The Environmental Health Impact of PM_{10} in Makkah, Saudi Arabia- A Case study

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Abstract

Respirable Particulate Matter (PM10) was considered the most important air pollutants in Makah city, KSA. Particles size, their chemical composition and atmospheric level are important factors for determining their adverse health impacts. In this manuscript, the main target of this work was focus on PM10 and its bio-accumulations (microbial load) in Makkah during Hajj seasons 2016 (1437 AH). This paper discussed the concentration of PM10 and its water-soluble ions (WSIs) around Haram in Makkah. PM10 and WSI concentrations 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-> Mg2+> NO3-> SO42-> NH4+> PO43-> Br-> Ca2+> F-. Furthermore, all concentrations recorded in this paper were lower than the daily mean limitation of PM10 (340 µg/m3) in Saudi Arabia. In addition, people were 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, WSIs, Microbial air pollution, Makkah, KSA.

1. Introduction

Air pollution is becoming a growing environmental issue in both developing and developed countries throughout the world (Colls, 2002). 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 (Jacobson et al., 2000). The size distributions and chemical compositions of atmospheric particles play significant roles in their transport, transformation, and removal mechanisms (Grivas et al., 2008; Mohammed et al., 2015). Airborne particles, especially fine particles are found to be widely associated with health problems, (Pisoni and Volta, 2009), 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 NO_3^-, Sulfate SO_4^{2-}, Chloride Cl^-, Phosphate PO_4^{3-}, Bromide Br^- and Fluoride F^-) and cations (Ammonium NH_4^+, Calcium Ca^{2+} and Magnesium Mg^{2+}), are the major components of atmospheric aerosols (Kumar and Sarin, 2010; Mohammed et al., 2015). In general, the WSIs account for about 60–70% of particulate mass (Wang and Shooter, 2001).

The pilgrims preferred to stay close to 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 (Habeebullah et al., 2013a).

In this study, the main objective was to focus on PM and its bio-accumulations (microbial load) in Makkah during Hajj seasons 2016 (1437 AH), especially those with aerodynamic diameter up to 10 µm (PM_{10}). PM_{10} have attracted a vast number of research investigations (e.g., AQEG, 2012; Harrison et al., 2010; Vu et al., 2015; Mohammed et al., 2015) 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 (WHO, 2003; Mohammed et al., 2015).

2. Material and Methods

2.1. Site description

Makkah City is located in the southwestern 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 (CDSI, 2010). 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 (Fig. 1), which is situated about less than 1 kilometre around Harm Mosque, during Hajj seasons.

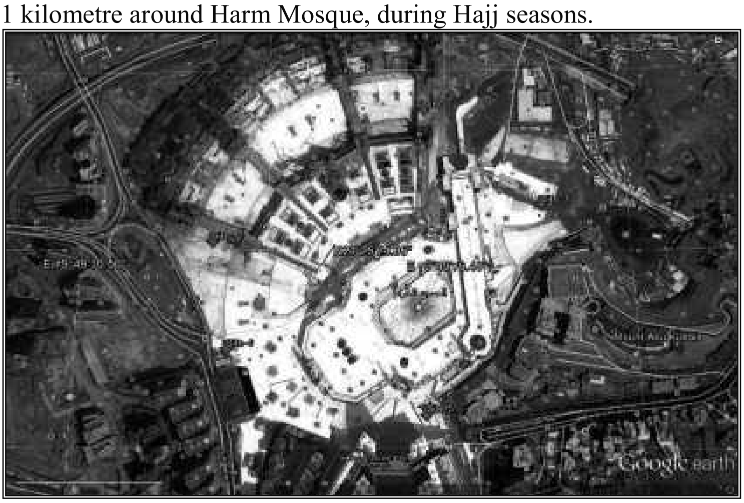


Figure 1: sampling sites around Haram Mosque

2.2. Water soluble ions (WSIs)

The atmospheric aerosols such as anions (NO_3^-, SO_4^{2-}, Cl^-, PO_4^{3-}, Br^- and F^-) and cations (NH_4^+, Ca^{2+} and Mg^{2+}) were found mainly in respirable particles (PM_{10}) (Lun et al., 2003; Tang et al., 2005). Many previous studies (Lee and Sequeira, 2002; Chang and Park, 2004; Latha and Badarinath, 2005) have shown that aerosols, especially anthropogenic aerosols can affect global radiation.

The study is based on the concentrations of suspended particulate matter (PM_{10}), 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 14 L/min (Fig. 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.

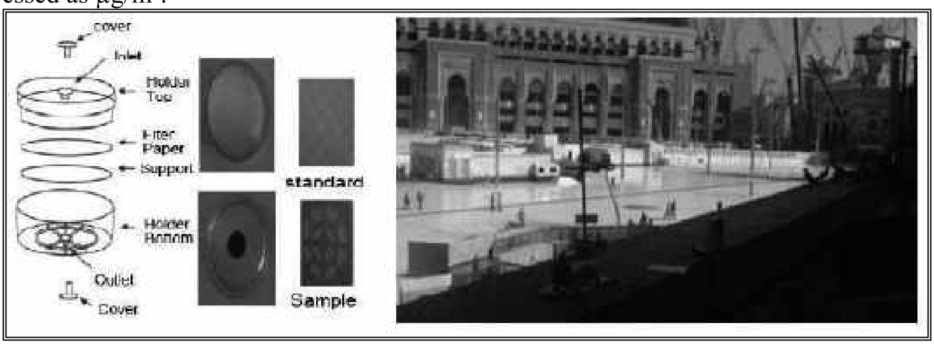


Figure 2: sampling method (Low volume sampler)

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) (Fig. 3).

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

2.3. Air microbial pollution (bio-aerosols)

The microbial air samples were collected at five sites around haram Mosque in Makkah during hajj season (1437AH). The frequency of samples was one for each site per 5 days. 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 8.5 cm) 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 ºC for 15 minutes and incubate the plates of environmental bacteria (25 ºC), Aerobic bacteria (37 ºC) for 48 hours and fungi (25 ºC) for 5 days.

Concentrations were calculated using the formula of Omlinsky (1940) as follows:

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

where:

N: the number of colonies per cubic meter of air Colony Forming Unit CFU / m^3

a: the number of colonies in each plate

b: the plate area (Cm^2)

t: exposure time per minute

3. Results and Discussion

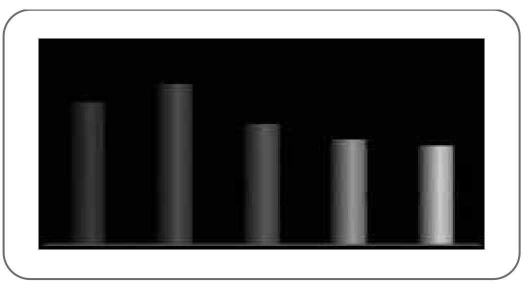
3.1. Water soluble ions (WSIs)

The daily mean concentrations of respirable particulate (PM_{10}) at the five sites were 284, 320, 241, 211 and 198 µg/m^3 during hajj season of 1437H (2016). The concentrations recorded in this study were lower than the daily mean limitation of PM_{10} (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 (PM_{10}) recorded in during hajj season.

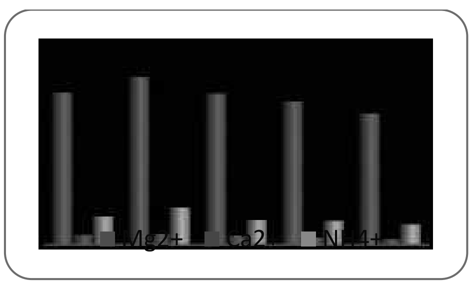
Figure 4 showed the daily average concentration of cations (NH_4^+, Ca^{2+} and Mg^{2+}), which ranged between 1.5 – 2.7, 0.39 – 0.82 and 9.8 – 12.5 µg/m^3, where higher concentrations were recorded at site 2 and site 1. The daily mean concentration of anions (NO_3^-, SO_4^{2-}, Cl^-, PO_4^{3-}, Br^- and F^-) 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 – 0.034 µg/m^3, where higher concentrations were recorded at site 2 and site 1.

The results indicated that Cl^-, NO_3^- and SO_4^{2-} were the most predominant species of WSI in particulate (PM_{10}) during Hajj seasons 2016 (1437 AH). 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.

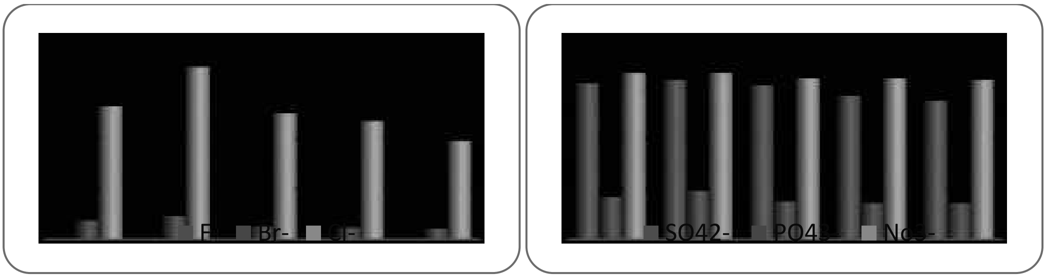
The study also demonstrated a strong positive relationship between NO_3^- and SO_4^{2-} observed in particulate (PM_{10}). This may be attributable to the interaction of SO_2 and NOx and sharing the same source of emissions (road traffic).



A) PM_{10}



B) Cations (NH_4^+, Ca^{2+} and Mg^{2+})



C) Anions (NO_3^-, SO_4^{2-}, PO_4^{3-}, Cl^-, Br^- and F^-)
Figure 4: The daily mean concentrations of respirable particulate (PM_{10}) and its (Ctions + anions)

The ratios of NO_3^-/SO_4^{2-} in PM_{10} ranged between 1.05 - 1.15 during hajj season 2016 (1437 AH). These ratios were higher than the 0.14–0.70 ratio found by Zhou et al. (2002), 0.3–0.5 ratio reported by Hueber et al. (1988). SO_2 and NOx were the major atmospheric pollutants in Makkah city as represented by Nasralla and Albar, 2005. And their concentrations are important factors in controlling sulphate and nitrate formation. SO_4^{2-} and NO_3^-, being secondary pollutants are formed by various heterogeneous and homogenous chemical reactions in the atmosphere. (Seinfeld, 1986; Ding and Zhu, 2003). SO_2 and NOx are the major precursors for their formation and therefore controlling the emission of SO_2 and NOx can directly affect the concentrations of SO_4^{2-} and NO_3^-.
It was shown in Table 1 that the WSIs concentrations in PM_{10} were lower than that recorded in China, Beijing (Zhang et al., 2007) and India, Ahmadabad (Rengarajan et al., 2011), although within those recorded by some other countries such as Jungfraujoch, Switzerland (nyeki et al., 1996; Krivacsy et al., 1988), Monte Cimone, Italy (Marenco et al., 2006), Brazil, Tanzania and Taiwan.

Table 1: Water soluble Ions (µg/m^3) in different countries around the world.

Country		PM_{10}				Reference
		NO_3^-	SO_4^{2-}	NH_4^+	PM_{10}	
KSA	Makkah	6.46	5.96	2.0	250.8	The current study
China	Beijing	90.0	90.9	78.6	506.9	Zhang et al., 2007
India	Ahmadabad	7.2	13.8	3.7	171.0	Rengarajan et al., 2011
Taiwan	Chaochou	23.1	9.6	7.1	115.0	Chena et al., 2006
Switzerland	Jungfraujoch	0.03	0.3	0.1	-	Nyeki et al., 1996
Italy	Monte Cimone	0.9	3.5	1.4	16.0	Marenco et al., 2006
Brazil	Sao Paulo	3.4	5.1	1.9	38.0	Vasconcellos et al., 2010
Tanzania	Dar Essalaam	0.7	1.4	0.2	69.0	Mkoma et al., 2009

3.2. 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 formers bacteria by 8% (as shown in Fig. 5).

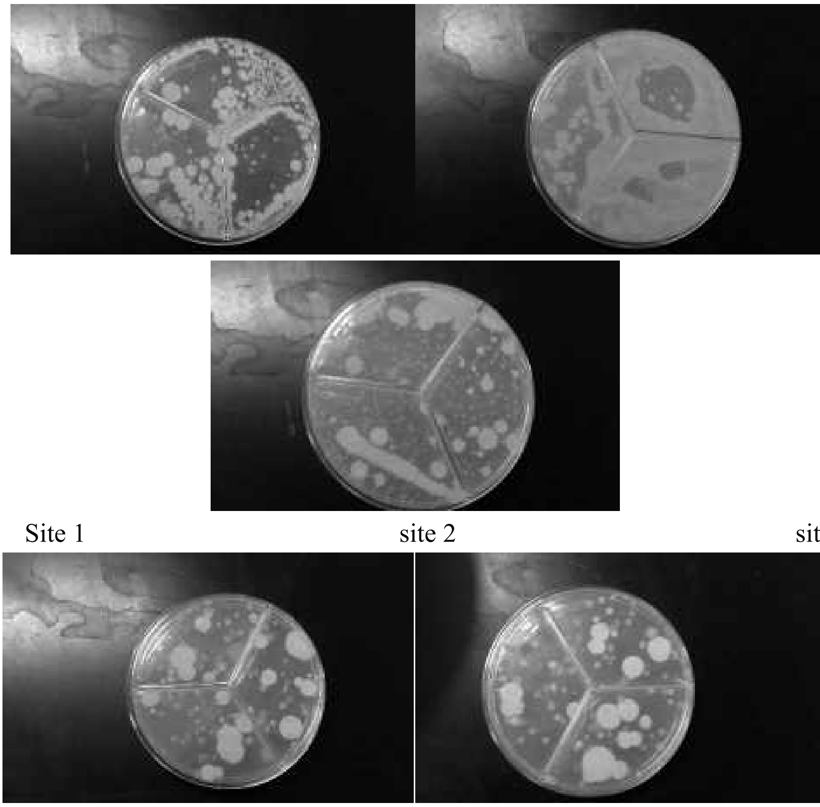


Figure 5: The microbiological air pollution

The results demonstrated the permanent presence of bacteria gram positive because it is linked with activities of humanity and the numbers of people and rates of ventilation (Matkovic et al., 2007; Shaffer and Lighthart, 1997). The bacteria Bacillus they grow in the presence of decomposing organic material, usually found in soil, dust, water and are present in the sands of the desert (Mahdy and EL Sehrawi, 1997; Fang et al 2005). G-ve bacteria are often rare in the air, and was considered the bacteria Pseudomonas (Abdel Hameed and Khoder, 2001), one of the opportunistic organisms that can cause disease (Rahkonen and Ettala, 1990) but not to cause damage to people health.

The G -ve bacteria was not present, which was probably because that it is more sensitive to environmental conditions as 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 (Karra and Katsivela, 2007).

Furthermore, the microbial load difference in all locations may be attributed to that fact that 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 (Tong and Lighthart 1997). Microbes can grow and reproduce in the air and thus lead to changing the composition of the microbial load of place. Change in 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 in air at each site (Fahlgren et al., 2010).

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. Bacteria concentrations ranged from $10^3 \times 1.6$ - $10^4 \times 2.3$ CFU/m^3, these results were agreement with (WU etal., 2012; Fang et al., 2005).

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 was resulting in dirt and dust. 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 high relative humidity.

Fungus concentrations recorded at five sites around the Haram in Makkah were relatively low, which ranged between $<10^2$ - 4 x 10^2 CFU/m^3, and the average concentrations were 2.8 x 10^2, 2.2 x 10^2, 1.4 x 10^2, 1.8 x 10^2 and 2.0 x 10^2 CFU/m^3, 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 vary from one place to another as a result of different weather conditions and vegetation, agricultural and human activities (Mitakakis et al., 2005), time, season, and geographical conditions (Klarić and Pepeljnjak, 2006).

In this study, fungi concentrations did not exceed 4x10^2 CFU/m^3. Alsrany and bin Turki (1415 AH) recorded fungus concentrations ranged between 2.9 - 10 CFU/m^3 at the Prophet's Mosque in Medina, Abed (1421 AH) found the contamination rates of microbial air conditioning in the Makkah area during the month of Ramadan for the year 1421 AH was between 42 - 284 CFU/m^3.

4. Conclusions

The main objective of this work was to focus on PM_{10} and its bio-accumulations (microbial load) in Makkah during Hajj seasons 2016 (1437 AH). This study concluded that the concentrations of respirable particles (PM_{10}) 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 NOx are the major precursors for their formation and therefore controlling the emission of SO_2 and NOx can directly affect the concentrations of SO_4^{2-} and NO_3^-.

Assessment of microbial air pollution is 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. 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.

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