Assessment of PM_{10}, CO and noise levels at the central area of Makkah during Hajj season 1429H (2008)

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Abstract

The present investigation aims to study temporal and spatial variation in the concentrations of PM_{10}, CO and noise levels at the central area (322 m altitude, 21º.25 N, 39º.52 E) in Makkah, Saudi Arabia, during hajj season in 1429H (2008). Measurements of PM_{10}, CO and noise levels were conducted using the High Volume Sampler of PM_{10}, CO gas monitor and the Sound level Meter of model CR812B, respectively. The daily averaged measured PM_{10} concentrations at the central area were high and ranged between 85 and 200 $\mu g/m^3$. Despite such PM_{10} concentrations are lower than the recorded one (250 $\mu g/m^3$) by previous studies and are within the permissible limits by GERRI (340 $\mu g/m^3$) but they were still exceeding the recommended limits of PM_{10} (20 $\mu g/m^3$) by WHO. However, the averaged measured concentrations of CO were less than 20 mg/m^3/hr except Tunnel (1) that reached 97 mg/m^3/hr. The measured LAeq at the central area sites varied between 71 and 98 dB exceeding the recommended value of 70 dB by WHO. This study also discussed the temporal variation of all these pollutants during hajj season and its expected sources in the central area and its health effects on pilgrims. The solutions were suggested to improve the air quality. Most important suggestion is adopting a new public transportation system at this central area in Makkah such as monorail, trams or train networks that would extremely reduce air pollutant concentrations and noise levels. A comprehensive program is required for the safety environmental management.
Keywords: PM_{10}, CO, noise levels, air pollution, central area, Hajj, Makkah.

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1 Introduction

Makkah is the Holy Capital City (322 m altitude, 21°.25 N, 39°.52 E) in Saudi Arabia and it is a valley that is surrounded by many mountains from all directions. Makkah is considered as the holiest city on the earth to Muslims. The Holy Mosque is located at the middle of the city centre of Makkah that is also known as the central area. Many studies were published for assessing air quality at the central area in Makkah during Hajj seasons to protect pilgrims from air pollution. For example, the conducted studies by the Institute of the Custodian of the Two Holy Mosques for Hajj Research in Makkah from 2004 to 2009, showed high concentrations of air dust and pollutants at the central area particularly in roads and tunnels leading to the Holy Mosque (Nasralla [1], Nasralla and Seroji [2, 3], Seroji [4]). Air dust studies showed increase of the total suspended particulates (TSP, larger than 10 micrometers), as well as particulates matters of less than 10 micrometers and greater than 2.5 micrometers (PM_{10}) in the air of the central area (Nasralla and Seroji [3]). In terms of other pollutant concentrations, such as carbon monoxide (CO), recent study showed that the average concentration of CO was very limited (7–13 mg/m^3 for 15 minutes) in the halls of the Holy Mosque near the ventilation halls of Assog Assageer tunnel (Seroji [5]). In addition, the noise studies at the central area in Makkah were performed by some researchers showing that the high levels of noise were ranging between 80 and 95 dB (Seroji [5], Saati and Shaheen [6], Shehatah [7]).

The aim of this study was to assess the concentrations of both PM_{10} and CO, as well as the LAeq in streets and tunnels at the central area in Makkah during hajj season in 2008 (1429H).

2 Methodology

The PM_{10} concentration was collected every 24 hours daily by High Volume Sampler of PM_{10} that made by Staplex Air Sampler Division in USA. Such instrument was calibrated using the High Volume Calibration Kit of model CKHV810 with Air Sampler equipped with 8"×10" Filter Holder Assembly and includes a Calibration Orifice prescribed for use by U.S. Concentration of CO was measured using CO gas monitor that is manufactured by German company of Draeger. In terms of noise measurements, the LAeq, Lmax and Peak functions were detected using an integrated Average Sound Level Meters, models numbers of CR: 812B that is developed by the Cirrus research PLC, in UK. The LAeq is referred to a standard weighting of the audible frequencies designed to reflect the response of the human ear to noise during a period of time. The LAeq were sampled every 15 minutes. However, Lmax is referred to the maximum sound level, while the Peak function is referred to the maximum value reached by the sound pressure at any instant of time in dB unit.

Measurements were sampled daily for 24 hours from 00:00 to 24:00 in terms of PM_{10} and every 8 hours in terms of both CO and LAeq from 16:00 to 24:00 during the beginning of Zulhijah month (Hajj month) from 2–10/12/1429H (30/11–8/12/2008).

There were 7 sites of measurement in Makkah; five of them were inside the central area (Alshobikah, Ajiad Assod, Alghazah, Umm Alqura Street and Assouk Assagheer tunnel (Tunnel_1)) while, the other two were outside of the central area (Alaziziah and Mahbas Aljin tunnel (Tunnel_2)).

3 Results and discussions

3.1 PM_{10} concentrations

Temporal and spatial variations of PM_{10} levels were presented daily in Fig. 1 at four sites of Ajiad Assod, Alshobikah, Alghazah and Alaziziah from 3rd to 10th of Zulhijah. It was impossible to launch the High Volume Sampler of PM_{10} in Umm Alqura Street and tunnels, where there was not any source for electricity. However, most sites were covered here for several days (Fig. 1).

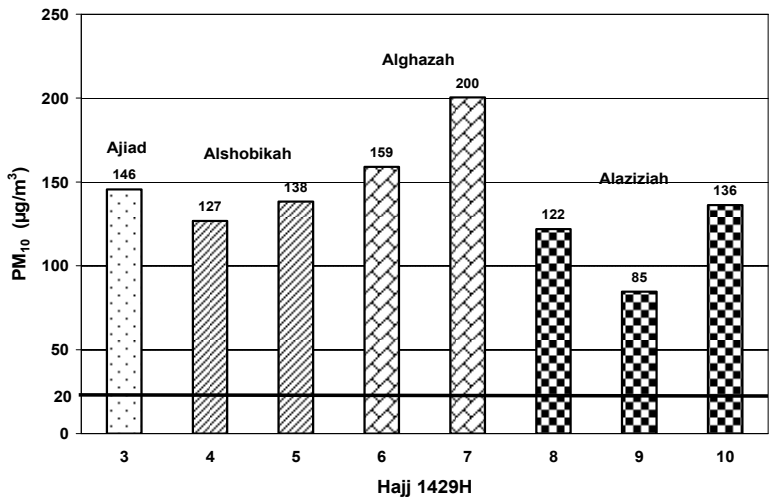

Figure 1: Concentration of PM_{10} at four sites in Makkah during hajj 2008.

It is clear that the PM_{10} concentrations in all sites were high and ranging between 85 and 200 µg/m^3. These values are within the permissible limits by GERRI (340 µg/m^3) (GERRI [8]) but they were still exceeding the recommended limits of PM_{10} (20 µg/m^3) by WHO [9] and by European Standards of 50 µg/m^3 (WHO [10]). In the central area sites Alghazah area has shown the highest concentrations between 159 and 200 µg/m^3 and then Ajiad Assod (146 µg/m^3), while the lowest values were measured in Alshobikah area and were ranging between 127 and 138 µg/m^3. The reasons of these high PM_{10} concentrations in the central area sites are related to the recent construction development in the region since 2007 until now. There are other factors that have caused such high PM_{10} concentration, such as overcrowding, traffic jam, density urban area, rising

numbers of attendees of the Holy Mosque and increasing different activities during Hajj season in the region. The reason of the highest concentration of PM_{10} in Alghazah, is because of the site being very close to the construction development areas. Moreover, the measurement days of 6th and 7th of Zulhijah were weekend period when most inhabitants (in addition to pilgrims) before to go to the holly Mosque. Nevertheless, PM_{10} concentrations at sites out of the central area were comparatively lower than that in the central area (Fig. 1) and were ranging between 85 and 136 $\mu g/m^3$. The highest concentration of PM_{10} (136 $\mu g/m^3$) in Alaziziah area was on 10th of Zulhijah when most of pilgrims return from Mina to Makkah passing Alaziziah area to make Tawaf Alefadah and pray Eead Aladha in the Holy Mosque. As a result numbers of buses and vehicles are increasing sharply in Alazizih area causing high density of transportation and hence large PM_{10} concentration. However, the lowest PM_{10} concentration of 85 $\mu g/m^3$ was observed on 9th of Zulhijah when all pilgrims were accommodating in Arafat area for Al-Wakffah day. On 8th of Zulhijah the measured PM_{10} concentration in Alaziziah has increased to 122 $\mu g/m^3$ due to moving of most pilgrims by buses from Makkah to Mina Valley to stay tonight following the guidance of Prophet Muhammad.

Fig. 2 showed temporal variations of the measured PM_{10} concentrations at the central area in Makkah during Hajj seasons in this study (2008) against the measured one in the previous studies (Nasralla and Seroji [3]) for two deferent years of 2004 and 2005. It is clear that the measured concentrations of PM_{10} in this study were generally higher than that in both years of 2004 and 2005. However, PM_{10} levels in days of 10th and 11th of Zulhijah in 2005 were higher

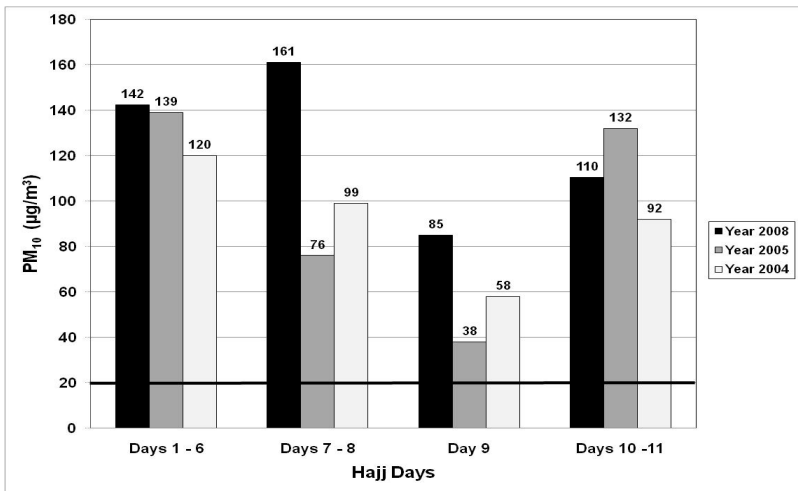

Figure 2: Concentration of PM10 during hajj days in three deferent years in Makkah.

than others. It is also observed that the concentrations of PM_{10} in days before Arafat day were greater than that after Arafat day. Nevertheless, the PM_{10} levels

on all hajj days in the three years were very high and exceeded the recommended limits of PM_{10} (20 μg/m^3) by WHO.

Such high concentration of PM_{10} in Makkah could affect pilgrims' health and pilgrims may face an acute health problem (Nasralla [11]) during hajj season. It is well known that long term exposure to PM_{10} concentrations can cause several diseases such as mortality due to cardiovascular, respiratory disease, chronic respiratory disease incidence and prevalence (asthma, COPD, chronic pathological changes), chronic changes in physiologic functions, lung cancer, chronic cardiovascular disease and intrauterine growth restriction (low birth weight at term, intrauterine growth retardation, small for gestational age) (WHO [12]).

3.2 CO concentrations

The variation of CO concentrations were sampled daily from 16:00–00:00 at seven sites of Alshobikah, Ajiad Assod, Alghazah, Umm Alqura Street, Tunnel_1, Alaziziah and Tunnel_2 from 3rd to 8th of Zulhijah and were presented in Fig. 3. Most sites showed low CO concentrations (<20 mg/m^3) every hour during the days of Zulhijah. The variations of CO concentration in most sites were almost similar and ranging between 1 and 17 mg/m^3. However, Tunnel_1 showed higher CO concentration and reached to the maximum hourly average CO concentration of approximately 97 mg/m^3 at 17:00 exceeding the allowed hourly CO concentration of 30 mg/m^3 by both GERRI [8] and WHO [9].

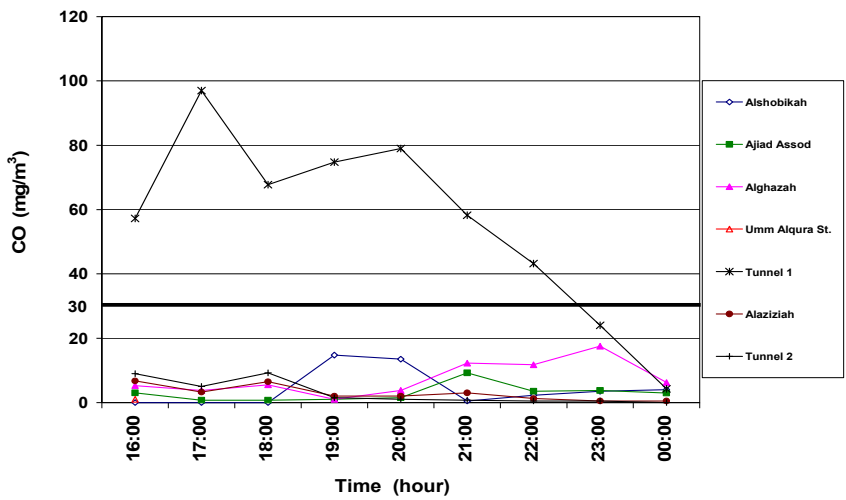

Figure 3: Hourly averages CO concentration at seven sites in Makkah during hajj 2008.

However, this concentration has sharply decreased between 20:00 and 00:00 when last prayer (Eshaa prayer) in the Holy Mosque has finished and most pilgrims have left to their accommodations causing low vehicle density in

Tunnel_1 at this time of period. Nevertheless, CO concentration at this tunnel was still the highest due to the design of this Tunnel_1, which is not straight (Shahatah, 2003). The ventilation system inside this tunnel also causes large air turbulences and captures gases inside it, leading to high CO concentration. Another reason for such high CO concentration is the location of this Tunnel_1, which is located underneath the Holy Mosque halls, where most pilgrims and inhabitants prefer to go through for prayers. Hence, numbers of vehicles passing this Tunnel_1 are increasing sharply, especially before and after prayers.

To compare the concentration of CO among these seven sites, the average CO concentration per 8 hours were calculated and presented in Fig. 4. Most sites were within the allowed CO concentration 10 mg/m^3/8hr that recommended by WHO. This is good result, confirming that the ambient air inside and outside the central area is healthy for pilgrims during the hajj season in Makkah. However, Tunnel_1 showed the highest average CO concentration among sites with value of 60 mg/m^3/8hr exceeding 6 times of the allowed value by GERRI (10 mg/m^3/8hr) (GERRI [8]).

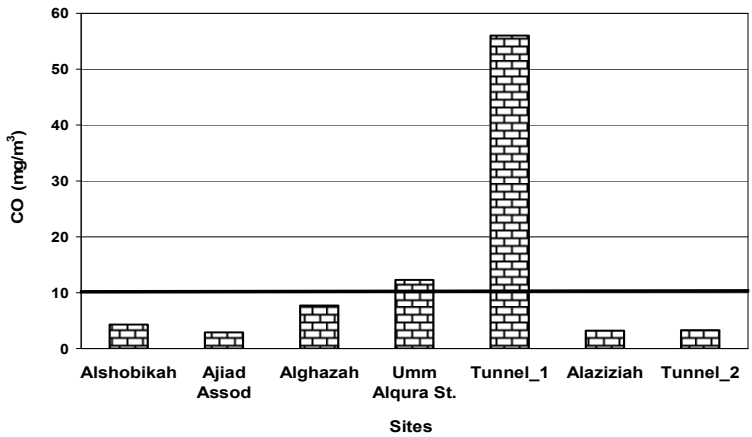

Figure 4: The average CO concentration per 8 hr at seven sites in Makkah during hajj 2008.

3.3 Noise levels

Measurements of noise levels were conducted daily between 16:00 and 00:00 at most sites inside and outside of the central area. Measurements have included three kinds of noise functions of LAeq, Lmax and Peak. Fig. 5 showed the noise levels of three functions in Alghazah site on 4th of Zulhijah. The LAeq values were ranging between 71 and 92 dB exceeding the recommended values of 70 dB in traffic areas by WHO [13]. Moreover, the highest values of Lmax and Peak were approximately 111 and 121 dB, respectively. However, the maximum noise level of LAeq (92 dB) was recorded at 21:30 after Esha prayer due to the traffic road at this time.

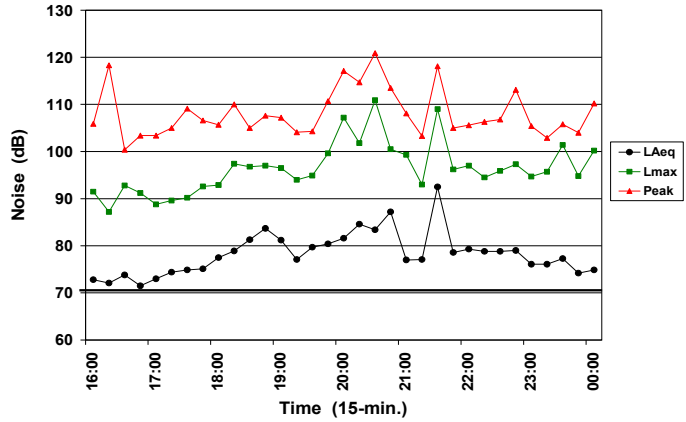

Figure 5: Variation of the three noise functions in Alghazah site on 4th of hajj 2008.

The LAeq values at sites of Ajiad Assod, Alghazah, Umm Alqura Street, Tunnel_1, Alaziziah and Tunnel_2 were measured from 2nd to 6th of Zulhijah and presented in Fig. 6. In general, most sites showed high noise levels ranging from 71–98 dB exceeding the recommended value by WHO in most time of measurements. The curves fluctuations at sites are due to the variation in numbers of cars per each 15 minutes that are related to the different times of prayers during the day.

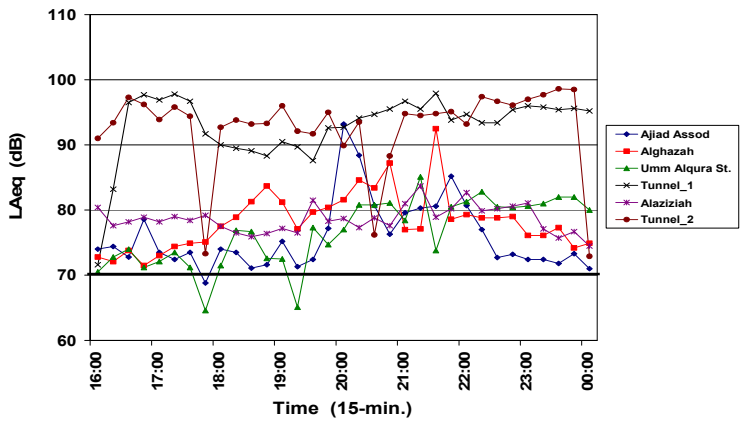

Figure 6: Variations of LAeq levels per 15 min at six sites in Makkah during hajj 2008.

The daily measured noises levels of LAeq (8 hours) at these six sites were computed using an algorithm equation of 5 and presented in Fig. 7 for comparison.

$$Leq=10*\log_{10}\{(10^{(Leq(1)/10)}+10^{(Leq(2)/10)}+\ldots\ldots 10^{(Leq(n)/10)})/n\} \quad (5)$$

where n = number of noise level samples.

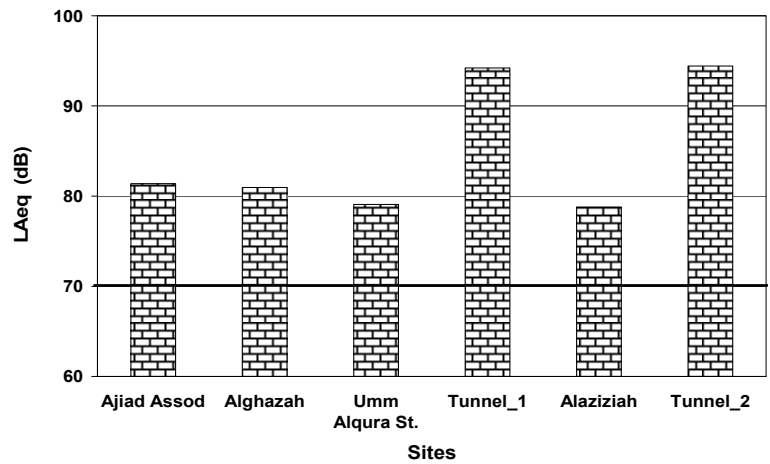

Figure 7: The daily average levels of LAeq per 8 hr at six sites in Makkah during hajj 2008.

Most sites except both tunnels have shown noise levels of approximately 81 dB even inside and outside the central area. However, both tunnels showed the highest level of LAeq of about 94 dB. The reason of these high noise levels in both tunnels is because these are closed areas and many cars (400 – 750 cars) were passing these tunnels at every 15 minutes during the time of measurements. Such high noise levels could cause speech intelligibility (Bradley [14]), sleep disturbance (Cohen *et al.* [15]), mental health problems (WHO [13]), physiological effects, such as tiredness and hypertension (IEH [16], Ising *et al.* [17]).

4 Conclusions

Temporal and spatial variations in the concentrations of PM10 and CO as well as noise levels were measured at the central area in Makkah, Saudi Arabia during hajj season in 1429H (2008). Results showed high concentration of PM_{10} at the central area ranging between 85 and 200 $\mu g/m^3$. The CO concentration and noise levels were also measured.

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