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EFFECT OF HEAVY CONSTRUCTION ON THE AMBIENT ENVIRONMENT OF AL-MASJID-E-NABAWI (ﷺ) AND HAREM AL-MADINAH

^aQazi Umar Farooq ^{1}, ^aWadea K. Sindi ², and ^aAyed E. Alluqmani ³*

a: Department of Civil Engineering, Islamic University of Madinah, 41411 Saudi Arabia

1: umar@iu.edu.sa; 2: wadeas@iu.edu.sa; 3: dr.ayed@iu.edu.sa

* Corresponding author: Email ID: umar@iu.edu.sa; qaziumar@gmail.com

Abstract- Al Masjid-e-Nabwi sharif is one of the holiest places in Islam. Everyday thousands of pilgrims from each part of the world, visit the masjid to offer regular and optional prayers. To accommodate the rapidly increasing number of pilgrims, throughout history, the complex of Harem Al-Madinah undergoes various expansions. The most recent expansion was announced in 2012 and construction was in full swing during the 2014-15 fiscal year. The expansion project not only involves heavy construction but also requires demolishing of pre-existing buildings in the surroundings. The key objective of this investigation is to monitor the effect of nearby heavy construction activities on the critical environmental indicators of the prophet's masjid and surrounding areas. In this study, the vital ambient air quality parameters and noise levels were measured at different locations of Masjid during peak hours. The results are then compared with international health and safety standards. It has been observed that overall indoor air quality (IAQ) was within tolerable limits. However, there were noise impacts at some locations. The health and safety measure adopted by the authorities comply with international standards and similar procedures can be applied to the other parts of the world where heavy construction is required in the built-up urban areas.

Keywords- Harem Al Madinah, Air quality, Dust concentration, Carbon oxides, Noise Level.

1 Introduction

The historic city of Al Madinah Al Munawara is a northwestern city in the kingdom of Saudi Arabia. The most important landmark of the city is the prophet Muhammad ﷺ's Masjid. It is the 2nd masjid built in Islam during the lifetime of the Prophet ﷺ. The first built masjid "Quba" is also located in the city towards the south of the masjid-e-Nabawi. Millions of Muslims from all over the globe visit the masjid every year. For example in 2019 alone about 2.5 million pilgrims performed the hajj including (1.9 million foreign pilgrims) and almost all of them visited Masjid-e-Nabawi[1]. The national and local authorities of the kingdom endeavors to provide a safe and healthy environment to the visitors. The number of pilgrims to the prophet's masjid is in constant increase through history and the masjid undergoes various expansions. The prophet ﷺ build the masjid in 622 CE with an area of 1050 m². The masjid undergoes first expansion during the lifetime of the prophet ﷺ after the battle of Khyber in 628CE and the area was increased to 2475m². The area of the masjid increased up to 500 % in 1994 during the era of the late King Fahad of Saudi Arabia [2][3]. The current expansion was inaugurated in 2012 by the late King Abdullah of Saudi Arabia and will increase the capacity of the worshippers up to 800,000 in the first phase[4][5].



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The recent images of the masjid taken on bright sunny afternoon (after Asar prayer) of 19th March 2021 are shown in *Figure 1*. *Figure 1(a)* shows the panoramic view of the masjid-e-Nabawi from the south i.e., qibla direction. Whereas the ongoing eastern expansion site is shown in *Figure 1(b)*.



a) Panoramic view of Masjid



b) Recent expansion Site

Figure 1: a) Panoramic View of Masjid from South and b) Image of an ongoing Expansion as of March 2021.

Most of the current and prospective construction for the expansion project requires heavy earthwork and RC construction. The construction industry is one of the largest material consumer and pollution contributor [6]. Heavy construction activities cause the release of various environmental distresses including but not limited to noise, dust, and vibrations. Studies regarding monitoring and implementation of environmental policies reveal that these distresses can be controlled by proper implementation of policies [7]. Most of the environmental and health policies are developed based on international guidelines such as world health organization (WHO) guidelines for air quality [8], American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) standards for indoor air quality [9], The National Institute for Occupational Safety and Health (NIOSH) standards and US environmental protection agency (EPA) guidelines. Despite the above guidelines and efforts, the economic real-time environmental monitoring system is required to be developed for the construction industry[10]. Apart from air quality, noise generation is additional environmental distress generated by the construction industry. It is associated with the health hazard, and required to be monitored and addressed[11].

Since Masjid e Nabawi is a unique project which is daily visited by thousands of pilgrims as well as there is a heavy construction site in the vicinity, both occupational and indoor standards are required to be implemented simultaneously. The study is innovative in terms of scrutinizing the environmental distresses, generated by the combination of heavy construction activities and high crowd intensity. In this study, various environmental parameters are compared with the most relevant standard applied at the specific location.

2 Methodology

In this study, the key ambient environmental parameters were measured at the most important locations of Al-Masjid-e-Nabawi ﷺ and the results are then compared with the respective ideal and threshold values provided by relevant indoor and outdoor quality standards. The measurement locations were selected based on the intensity of visitors. For example, all the visitors to the masjid like to offer salaam to the prophet Muhammad ﷺ, and want to offer salah at Riyadh-ul-Jannah. These two locations are always crowded and marked as locations A and B in this study. An effort has been made to cover at least one location of different crowd intensity and the nomenclature of the location has been decided on the likelihood of people intensity in descending order.

All the measurement locations are marked on the google maps satellite image acquired in March 2021[12] and presented in *Figure 2*. The two expansion sites are also indicated in the figure. The western expansion has already been completed and marked as recent expansion. Whilst the eastern expansion is still under construction and has been divided into two



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zones marked as Zone A and Zone B. The other vital locations include an internal courtyard, the previous northern expansion, two exterior courtyards, and the most crowded basement car parking.

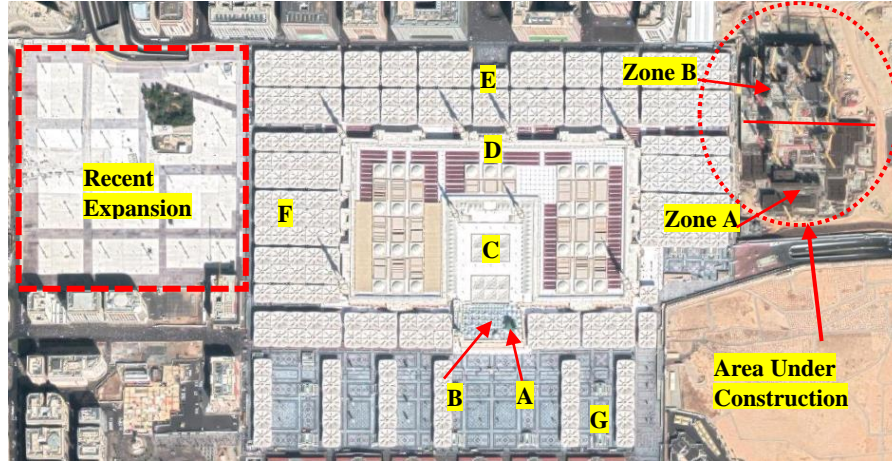


Figure 2 The Satellite Image of Masjid-e Nabawi Complex March 2021 with measurement Locations

A detailed description of all the measurement locations is presented in *Table 1*. The locations A to G are the harem areas where the likelihood of the people is always there, except for the current unusual circumstances applying COVID-19 protocols. The expansion sites are not yet open to the public and hence not included in the table.

Table 1 Description of Measurement Locations at Al-Harem

Sr. No	Location Description	Location Symbol	Remarks
1	Site for offering Salam to Prophet ﷺ	A	Critical and most crowded location
2	Riyadh-ul-Jannah الروضة الشريفة	B	Critical and most crowded location
3	2 nd Internal Courtyard	C	Crowded in Peak Season
4	Northern King Fahad Extension	D	Crowded only during Obligatory Prayers in Peak Season.
5	Northern Exterior Courtyard	E	Passageway /crowded in Peak Season
6	Western Exterior Courtyard	F	Passageway /crowded in Peak Season Close to recent expansion.
7	Basement Car Parking 1-A (The Upper Deck)	G	Always Crowded during obligatory Prayers

The data for the air quality parameters have been obtained from the comprehensive routine reports prepared by the “*Technical Committee for the expansion of the Prophet's Mosque*”, and “*Madinah Al Munawara Development Authority*.” In this study, four indoor air quality parameters, i.e., Relative humidity, Noise levels, carbon dioxide, and carbon monoxide were compared with the designated international standards. The time for the measurement was chosen is late August 2014 which corresponds to late Shawal and early Dul-Qidah 1435AH. The time marks the Hajj season when most of the international pilgrims start arriving in Madinah. The construction activities were in full swing at the time and many demolishing projects were also going on around the Harem area. Since Masjid is most crowded at Isha prayer due to the



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arrival of local residents. The data of environmental parameters just after Isha prayer has been used in the comparison. The four air quality parameters and their designated international guidelines are summarized in *Table 2*. The only outdoor air quality parameter is used in the study for the under-construction sites namely zone A and Zone B is inhale able Particulate Matter PM₁₀. The construction site (Zone A and B) is not yet open to the public.

Table 2: List of detrimental parameters with international Health and Safety Standards

Sr. No	Parameter	Symbol (units)	Guideline /Criteria
1	Relative Humidity	RH (%)	ASHRAE
2	Noise Level	-(dB)	WHO & NIOSH
3	Carbon dioxide	CO ₂ (ppm)	NIOSH/EPA
4	Carbon monoxide	CO (ppm)	WHO
5	Particulate Matter (only for construction Zones A and B)	PM ₁₀ (mg/m ³)	WHO

3 Results and Discussions

Madinah al Munawara is mostly a dry region with a desert climate and very limited precipitation [13]. The annual average relative humidity in the city is about 24%. As per ASHRAE standards, the comfortable relative humidity values range between 30 to 60%. Figure 3 represents the variation of relative humidity at studied locations of the harem. The upper and lower limits of the ASHRAE standards are marked as maximum and minimum and indicated by bold lines. The indoor relative humidity (location A to D) is within a comfortable zone, reflecting the performance of Haram Al Madinah's HVAC system. The Masjid is supported by one of the world's largest air-conditioning systems. The courtyards and the parking lot have low humidity values implying the outdoor conditions. The northern courtyard has a relatively better humidity reading due to continuous mist spray. The indoor relative humidity values drop to the lower limit on Thursday 21st of August 2014, whilst the readings improve on Saturday 23rd August. The reason behind this is the variation in crowd intensity. The Masjid is usually very crowded on Thursday night as many people visit the masjid at the beginning of the weekend. On the other hand, it is generally less crowded on Saturday night as Sunday is the first working day of the week in the kingdom.

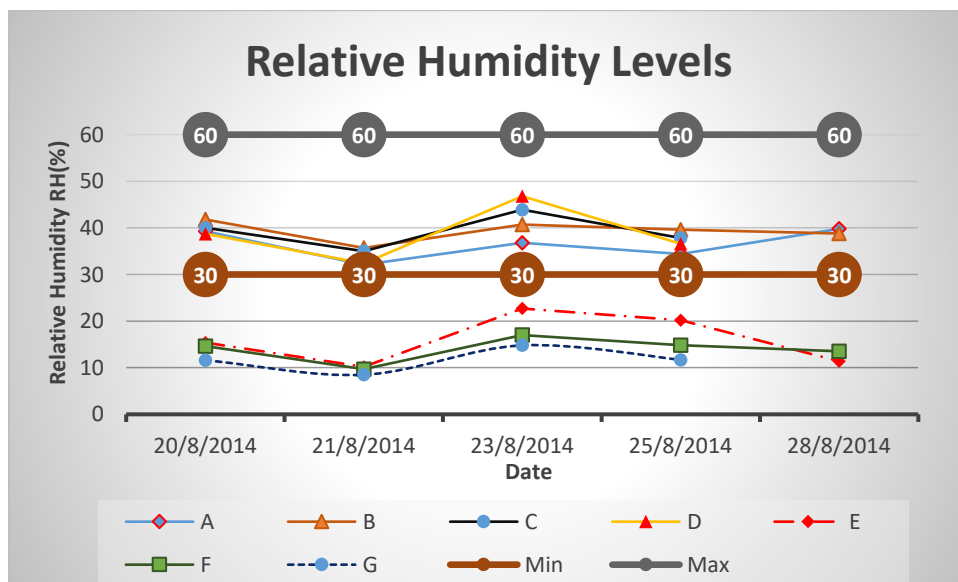


Figure 3: Relative humidity at Selected locations of Harem After Isha Prayer



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The noise levels at various locations of the harem are shown in Figure 4. The lower limit of 55 dB shown by a bold grey line represents the world health organization (WHO) standard value for an educational facility. While the upper limit of 80dB is the maximum tolerable limit for the workplace established by Occupational safety and health (NIOSH). The noise level readings for all locations are above WHO standard due to high crowd intensity and as such no significant noise was observed due to construction activity. This can be seen by comparing the noise history of location F (the closest to the construction area) and C (far from the construction zones). The car parking has the overall highest noise levels due to vehicle engines and horns. On Thursday 21st August, the parking location G has a drop in noise levels as visitors like to stay longer on weekends. All the noise readings are below the threshold value of 80dB.

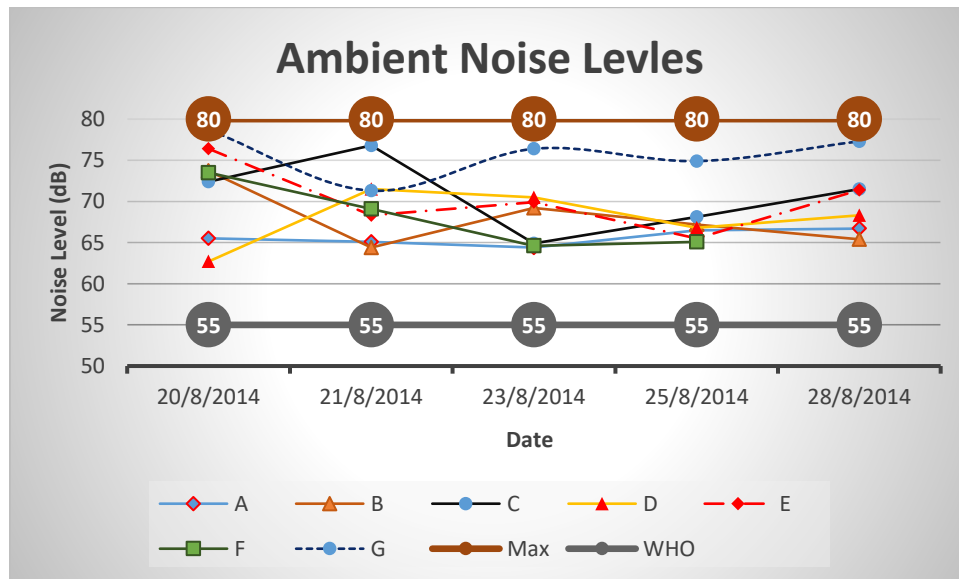


Figure 4 Ambient Noise Levels at Selected locations

The carbon dioxide levels in the masjid and surroundings are less than the threshold value of 1000 ppm established by NIOSH and US EPA, except for location B i.e. Riyadh-ul-Jannah. The location is extremely crowded at night, particularly on Thursdays and Fridays see Figure 5. The situation can lead to suffocation and people with respiratory disorders are recommended to avoid the peak hours' time. The ventilation at the location can be further improved by modifying the HVAC system. The CO₂ levels at other studied locations reflect that the CO₂ concentration at location B is not affected by the heavy construction.

The carbon monoxide concentration at all reference points is far below the benchmark value of 10 ppm set by the World health organization. The car parking has slightly higher readings of CO on Thursday due to idling vehicles which should be discouraged. The CO concentration history for the last week of August 2014 for various locations of the masjid and the benchmark value is shown in Figure 6.

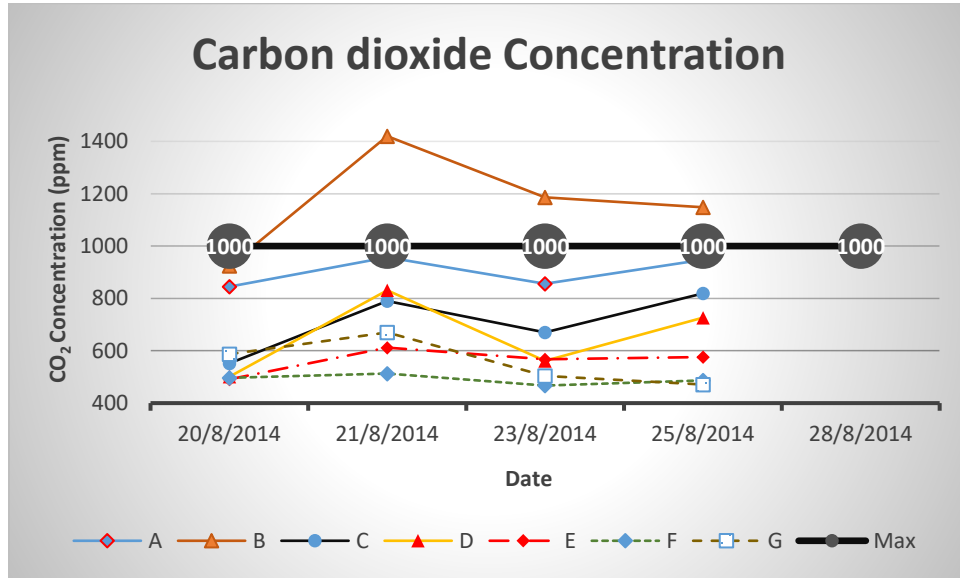


Figure 5 Carbon dioxide Concentration at various locations of Harem

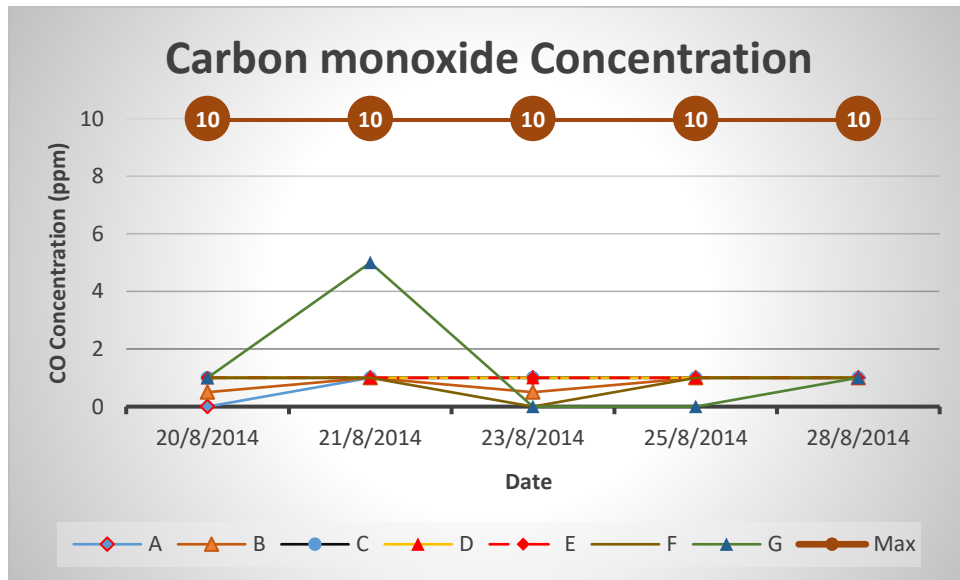


Figure 6 Carbon monoxide Concentration at studied locations

Due to limitations, the dust concentration data is only measured at construction zones A and B. It is measured in terms of inhalable particles having size $\leq 10 \mu\text{m}$ i.e., PM_{10} . The readings are taken for the whole month during peak working hours. The PM_{10} concentration in ppm for both the construction zones is shown in Figure 7. The PM_{10} concentration is very high as compared to the annual and daily outdoor air quality guideline reference values of WHO. This is particularly due



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to the marble cutting and other construction activities and the staff is provided with the best available safety equipment. The physical observation of dust concentration has not been reported in the prayer zones.

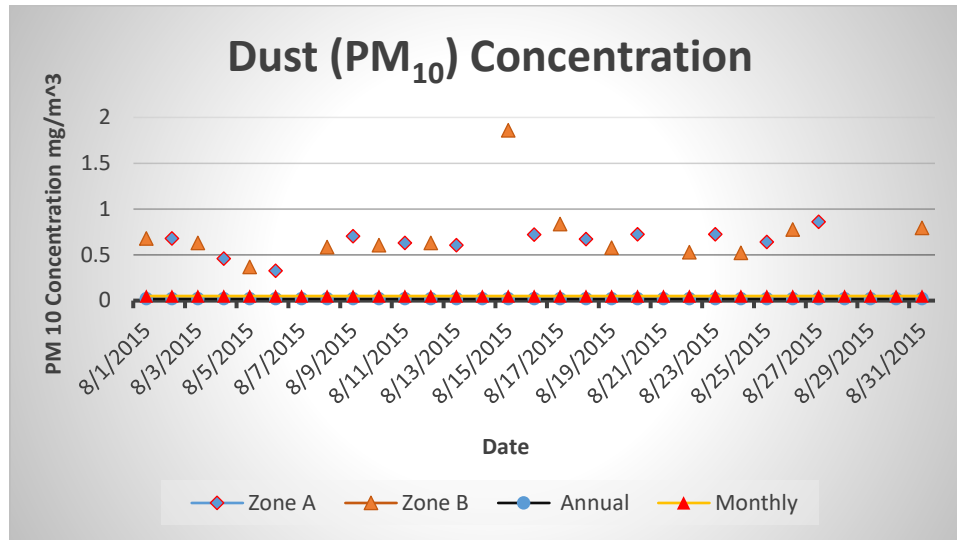


Figure 7: Dust Concentration at Zone A and Zone B

4 Conclusions

The ambient air quality of Masjid-e-Nabwi (ﷺ) complex including courtyards is not significantly affected by the nearby heavy construction of expansion projects. However, measurements of various air quality parameters revealed some interesting information which is summarized as follows:

- The HVAC system of the masjid is functioning quite nicely and maintaining comfortable indoor humidity levels despite the dry weather of the city.
- The overall environment of the masjid becomes noisy after prayers and pilgrims are required to be educated and guided to keep the decorum of the holy place even after completing the salah.
- The parking lots have sometimes higher carbon monoxide concentrations due to congestion and idling of vehicles and visitors must be reminded by signboards etc. to stop the engines while waiting for passengers in the parking areas.
- The dust concentration in terms of inhaling PM₁₀ is very high in the construction zones A and B of the expansion project. Although the construction activities are currently standstill, in case of resumption the public access to the areas near these zones should be restricted.
- Riyadh-ul-Jannah becomes overcrowded on weekends and has a high CO₂ concentration due to crowd intensity. Better crowd management techniques such as the current practice of issuing permits for praying in the noble Rawdah due to COVID 19 Protocols can be permanently adopted.

5 Recommendations

The IoT-based smart devices can be installed in large construction projects to continuously measure various air quality parameters, this enables the authorities to take real-time actions and accordingly guide the works and other stakeholders. Mandatory dust masks for workers and availability of respiratory support equipment must be ensured by the HSE engineers on sites where heavy marble installation is necessary. Buildings with high crowd intensity, such as public offices with long queues, etc., must be equipped with properly designed ventilation systems. The systems should be capable of accommodating higher CO₂ levels.



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Repentance

The authors seek the mercy of Allah (SWT) and ask his forgiveness if any information or phrase has been inadvertently misinterpreted or has been presented out of context.

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