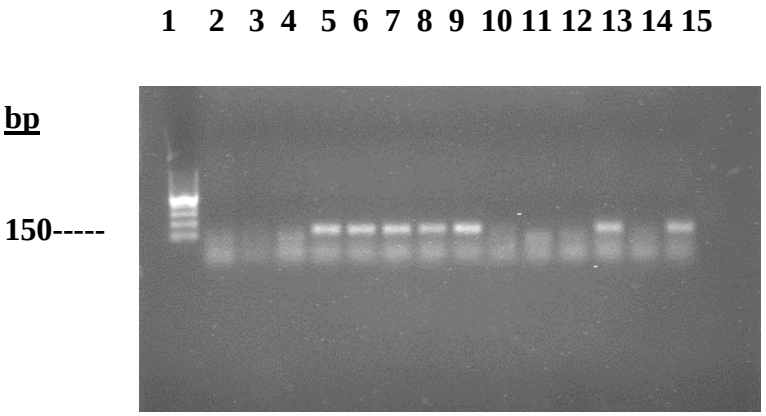

Figure 3.20 Agarose gel (%1) electrophoresis of fifteen well-isolated bacteria-*Micrococcus luteus* colonies amplification by specific bacteria PCR.

1. line size is a marker. Some of our samples are there from 2 to 15 line size (Figure 3.20). Length of PCR product (bp) is approximately 150 bp. According to bacterial PCR results, *Micrococcus luteus* bacteria was found in each place including, shopping centre_2, 1, kindergarten and home. These bacteria were determined in 27 samples out of 65.

Table 3.17 Concentrations and types of bacteria in shopping centre_1

Shopping Centre_1						
	Weekday			Weekend		
Location	Bioaerosol (cfu/mL)	Bacteria		Bioaerosol (cfu/mL)	Bacteria	
		Psaf	Mluf		Psaf	Mluf
1.Floor S1	12	+	+	14	+	+
1.Floor S2	34	+	+	4	+	+
2.Floor S1	32	-	-	74	-	-
2.Floor S2	12	-	-	32	-	-
Fast Food S1	8	-	-	10	-	-
Fast Food S2	40	-	-	22	-	-
Fast Food S3	36	-	-	10	-	-
Fast Food S4	38	+	+	14	+	+
3.Floor S1	52	+	+	10	+	+
3.Floor S2	22	-	-	10	-	-

Psaf: *Pseudomonas aeruginosa*, Mluf: *Miccroccocus luteus*

Samples were collected all floors on weekday and weekend (Table 3.17). There are three floors and fast food floor in Shopping Centre_1. All bacteria colony were counted. First floor on section_1 has 12 bacteria colony and these bacteria colonies include *Pseudomonas aeruginosa* and *Miccrococcus luteus.* There are 14 bacteria colony on first floor section_1 and this section includes *Pseudomonas aeruginosa* and *Miccrococcus luteus.* Fast food sections 1,2 and 3 have bacteria colony but these sections did not include our selected bacteria. But fast food section_4 include our selected bacteria. The presence of the bacteria in this section can be explained by the air contamination due to oil burning in the fast food place which can easily change the air composition. And third floor section_1 include all selected bacteria but the other section did not include selected bacteria. It can be explained by the air condition are not constant and air contamination easily change.

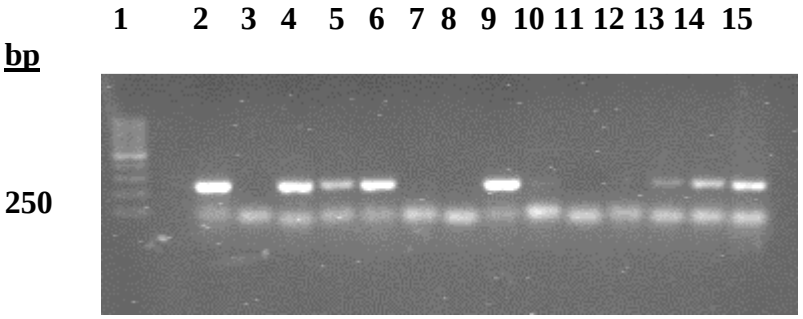

Figure 3.21 Agarose gel (%1) electrophoresis of fifteen well-isolated bacteria colonies-*Pseudomonas aeruginosa* amplification by specific bacteria PCR.

1. line size is a marker. Some of our samples are there from 2 to 15 line size (Figure 3.21). Length of PCR product (bp) is approximately 250 bp. According to bacterial PCR results, *Pseudomonas aeruginosa* bacteria were found in each. These bacteria were determined in 28 samples out of 65.

Samples were collected at home. There were kitchen, entrance, living and bed room at home. Nine points were selected. According to home results, *Pseudomonas aeruginosa* and *Miccrococcus luteus* were determined in 4 samples out of 9. Only living room didn't include these bacteria. There were seven rooms and kitchen on kindergarten. Eight points were selected. *Pseudomonas aeruginosa* were determined on kitchen, third, fourth, playing and sleeping room were determined. There were *Miccrococcus luteus* bacteria these points except fourth room.

Table 3.18 Concentrations and types of bacteria in shopping centre_2.

Shopping Centre_2						
	Weekday			Weekend		
Location	Bioaerosol (cfu/mL)	Bacteria		Bioaerosol (cfu/mL)	Bacteria	
		Psaf	Mluf		Psaf	Mluf
1.Floor S1	28	-	-	202	-	-
1.Floor S2	102	+	+	106	-	-
1.Floor S1	244	-	-	238	+	+
2.Floor S1	168	-	-	38	-	-
2.Floor S2	222	-	-	252	+	+
2.Floor S3	194	-	-	150	+	+
3.Floor S1	208	-	-	60	+	+
3.Floor S2	38	+	+	24	+	+
3.Floor S3	152	-	-	322	-	-
3.Floor S4	156	-	-	320	+	+
Fast Food S1	120	-	-	296	+	+
Fast Food S2	112	-	-	340	+	+
Fast Food S3	94	-	-	378	+	+
Fast Food S4	52	-	-	254	-	-

Psaf: *Pseudomonas aeruginosa*, Mluf: *Miccroccocus luteus*

Shopping Center_2 samples were collected all floors on weekday and weekend (Table 3.18). There are four floors in Shopping Centre_2, last floor named fast food floor. All bacteria colonies were counted. First floor on section_1 has 28 bacteria colony on weekday and these bacteria colonies did not include *Pseudomonas aeruginosa* and *Miccrococcus luteus*. There are 202 bacteria colony on first floor section_1 and this section did not include, too. But on the first floor section_2 included selected bacteria species on weekday. In contrast to weekday results, on the weekend these bacteria did not appear. Fast food sections 1,2 and 3 have bacteria colony but these sections did not include our selected bacteria on weekday. But these sections included our selected bacteria on weekend. The presence of the bacteria in this section can be explained by the air contamination due to oil burning in the fast food place which can easily change the air composition. And third floor sections included all selected bacteria on weekend except section_3. On weekday these sections were changed. These changes explained by the air condition are not constant and air contaminations easily change.

CHAPTER 4

CONCLUSIONS

This thesis proposed a flexible and practical indoor air quality monitoring and assessment protocol for air-conditioned samples collected in different places. This protocol offers choices of sampling schemes of assessment parameters, sampling locations and times in assessing indoor air quality for the statutory control at the acceptable measurement accuracy. The protocol also promotes the indoor air quality by presenting the assessment results with a simple benchmark so that occupants can easily realize the relative environmental performance in the places and active participation in the indoor air quality award would become possible.

This study included important findings about indoor air quality. Based on the plan of this thesis, all the scheduled places and areas were analyzed completely and all results were determined successfully and the analyses were done as planned.

The aims of this thesis were successfully reached by giving a clear picture about the quality of the indoor environment in a significant place like kindergarten, house and shopping malls. As a matter of fact people spend a large part of their time each day indoors; in homes, offices, schools, health care facilities, or other buildings. It was found that the main factor that affects the presence of bacteria in the indoor environment is outdoor air, people and indoor bacterial growth.

Everybody has concerns about the adverse effects of air pollution on children's health and developments as important determinants of environmental and public health policies. This study revealed that inadequate ventilation creates a considerable health

burden. Bacteria and fungi were detected in almost all of the indoor spaces studied and their growth boasted when sufficient moisture is available.

The knowledge of the pollution sources in the areas studied is important to explain the result of indoor air quality results. Excess moisture on almost all indoor materials leads to growth of microbes, such as fungi and bacteria, which subsequently emit spores, cells, fragments into indoor air. In this study similar situations appeared in some places such as kindergarten and shopping centers' floors. According to some studies, bacteria grow in the same area as fungi. The results of studies regarding particulate matter consistently show an association with respiratory symptoms. There was a positive association between different size fractions of particulate matter in the indoor environment.

In all sampling places particulate matter showed very high correlations among each size fraction. This could be attributed to the ventilation of and air exchange and mixing in the selected study areas In addition to that, this could be an indication of contribution of physical activity relating dust generation to higher level of PM ranges which have altering affects on the typical behavior of PM levels.

As a result of this study, microbes propagate rapidly whenever indoor condition is available. The dust and dirt normally present in most indoor spaces provide sufficient nutrients to support extensive microbial growth. The problem of excess moisture and dampness can be tackled. This could be achieved by controlling the quality of the building envelope regarding air infiltration, by ensuring adequate thermal insulation and by avoiding condensation indoors through the control of moisture sources and of temperature, humidity and velocity of the air in the proximity of the surfaces. Indoor air quality can be investigated by using PCR techniques. There are other microorganisms which are dangerous for human health such as *Penicillium Spp*., *Alternata Spp*. these microorganisms should examine.

Identifying areas for further research was another major objective of this dissertation. The results of the research provided by different places in Istanbul city Indoor Air Study and this dissertation contribute to the current body of knowledge

related to the indoor environment of the places studied. Further research needs have been identified as follows:

1. The study identified the measurement of indoor air quality parameters in different locations of the places chosen in this study. However, the study did not obtain the sources of the air contamination. The knowledge about air composition of each place studied and its environment can help easily to understand the differentiation of the result obtained in the microorganism's measurement.
2. This dissertation provided a baseline for indoor air quality in the different areas studied only. Future research is needed to investigate high performance of these areas. Data should be collected using the methodology provided by this dissertation for direct comparison. These direct comparisons can justify benchmark practices identified at high performance of all areas studied.
3. Other microorganisms which present a danger for human health such as *Penicilium*, *Alternata* species could be examined in indoor air.
4. To have knowledge about the population in different areas studied.

REFERENCES

Alvarez, AJ., Buttner, M. P., Stetzenbach, L.D., ‘’Use of solid-phase PCR for enhanced detection of airborne microorganisms’’, *Applied and Environmental Microbiology*, Vol. 60, pp. 374–376, 1994.

ASHRAE Standard 62-1989, ‘’Ventilation and Acceptable Indoor air quality in low-rise residential buildings’’, Available, http://www.ashrae.org/technology/, accessed, 30 November 2010.

Aydoğdu, H., Edirne ilindeki kreş ve gündüz bakım evlerinin iç ve dış ortamında havayla taşınan funguslar ve bakteriler, *Ph.D. Thesis*, Trakya University, Edirne, 2004.

Balcht, Aldona, and Smith, ‘’*Pseudomonas aeruginosa: Infections and Treatment*’’, *Informa Health Care*, pp. 83–84, Raymond, 1994.

Bulut, H., ‘’Isıtma sezununda ofislerde iç hava kalitesinin araştırılması’’, İklim 2007- II. Ulusal İklimlendirme Kongresi Bildiriler Kitabı, pp. 285-295, Antalya, 2007.

Burroughs, H.E., Shirley, J. H., ‘Managing indoor air quality’’, Fourth edition, CRC Press, 2008.

Estokova, A., Stevulova, N., Kubincova, L., ‘’Particulate matter investigation in indoor environment’’, *Global NEST Journal*, Vol. 12, pp. 20-26, 2010.

Fromme, H., Twardella, D., Dietrich, S., Heitmann, D., Schierl, R., Liebl, B., Rüden, H., ‘’Particulate matter in the indoor air of classrooms-exploratory results from Munich and surrounding area’’, *Atmospheric Environment*, Vol. 41, pp. 854-866, 2007.

Gravensen, S., Frisvad J.C., Samson, R.A. ‘’*Microfungi*’’, Munksgaard, Copenhagen, pp. 168, 1994.

Green, C. F., Scarpino, P. V., Gibbs, S. G., ‘’Assessment and modeling of indoor fungal and bacterial bioaerosol concentrations’’, *Aerobiologia*, Vol. 19, pp. 159-169, 2003.

Health Canada, 1995, ‘’Exposure Guidelines for Residential Indoor Air Quality: A Report of the Federal Provincial Advisory Committee on Environmental and Occupational Health Ottowa: Health Canada’’, Available: www.hc-sc.gc.ca/, accessed: 25 December 2010.

Hermann, E., Call, J., Hernandez, M. V., Hare, B., Tomasello, M., ‘’Humans Have Evolved Specialized Skills of Social Cognition: The Cultural Intelligence Hypothesis’’, Vol. 317, pp. 1360-1366, 2007.

Heudorf, U., Neitzert, V., Spark, J., ‘’Particulate matter and carbon dioxide in classrooms-The impact of cleaning and ventilation’’, *International Journal of Hygiene and Environmental Health,* Vol. 212, pp. 45-55, 2009.

Hess-Kosa, K., Indoor air quality, sampling methodologies, Boca Raton, FL, USA: Lewis Publishers, CRC Press, 2001.

Ismail, M., Sofian, N. Z. M., Abdullah, A. M., ‘’Indoor Air Quality in Selected Samples of Primary Schools in Kuala Terengganu, Malaysia’’, pp. 103-108, 2010, Available: www.tshe.org/EA, accessed, 25 December 2010.

Kalogerakis, N., Paschali, D., Lekaditis, V., Pantidou, A., Eleftheriadis, K., Lazaridis, M., ‘’Indoor air quality-bioaerosol measurements in domestic and office premises’’, *Aerosol Science,* Vol. 36, pp. 751-761, 2005.

Kuş, M., Şanlıurfa ilindeki yükseköğretim kurumları dersliklerinde iç hava kalitesinin incelenmesi ve modellenmesi, M.S. Thesis, Şanlıurfa, 2007.

Lee, S. C., Li, W. M., Ao, Chio. H., ‘’Investigation of indoor air quality at residential homes in Hong Kong’’, *Atmospheric Environment*, Vol. 36, pp. 225-237, 2002.

Li, C. S., Hou, P. A., ‘’Bioaerosol characteristics in hospital clean rooms’’, *The Science of the Total Environment*, Vol. 35, pp. 169-176, 2004.

NIOSH, ‘’Bioaerosol Sampling (Indoor Air) Method 0800’’, 1998, Available, http://www.cdc.gov/niosh/docs/2003-154/pdfs/0800.pdf, accessed, November 2010.

OSHA, ‘’U.S. Department of Labor, Occupational Safety and Health Administration, Code of Federal Regulations’’, Title, 29, Part 1910.1000-1910.1450, Available, www.osha.gov, accessed, 30 November 2010.

Önoğlu, N., Fatih bölgesi kreşlerinde iç ortam havasının mikrobiyolojik açıdan değerlendirilmesi, M.S. Thesis, İstanbul, 2008.

Pastuszka, J. S., Tha Paw, U. K., Lis, D., Wlazlo, A., Ulfig, K., ‘’Bacterial and fungal aerosol in indoor environment in Upper Silesia, Poland’’, *Atmospheric Environment*, Vol. 34, pp. 3833-3842, 2000.

Rowe, M., Leete, S., ‘’The energy crisis of the 1970’s was caused by our reliance on foreign oil and triggered a nationwide movement that advocated energy conservation and alternate energy sources, USA’’, 2003.

Samet, J. M., Spengler, J. D., ‘’Indoor air Pollution, A health perspective’’, The Johns Hopkins University Press, 1991.

Shan, H., ‘’An Indoor Air Quality Monitoring And Assessment Protocol for Air Conditioned Offices in Subtropical Climates’’, The Hong Kong Polytechnic University, 2009.

Storey, E., Dangman, K.H., Schenck, P., Debernardo, R.L., Yang, C.S., Bracker, A., Hodgson, M.J., ‘’Guidance for Clinicians on the recognition and management of health effects related to mold exposure and moisture indoor’’, 2004.

Yang, W., Sohn, J., Kim, J., Son, B., Park, J., ‘’Indoor air quality investigation according to age of the school buildings in Korea’’, *Journal of Environmental Management*, Vol. 90, pp. 348-354, 2009.

WHO, ‘’Guidelines for concentration and exposure-response measurements of fine and ultra fine particulate matter for use in epidemiological studies’’, 2002.

WHO, ‘’Guidelines for indoor air quality: dampness and mould’’, 2009.

Wong, S. K., Lai, C., Ho, D. W., Chau, K. W., Lam, K., Ng, F., ‘’Sick building syndrome and perceived indoor environmental quality: A survey of aparyment buildings in Hong Kong’’, *Habitat International*, Vol. 33, pp. 463-471, 2009.