



Air Pollution and Respiratory Diseases During The Hajj Season in The Holy City of Makkah

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Abstract

The holy city of Makkah is one of the big cities in Saudi Arabia that is densely populated, especially during the Hajj season. In recent years, air pollution in Makkah has been a growing problem due to construction activities, motor vehicle fumes, rising temperatures, rainfall and humidity. The higher the level of air pollution exposure, the more it has an impact on human health, especially the lungs and airways. The health impacts associated with air pollution include an increase in the incidence of respiratory infections, asthma, chronic obstructive pulmonary disease and other lung diseases. Better knowledge of the correlation between air pollution and lung and airway diseases will contribute to developing more strategies to reduce air pollution in the holy city of Makkah.

Keywords: air pollution, pilgrims, holy city of Makkah, respiratory disease

INTRODUCTION

Hajj is the fifth pillar of Islam. Around three million Muslims worldwide travel to the holy city of Makkah and perform various prayers in Makkah, Arafah, Muzdalifah, and Mina. During the pilgrimage season in the area, the human population increases significantly, and the activity is very high. Pilgrims spend several days on foot, driving cars, buses, trucks, and trains from one place to another, so these various activities produce a lot of air pollutants. In Makkah, the air quality data shows that air pollution during the Hajj

season is among the worst in the world. This literature review will discuss the condition of air pollution and respiratory diseases in the holy city of Makkah during the Hajj season.

AIR POLLUTANTS IN THE HOLY CITY OF MAKKAH

Particle

In terms of health impacts, environmental damage, and impaired visibility, particulate matter (PM) is considered one of the most important air pollutants. Particle size, chemical composition, and pollution levels in the

atmosphere are essential factors affecting human health. The size of the particles defines where they are deposited in the respiratory tract, while the chemical composition of the particles determines the sort of body response.

Habeebullah et al. conducted research in the Shebeka, Aziziah, Masfalah, and Awaly districts of Makkah. When compared to the proportion of total suspended particles (TSP), medium and coarse PM sizes are the most prevalent.¹

Habeebullah conducted the investigation to assess the levels and chemical composition of TSP, PM10, and PM2.5. Total suspended particles, PM10, and PM2.5 were detected in Makkah from August 2012 to September 2013. Heavy metals, cations, and anions were also analyzed. The study revealed that a significant majority of PM is not caused by fossil fuels, but rather by particle re-suspension, building, and demolition operations, as well as dust and sand particles driven by the wind. Research is needed to discover the specific source of PM in Makkah as part of efforts to enhance air quality in the city.²

Mohammed conducted a study to measure the spatial variation of PM10 in Makkah. In the north-western part of Makkah, PM10 levels are higher than in the southeast. The intensity of construction activities, transportation on highways, and city development in various locations in the central area of Makkah is the biggest contributor to the high levels of PM10.³

In the 2013 Hajj season, Khwaja et al. conducted a study to assess the air

quality around the holy place of Makkah. They measured PM7, PM2.5, O3, and black carbon (BC) levels up to 9,433 $\mu\text{g}/\text{m}^3$, 484 $\mu\text{g}/\text{m}^3$, 444 ppb, and 468 $\mu\text{g}/\text{m}^3$, respectively. This average level has exceeded the standards of the World Health Organization (WHO) for PM10 and PM2.5. High traffic volume, construction activities, particle re-suspension, and geographical conditions (dry areas) are the main causes of air pollution.⁴

In the month of Ramadan and the Hajj seasons of 1424 and 1425 H, Seroji researched the levels of TSP, PM10, and PM2.5 in the air of Makkah and the Mina valley. The daily cycle of PM10 in the air is related to traffic activity patterns. During the pilgrims' presence in Mina, daily levels in the Mina valley air ranged from 191–262 $\mu\text{g}/\text{m}^3$ exceeding the European standard of 50 $\mu\text{g}/\text{m}^3$. Pollutants contain up to 34%–40% TSP. During the last ten days of Ramadan, TSP levels in Makkah reached 665 $\mu\text{g}/\text{m}^3$ compared to the Saudi Arabian standard of 340 $\mu\text{g}/\text{m}^3$. Chemical analysis of PM10 shows high levels of sulphate, ammonium, nitrate, and chloride.⁵

PM10 levels and their chemical composition were measured in six locations (Al-Haram, Arafah, Muzdalifah, Aziziyah, Al-Nuzhah, and Al-Awali) in a study conducted by Adly et al. They found that PM10 levels were highly correlated with levels of cadmium, chromium, arsenic, beryllium, and nickel.⁶

Siddique studied air pollution levels in Makkah during the Hajj seasons of 2012 and 2013. Pollutant levels on most pilgrims' travel routes have surpassed WHO

standards for PM₁₀ and PM_{2.5}. High traffic volumes, construction activity, particle re-suspension, and geographical circumstances all contributed to high levels of air pollution (dry areas).⁷

Hazardous Gases

Al-Jeelani conducted a study in Makkah during the Hajj season on January 14-25, 2005, to assess air quality due to emissions from the daily activities of pilgrims associated with increased transportation needs. Measurements of the levels of several harmful air pollutant gases and several meteorological parameters, including temperature, wind speed, and wind direction, were carried out. At the beginning of the day, residents' activities were traveling to work, and high traffic volume had affected pollutants. Carbon monoxide, NO, and NO₂ levels change throughout the day, whereas sulfur dioxide levels remain relatively constant.⁸

Habeebullah conducted a graphical approach to measure the main air pollutant sources near the Al-Haram Mosque in Makkah. Air pollutants considered in this study are nitrogen oxides (NO_x), nitrogen dioxide (NO₂), nitric oxide (NO), carbon monoxide (CO), sulphur dioxide (SO₂), ozone (O₃) and particulate matter with an aerodynamic diameter of 10 µm or less (PM₁₀). Polar plots, time variation plots and correlation analysis are used to analyse the data and identify the major sources of emissions. Most of the pollutants demonstrate high concentrations during the morning traffic peak hours, suggesting road traffic as the main source of

emissions. The density of road traffic, re-suspension of particles, and dust or sand particles blown by the wind are the main sources of pollutant emissions identified in Makkah.⁹

Simpson et al. conducted a research to investigate air pollution levels in Makkah during the Hajj season in 2012. The study discovered significant amounts of carbon monoxide (CO) and volatile organic compounds (VOC) throughout the pilgrimage routes, particularly in the Makkah tunnels. Benzene i-pentane is the most prevalent volatile organic compound. The primary sources of volatile organic compounds are automobile exhaust emissions, gasoline evaporation, liquefied petroleum gas, and air conditioning.¹⁰

Al-Jeelani conducted a study to measure the impact of motor vehicle emissions on air quality around the Al-Haram Mosque in Makkah. Experimental, numerical, and statistical research were conducted. Several levels of harmful gases due to motor vehicle emissions are measured and analyzed. Research shows that the Masjid Al-Haram area has high levels of harmful gas pollutants. In addition, there was resistance to wind currents due to the height of the buildings around the Al-Haram Mosque.¹¹

Research in the Taneem area by Al-Jeelani showed that levels of nitrogen oxides and carbon monoxide in the morning increased, while sulphur dioxide levels were relatively low and constant. In addition, photochemical reactions affect ozone levels.¹²

Microbes

Abdel Hameed conducted a study to measure levels of microbial air pollutants. Using the gravity method, microbial contamination in the air is collected from the main direction of the Al-Haram Mosque in Makkah. In all directions, the concentrations of bacteria, fungi and actinomycetes ranged from 1,470 - 21,800 CFU/m³, respectively; 44 - 572 CFU/m³ and 0.0264 CFU/m³. Bacterial levels differed significantly, and gram-positive bacteria constituted 90-100% of the total bacterial isolates. Gamma proteobacteria are the common gram-negative bacteria, and *Aspergillus* is the predominant genus of fungi. Human activities have a greater influence on microbial levels than meteorological factors.¹³

Mohammed et al. conducted a study to measure particulate matter and biological contaminants in Makkah during the Hajj season of 1437H. Microbial air samples were collected at five locations around the Al-Haram Mosque. The results showed that the percentage of gram-positive bacteria ranged from 85-90% of the total bacteria isolated, while the percentage of gram-negative bacteria ranged from 5-9% of the total bacteria isolated. Spherical bacteria (cocci) were most commonly found in the gram-positive group and made up 35-80% of the total bacteria isolated. Around the Al-Haram Mosque in Makkah, humans are the main source of microbial air pollution.¹⁴

Air Allergens

The problem of allergic diseases has increased significantly over the last 50 years. Despite increasingly clear information on pathogenesis, risk factors, and treatment, allergies are on the rise. Allergens are proteins or glycoproteins that can induce a sIgE response. The top five inhalant allergens in the holy city of Makkah are the American cockroach, *Dermatophagoides pteronyssinus*, epithelia/cat hair, desert palm pollen, and *Dermatophagoides farina*.¹⁵

AIR POLLUTION AND RESPIRATORY DISEASES

The respiratory tract is the primary portal of entry for air pollutants; consequently the respiratory effects of pollutants have been studied for decades. Table 1 provides examples of common respiratory conditions and outcomes that have been associated with air pollution exposure. Meanwhile, Table 2 provides examples of biomarkers of respiratory health or function that have been used in studies of the respiratory effects of air pollution.¹⁶

Examples of respiratory clinical effects associated with air pollution:¹⁶

1. Increased mortality of the respiratory disease
2. Increased incidence of respiratory tract malignancies
3. Increased incidence, prevalence, or frequency of exacerbations in the disease
4. chronic lung: asthma, COPD, and cystic fibrosis

5. Increased incidence or severity of upper respiratory tract infections and
6. lower
7. Increased respiratory symptoms that affect the quality of life:
8. cough, phlegm, wheezing, shortness of breath, and runny nose
9. Increased incidence of preterm birth, low birth weight or growth inhibition
10. Impaired lung function growth in children
11. A temporary decrease in lung function
12. A transient decrease in lung function without symptoms, especially in
13. individuals who are susceptible (e.g., children with severe asthma)
14. The persistent or chronic decline in lung function (weeks, months, or years)

Examples of biomarkers of potentially adverse respiratory health effects:¹⁶

1. Elevated levels of airway inflammatory markers (e.g., PMN or cytokines in bronchial lavage or phlegm)
2. Elevated levels of markers of airway inflammation or inflammation in:
 - a. The exhaled breath (e.g., increased acidity)
 - b. The exhaled breath condensate or increased FeNO in asthmatics)
3. Elevated blood markers in lung injury (e.g., 8-isoprostane, club cell
4. secretory protein)
5. Imaging evidence of lung injury or reduced lung volume
6. Decreased pulmonary gas exchange (e.g., DLCO, DLNO, PaO₂, pulse
7. oximetry)
8. Improved airway responsiveness to nonspecific challenges

9. Increased airway hyper-reactivity in asthmatic patients

There are six types of substances present in the air that have a significant negative impact on public health: ozone, PM with different diameters - PM_{2.5}, PM_{2.5-10} μ , PM₁₀ μ , nitrogen dioxide, sulphur dioxide, carbon dioxide monoxide, and lead. Particular attention should be paid to small dust particles (PM₁₀ and PM_{2.5}) as they can penetrate the lower respiratory tract. The development and worsening of respiratory symptoms such as asthma, chronic obstructive pulmonary disease, respiratory infections, and lung cancer are all caused by air pollution.¹⁷

Research shows a relationship between air pollution and hospital admissions in adults due to Chronic Obstructive Pulmonary Disease (COPD). Increases in daily NO₂ and particulate matter levels were associated with a 4.60% and 3.01% increase in COPD hospital admission rates, respectively, in Sydney.¹⁸ Another study on hospital admissions in Birmingham, England, reported an association between PM₁₀ and rates of hospital admission due to pneumonia and mortality from COPD.¹⁹

Mohammed conducted a study in Makkah to evaluate the effect of a crushed mountain environment resulting in the dust on asthma patients. In the group exposed to a dusty environment, asthma symptoms worsened, lung function decreased, and the need for medication for relief and control of asthma attacks increased.²⁰

Many previous studies have shown that respiratory infections increase during

the Hajj season. Although upper respiratory tract diseases are prevalent, lower respiratory tract infections (pneumonia) can occur, and the latter is much more deadly than the former. The leading causes of illness include the influenza virus and other viruses and bacteria. The increase in respiratory infections during the Hajj season has severe implications for public health. It can lead to epidemics and adversely affect the economy due to increased health care costs, the need for hospital beds, and lost working days.

Strong evidence suggests an association between air pollution and the severity of illness associated with respiratory tract infections. Individuals with pre-existing lung disease are at higher risk. The majority of pilgrims are adults and the elderly. Complications, hospitalizations, and deaths from respiratory tract infections are most significant in the elderly and those with comorbidities. The disease that most often occurs during the Hajj season is a respiratory infection. The most common causes of respiratory tract infections are viral upper respiratory tract infections and bacterial respiratory infections.²¹

Sputum cultures were examined in outpatients for respiratory tract infections during the hajj season from 1991 to 1992. Three hundred and ninety-five samples were examined. Positive cultures were found in 118 specimens (30%); The most common pathogens found were *Haemophilus influenza*, *Klebsiella pneumonia*, and *Streptococcus pneumonia*. In the same study, 761 throat swabs were

performed for virus examination, 20% of which were positive, especially influenza and adenovirus.²²

High-density areas pose a risk of local outbreaks and the worldwide spread of infectious agents. The study was conducted on 566 patients of Hajj pilgrims in 1434H. Most of them (92%) suffer from respiratory symptoms.²³ Acute respiratory infections (ARI) are the leading cause of hospital admissions in Saudi Arabia during the Hajj season.²⁴

In 2016, 2017 and 2018, the morbidity rate of Indonesian Hajj pilgrims due to a combination of various respiratory diseases was 49.0%, 51.95% and 49.31%, respectively. Meanwhile, in 2016, 2017 and 2018, the mortality rate of Indonesian Hajj pilgrims due to respiratory diseases was 27.5%, 30.7% and 36.8%, respectively.²⁵⁻²⁷

Elderly pilgrims are more susceptible to infectious diseases due to eating disorders, sleeping patterns, and damage to the immune system. In terms of nationality, the majority of infectious disease cases were discovered in Indonesian pilgrims (18.4%), Saudi pilgrims (17.1%), and Pakistani pilgrims (11.8%).²⁸

CONCLUSION

About three million pilgrims come to the holy city of Mecca every year to perform the pilgrimage. The increasing number of pilgrims is accompanied by an increase in daily activities and transportation needs. As a result, large

amounts of solids, gases, microbes, and other pollutants are emitted into the air. Pollutants produced can cause various adverse effects on the health of pilgrims.

The respiratory tract is the main entrance point for air pollutants into the body. The effects of air pollution on respiratory tract diseases include an increase in asthma exacerbations, COPD and cystic fibrosis infections, hospital clinic visits, hospital emergency visits, hospital admissions, morbidity, and mortality. Every year, respiratory disease is one of the leading causes of illness and death among Indonesian pilgrims.

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