

PM₁₀ and their bio-contamination in Makkah Saudi Arabia- case study

Abstract

Atmospheric Particulate Matter (PM) is considered one of the most important air pollutants in terms of its health impacts, environmental degradations and visibility. Particles size, their chemical composition and atmospheric level are important factors for determining their adverse health impacts. In this paper the main objective of this work was focus on PM₁₀ and its bio-accumulations (microbial load) in Makkah during Hajj seasons 2016 (1437AH). This study concluded that the concentration of respirable particles (PM₁₀) and its water-soluble ions were much higher at site 2, site 1 than that at sites 3, 4 and 5 around Haram in Makkah. The secondary aerosols in terms of their concentrations can be arranged as follows: Cl⁻>Mg²⁺>NO₃⁻>SO₄²⁻>NH₄⁺>PO₄³⁻>Br⁻>Ca²⁺>F⁻. Furthermore, the concentrations recorded in this study were lower than the daily mean limitation of PM₁₀ (340) in Saudi Arabia.

In addition, Man is the main source of air microbial contamination surrounding Haram in Makkah. Fungi evidence of the lack of output from natural sources of pollution. Spotted Staphylococcus bacteria were at high rates in all sites and micro-organisms at the site 2. The source of microbial contamination in all sites was the same, while the source of fungi differs especially at the site 2. The natural resources were the most predominant at the site of 2 and 1, as compared to sites 3, 4 and 5.

Keywords: PM₁₀, microbial air pollution, Makkah, Saudi Arabia

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Atef MF Mohammed,^{1,2} Ossama A Attala,^{1,3}
Turki M Habeebullah¹

¹Umm Al-Qura University Makkah, Saudi Arabia

²Air pollution Department, Cairo University, Egypt

³Cairo University, Egypt

Correspondence: Atef MF Mohammed, The Custodian of the Two Holy Mosques Institute for Hajj and Umrah research, Umm Al-Qura University Makkah, Saudi Arabia,
Email ateffathy2006@yahoo.com

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Introduction

Air pollution is becoming a growing environmental issue in both developing and developed countries throughout the world.¹ Growing urbanization, transport vehicles on the roads, and biomass and fossil fuels burning to meet the energy needs of growing population have resulted in large amount of emissions of both gaseous pollutants and particulate Matter (PM). Atmospheric aerosols are tiny liquid or solid particles suspended in the air. Aerosols vary in size, composition, number and lifetime due to their hygroscopic nature.² The size distributions and chemical compositions of atmospheric particles play significant roles in their transport, transformation, and removal mechanisms.^{3,4} Airborne particles, especially fine particles are found to be widely associated with health problems,⁵ such as increased illness and hospitalization. Therefore, a considerable amount of research is devoted to source identification and control strategy of airborne particle. Water-soluble inorganic ions (WSIs), including anions (Nitrate NO₃⁻, Sulfate SO₄²⁻, Chloride Cl⁻, Phosphate PO₄³⁻, Bromide Br⁻ and Fluoride F⁻) and cations (Ammonium NH₄⁺, Calcium Ca²⁺ and Magnesium Mg²⁺), are the major components of atmospheric aerosols.^{4,6} In general, the WSIs account for about 60-70% of particulate mass.^{7,8}

The pilgrims preferred to stay close haram Mosque in Makkah. The high density of peoples in the central area from all directions around haram mosque increase exposure of pilgrims to microbial contaminants, which may cause health and environmental problems. Air microbial pollution (bio-aerosols) are the particles living airborne or those created by exposure to the atmospheric aerosols, which leads to health effects. Bio-aerosols concentrations and types of microbial organisms were depending on weather factors and the geographic location and the rate of air pollution.^{4,9}

In this study The main objective of this work was focus on PM and its bio-accumulations (microbial load) in Makkah during Hajj seasons 2016 (1437 AH), especially those with aerodynamic diameter up to 10µm (PM₁₀). PM₁₀ have attracted a vast number of research investigations^{10,11} due to their importance for public health, visibility, vegetation and other environmental impacts. Many scientists have investigated the health impacts of PM and have reported that PM can cause various health impacts, including respiratory diseases, rhinosinusitis, cardio-vascular diseases, asthma, and chronic obstructive pulmonary diseases.^{4,12}

Material and methods

Site description

Makkah City is located in the south western part of the KSA between the low-lying coastal plain. The Holy City of Makkah is characterized by a moderate to steep topography with an average elevation of around 277 m above sea level. The underlying topography and the presence of several mountain ranges have controlled the contemporary expansion of this metropolitan city, which accommodates a total population of 1,700,000.¹³ Furthermore, the city hosts several millions of pilgrims each year coming for Hajj season. Additional transportation facilities, mainly buses and cars are required during the Hajj season. Which increase the emissions of traffic related air pollutant in the local area. Sampling sites (five sites) is located in Makkah around Harm (Figure 1), which is situated about less than 1 kilometer around Harm Mosque, during Hajj seasons.

Water soluble ions (WSIs)

The atmospheric aerosols such as anions (NO₃⁻, SO₄²⁻, Cl⁻, PO₄³⁻, Br⁻ and F⁻) and cations (NH₄⁺, Ca²⁺ and Mg²⁺) were found mainly in

respirable particles (PM₁₀).¹⁴⁻¹⁶ Many previous studies¹⁷⁻²⁰ have shown that aerosols, especially anthropogenic aerosols can affect global radiation.

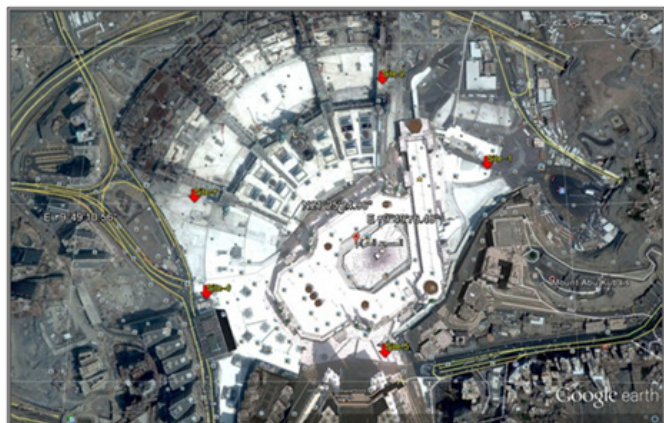


Figure 1 Sampling sites around Haram Mosque.

The study is based on the concentrations of suspended particulate matter (PM₁₀), which was collected in five sites around Haram Mosque. Low volume sampler was used for collection of samples. The flow of air through the glass wool filter paper was 14L/min (Figure 2). Filtration method was used to estimate the total concentration of suspended particulate. The filter paper was weighed dried in the lab and transported in an airtight container to the site. At the end of sampling period (24 hours), samples were transferred carefully to the lab, and weighed again. The difference in weight was considered as the weight of suspended particulates in the air. Concentrations were calculated and expressed as µg/m³. Water soluble ions (WSIs) were extracted in deionised water using ultrasonic water bath (Ultra-sons-H, J.P., and Selecta, Spain) and then the sample was filtered. Filtrate was used to estimate the concentration of WSIs using ion-chromatography system (850 Professional IC-Metrohm) (Figure 3).

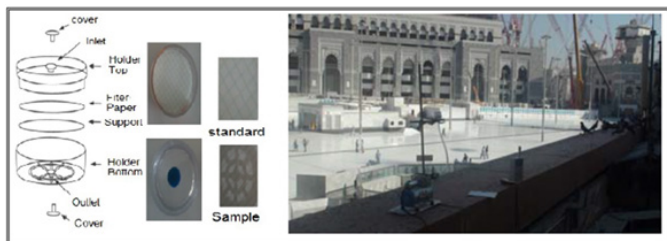


Figure 2 Sampling method (Low volume sampler).



Figure 3 Ion-chromatography system (850 Professional IC-Metrohm).

Air microbial pollution (bio-aerosols)

The microbial air samples were collected five sites around haram Mosque in Makkah during hajj season (1437AH). The frequency of samples was one for each site per 5days. Open plate method (sedimentation) was used for collection of microbial contaminants signs of Environmental bacteria and heat-loving moderate (Mesophilic bacteria) and fungi. Exposing two plates (diameter of 8.5cm) for each site, with a total 10 plates at each site (a total of 50 plate) for a period ranging from 5-10 minutes. The media used were Nutrient agar (for counting the total bacterial colonies) and Sabouraud agar (for count of fungal colonies). All media are sterilized at 121°C for 15 minutes and incubate the plates of environmental bacteria (25°C), Aerobic bacteria (37°C) for 48 hours and fungi (25°C) for 5 days.

Concentrations were calculated using the formula of Omlinsky²¹ as follows:

$$N=5.a .10^4 (bt)^{-1}$$

Whereas:

N: the number of colonies per cubic meter of air Colony Forming Unit CFU/m³

a: the number of colonies in each plate

b: the plate area (Cm²)

t: exposure time per minute

Results and discussion

Water soluble ions (WSIs)

The daily mean concentrations of respirable particulate (PM₁₀) were 284, 320, 241, 211 and 198µg/m³ during hajj season of 1437H (2016), respectively. The concentrations recorded in this study were lower than the daily mean limitation of PM₁₀ (340) in Saudi Arabia (PME, 1422). Emissions from road traffics, human activities, construction activities, re-suspension of dust particles and poor ventilations were considered to be the main reasons for the high concentrations of particulate matter (PM₁₀) recorded in during hajj season. Figure 4 showed the daily average concentration of cations (NH₄⁺, Ca²⁺ and Mg²⁺) were ranged between 1.5-2.7, 0.39-0.82 and 9.8-12.5µg/m³, where higher concentrations were recorded at site 2 and site 1. The daily mean concentration of anions (N⁻, SO₄²⁻, Cl⁻, PO₄³⁻, Br⁻ and F⁻) were ranged between 6.3-6.6, 5.5-6.3, 9.8-17.1, 1.4-1.9, 1.1-2.3 and 0.007-0.034µg/m³, where higher concentrations were recorded at site 2 and site 1. The results indicated that Cl⁻, NO₃⁻ and SO₄²⁻ were the most predominant species of WSI in particulate (PM₁₀) during Hajj seasons 2016 (1437AH). The study identified that emissions from human activities, construction activities and vehicle exhaust emissions, especially private diesel vehicles were the main source of WSI in the atmosphere of area around haram in Makkah. The study also demonstrated a strong positive relationship between NO₃⁻ and SO₄²⁻ observed in particulate (PM₁₀). This may be attributable to the interaction of SO₂ and NOx and sharing the same source of emissions (road traffic).

The ratios of NO₃⁻/SO₄²⁻ in PM₁₀ ranged between 1.05 - 1.15 during hajj season 2016 (1437AH). These ratios were higher than the 0.14-0.70 ratio found by,²² 0.3-0.5 ratio reported by.²³ SO₂ and NOx were the major atmospheric pollutants in Makkah city as represented by.²⁴ And their concentrations are important factors in controlling sulphate and nitrate formation. SO₄²⁻ and NO₃⁻, being secondary pollutants are formed by various heterogeneous and homogenous chemical reactions

in the atmosphere.^{25,26} SO₂ and NO_x are the major precursors for their formation and therefore controlling the emission of SO₂ and NO_x can directly affect the concentrations of SO₄²⁻ and NO₃⁻. It was shown in (Table 1) that the WSIs concentrations in PM₁₀ were lower than

that recorded in China, Beijing^{13,27} and India, Ahmadabad,²⁸ although within those recorded by some other countries such as Jungfrauoch, Switzerland,²⁹ Monte Cimone, Italy,³⁰ Brazil, Tanzania and Taiwan.

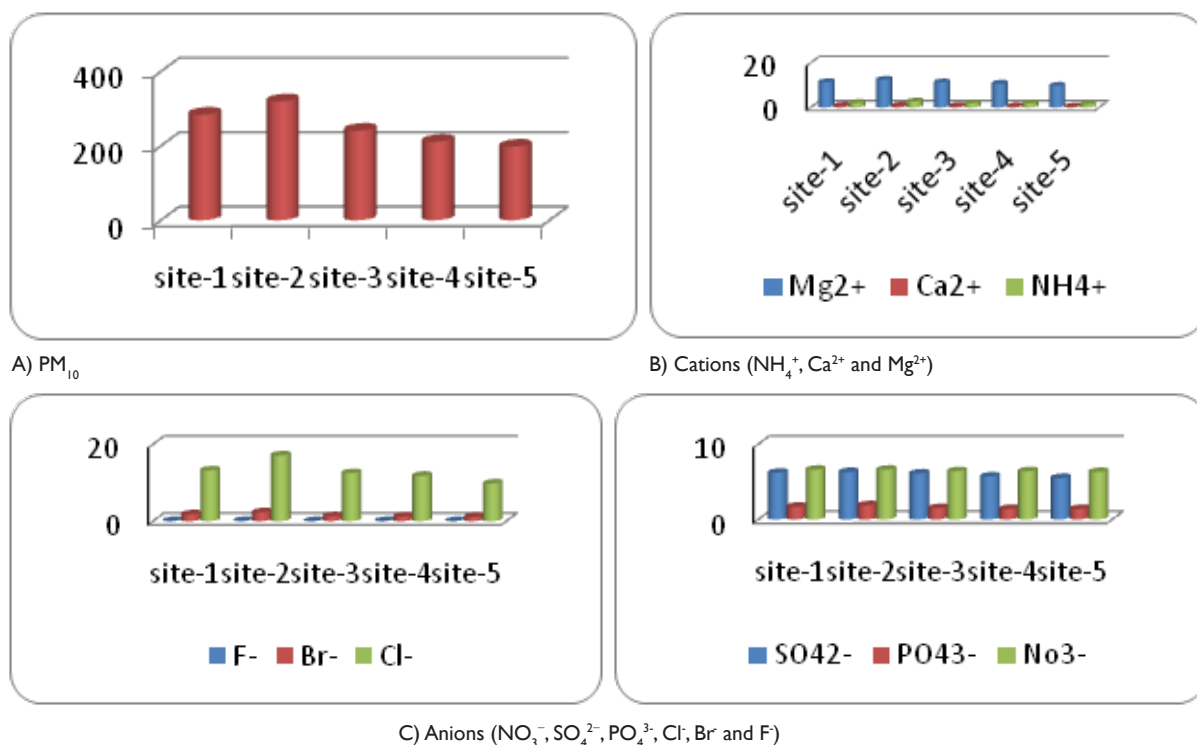


Figure 4 The daily mean concentrations of respirable particulate (PM₁₀) and its (Cations + anions).

Table 1 Water soluble Ions (µg/m³) in different countries around the world

Country	PM ₁₀	PM ₁₀			Reference	
		NO ₃ ⁻	SO ₄ ²⁻	NH ₄ ⁺		
KSA	Makkah	6.46	5.96	2	251	The current study
China	Beijing	90	90.9	78.6	507	Zhang et al. ²⁶
India	Ahmadabad	7.2	13.8	3.7	171	Rengarajan et al. ⁶
Taiwan	Chaochou	23.1	9.6	7.1	115	Chena et al. ²⁹
Switzerland	Jungfrauoch	0.03	0.3	0.1	-	Nyeki et al. ²⁸
Italy	Monte Cimone	0.9	3.5	1.4	16	Marenco et al. ²⁹
Brazil	Sao Paulo	3.4	5.1	1.9	38	Vasconcellos et al. ¹⁷
Tanzania	Dar Essalaam	0.7	1.4	0.2	69	Mkoma et al. ⁴³

Air microbial pollution (bio-aerosols)

The results of the current study showed the types and proportions of bacteria isolated and knowledge in the five sites around Haram in Makkah. Where bacteria gram positive (G +ve) were prevailing accounting ratios ranged between 85-90% of the total number of isolated bacteria, while the percentage of bacteria gram negative (G-ve) 5-9% of the total number of isolated bacteria. The spherical bacteria (Cocci) are the most prevalent among gram positive group and formed 35-80% of the total number of isolated bacteria. Formed Bacillus bacteria (Bacilli) ratios ranged between 4-28% of the total number of isolated bacteria. And also it has been monitoring the organisms forming spores Spore formers bacteria by 8% (Figure 5).

The results demonstrated for the permanent presence of bacteria positive because it is linked with activities humanity and the numbers of people and rates of ventilation^{31,32} The bacteria Bacillus they thrive and grow in the presence of decomposing organic material, usually found in soil, dust, water and be present in the sands of the desert.^{33,34} G-ve bacteria often rare in the air, and was considered the bacteria Pseudomonas,³⁵ one of the opportunistic organisms that can cause disease³⁶ but not to cause damage to people their health. The G -ve bacteria un-presence was generally attributed to it was more sensitive to environmental conditions compared to G +ve bacteria, where the main base that pathogenic bacteria do not live long in the air, due to the speed of her death and decay of activity.³⁷

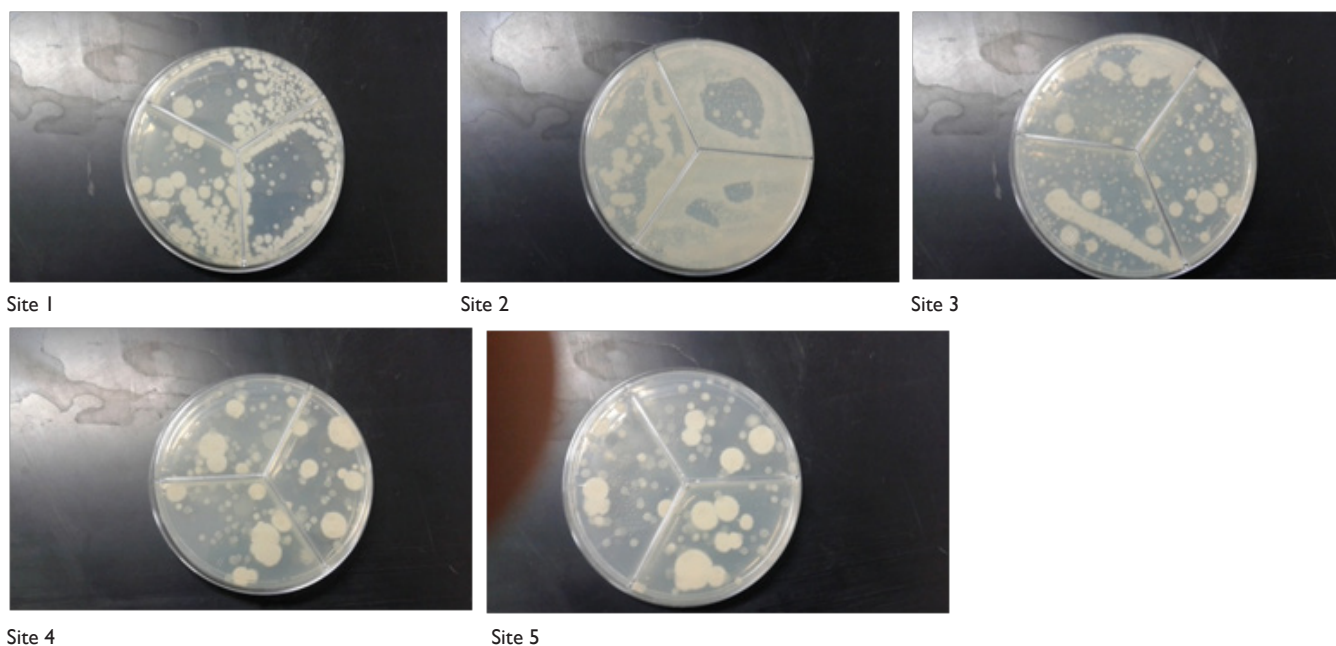


Figure 5 The microbiological air pollution.

Furthermore, the microbial load difference in all locations may be attributed to: the air environment was appropriate, therefore, the microbial cells were working to take some of the strategies in order to resist the difficult environmental conditions in the air, such as the composition dyes, germs or protection dusty.³⁸ Microbial pregnancy can grow and reproduce in the air and thus lead to changing the composition of the microbial load of place where different from consequential of sources and it is difficult multiplication of microbes with air due to non-favorable conditions. Change the earth's surface and the nature of the source determine the composition of microbial air at each site. All of these factors could change the types and concentrations of microbial community air at each site.³⁹ Concentrations of microorganisms in the air is a transitional state, as a result of a dynamic balance between interventions objects (sources) and output (factors that affect the vitality of the object and the dispersion and deposition), and the results showed that the bacteria were no concentrations always more than fungi, due to the large number of inputs for bacteria and fungus. Bacteria concentrations ranged from $10^3 \times 1.6 - 10^4 \times 2.3$ CFU/m³, these results were agreement with.^{17,30}

In the current study aerobic bacteria concentrations were higher than environmental bacteria. The highest concentration was at site 2, in which the presence of building and construction area resulting in dirt and dust, also entering the means and Light Vehicles (motorcycles), which was working on the emission of dust rates affect the environment in the northern direction, because the dust suspended work on increasing concentrations of microorganisms in the air, because they are protected from the harmful effects of the environment and provide food to them. Furthermore, the lowest concentration of bacteria was at the site 1, as a result of good ventilation. In addition, the concentrations were relatively high in site 3, 4 and 5, due to human activities and increase the relative humidity.

Fungus concentrations recorded at five sites around the Haram in Makkah were relatively low, which it were ranged between $<10^2 - 4 \times 10^2$ CFU/m³, and the average concentrations were 2.8×10^2 ,

2.2×10^2 , 1.4×10^2 , 1.8×10^2 and 2.0×10^2 CFU/m³, at site 2, 5, 1, 3 and 4 Respectively. The concentrations of fungi were recorded at site 2 and 5 higher than that at 1, 3 and 4. Concentrations of fungi from one place vary to another as a result of differing weather conditions and vegetation, agricultural and human activities,⁴⁰ time, season, geographic.³⁹ In addition to the method of sample collection, number and media used. In this study, fungi concentrations did not exceed 4×10^2 CFU/m³.⁴¹ recorded fungus concentrations ranged between 2.9-10 CFU/m³ at the Prophet's Mosque in Medina, Abed (1421 AH)⁴² was found contamination rates of microbial air conditioning in the Makkah area during the month of Ramadan for the year 1421 AH between 42-284 CFU/m³.

Conclusion

The main objective of this work was focus on PM₁₀ and its bio-accumulations (microbial load) in Makkah during Hajj seasons 2016 (1437AH). This study concluded that the concentration of respirable particles (PM₁₀) and its water-soluble ions were much higher at site 2, site 1 than that at sites 3, 4 and 5. The secondary aerosols in terms of their concentrations can be arranged as follows: $Cl > Mg^{2+} > NO_3^- > SO_4^{2-} > NH_4^+ > PO_4^{3-} > Br > Ca^{2+} > F^-$. In addition, It is well known that SO_4^{2-} and NO_3^- , being secondary pollutants are formed by various heterogeneous and homogenous chemical reactions in the atmosphere. SO_2 and NO_x are the major precursors for their formation and therefore controlling the emission of SO_2 and NO_x can directly affect the concentrations of SO_4^{2-} and NO_3^- .

Assessment of microbial air pollution important to know the health risks, especially for groups most at risk. Man is the main source of air microbial contamination surrounding the Haram al-Sharif region. Fungi evidence of the lack of output from natural sources of pollution. Spotted *Staphylococcus* bacteria were at high rates in all sites and micro-organisms at the site 2^{43,44} The source of microbial contamination in all sites was the same, while the source of fungi differ especially at the site 2. The natural resources were the most predominant at the site of 2 and 1, as compared to sites 3, 4 and 5.

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Conflict of interest

The author declares no conflict of interest.

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