

Carbon Monoxide and Photochemical Oxidants in Muna Valley during Pilgrimage

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ABSTRACT. This work presents the outcome of a research conducted during pilgrimage period of 1402 H (1982 AD) where 2 million persons gathered in Muna valley of the 4 km² area. Photochemical oxidants had been found to exceed the limit which can be taken as evidence of photochemical smog formation in the valley under appropriate weather condition that exist. High concentrations of carbon monoxide were detected in the atmosphere of the valley. For example, more than 50 ppm, average over 1 hr. was recorded during morning peak time of pilgrims movement from Arafat to the valley due to high traffic density and the nocturnal stable condition. Moreover, the CO air quality standard of 9 ppm, average over 8 hrs. was exceeded as an average over 24 hrs. during pilgrims full occupancy of the valley. Control measures should be undertaken to avoid future air pollution episode. Conclusions and recommendations are included.

Muna is a valley located 7 km east of the Holly City "Mecca", Saudi Arabia. The valley's area is about 4 km² and surrounded by chain of mountains ranging between 440 m and 900 m in height. The valley has two main entrances towards Mecca and Arafat, about 12 km to the south of the valley. Every year, about 2 million muslims gather in the valley to perform the major parts of pilgrimage rites. Most pilgrims (about 85%) spend the night of 8th Zul Hijjah H (muslims calender year) in the valley, usually in tents, before moving on the next morning of 9th Zul Hijjah to join the rest of pilgrims at Arafat. All pilgrims (about 2 million people) return back early on the morning of 10th Zul Hijjah (starting from midnight) to spend 3 days of approximately permanent residence in the valley. Pilgrims use more than 150,000

motorcars, buses, lorries etc. for their transportation. These vehicles emit large amounts of autoexhaust pollutants in the limited area of the valley. Furthermore, the meteorological conditions in such a valley favours pollutants accumulation. Pilgrims are exposed to these pollutants under hot and humid climate. They are also have to make physical effort in performing pilgrimage rites. Consequently, the present work was undertaken to study air quality in the valley during pilgrimage period, with reference to autoexhaust emitted primary pollutant (CO) and the possibility of photochemical smog formation in the Muna valley under such subtropical condition.

Methodology

Air samples were drawn from outside the building of "Amant El-Asema", representing the most busiest site in the valley. Air was sampled at 8 m above the ground during pilgrimage period from 7th to 14th Zul Hijjah 1402 (24th Sept. to 1st Oct. 1982). Photochemical oxidants were measured with the standard neutral KI method (Katz 1968). Carbon monoxide was monitored using Ecolyser, Energetic Company. Temperature, wind speeds and wind direction were also recorded at the site of measurements.

Results and Discussions

Photochemical oxidants:

Photochemical oxidants were measured 3 times daily during times of measurements from 6.00-7.00 hr (morning), 1200 hr - 1300 hr (noon) and 1600-1700 hr (afternoon). Figure 1 shows the detected concentrations of photochemical oxidants in the atmosphere of Muna valley. This Figure shows that concentrations of oxidants were ranging between 40 and 63 $\mu\text{g}/\text{m}^3$ during early morning (600-700 hr). In other words, morning concentrations were approximately at the same order of magnitude during all days of measurements and similar to those recorded during morning time in the atmosphere of subtropical areas such as Cairo (Nasralla and Shakour 1981). These concentrations include ozone created by natural processes and possibly some locally produced photochemical oxidants, through sunlight initiating atmospheric photochemical reactions between the autoexhaust emitted NO_x and hydrocarbons. The high concentrations of 80 $\mu\text{g}/\text{m}^3$ to 205 $\mu\text{g}/\text{m}^3$ recorded during noon and afternoon at times pilgrims occupied the valley (10th to 13th Zul Hijjah) confirm the local production of photochemical oxidants due to the accumulation of NO_x and hydrocarbons, calm winds, and long periods of sunshine. Fig. 1 shows that concentrations of photochemical oxidants, sometimes, exceed the 200 $\mu\text{g}/\text{m}^3$ which can be taken as evidence of photochemical smog formation (Nasralla and Shakour 1981 and Nasralla 1983). Therefore, it may be concluded that the amount of pollutants, with reference to NO_x and hydrocarbons, in the atmosphere of Muna Valley during pilgrimage days are enough to create photochemical smog under the favourable weather conditions that exist.

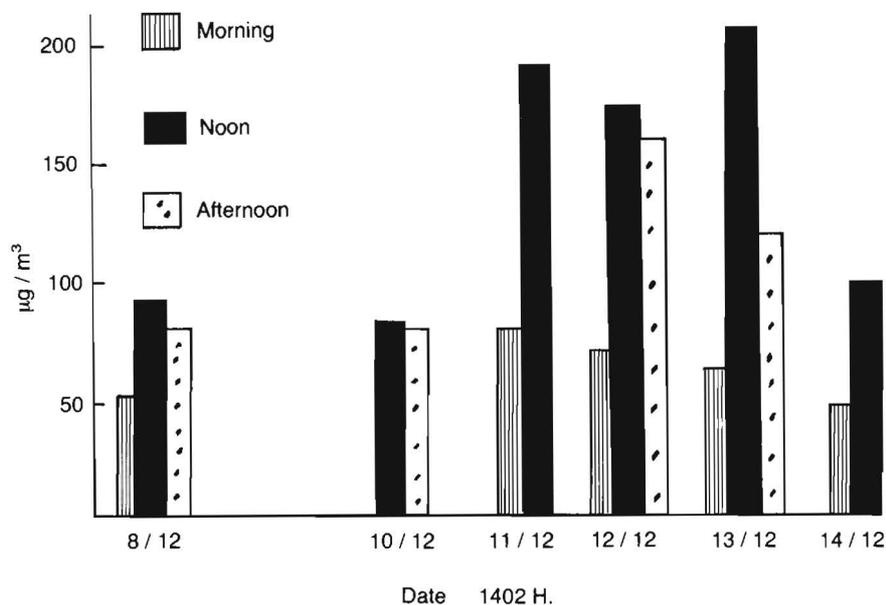


Figure 1. Concentrations of photochemical oxidants recorded in Muna Valley during Pilgrimage days.

Photochemical oxidants recorded at noon time of 11th and 13th Zul Hijjah are similar to the concentration of $200 \mu\text{g}/\text{m}^3$, average over one hour, which has been reported to cause pulmonary dysfunction and increase asthmatic attacks (WHO 1972). Taking into account the high concentrations of SO_2 and suspended particulate found in the valley's atmosphere during pilgrimage period (Nasralla 1982), it may be concluded that detected oxidants may pose an adverse health effects for pilgrims, especially those having chest troubles. Moreover, it has been reported that the exposure to $160 \mu\text{g}/\text{m}^3$ photochemical oxidants for 3 hrs increases mortality when infection aerosols are subsequently introduced (WHO 1972). Such bacteria were detected at high concentrations in the valley's air during pilgrimage period (Hammed 1982). Concentrations above $160 \mu\text{g}/\text{m}^3$ persisted for long periods (more than 3 hrs) during 11th to 13th Zul Hijjah, in the valley's atmosphere.

Carbon Monoxide:

This gas, which has an affinity to combine with haemoglobin 240 times greater than oxygen, forming carboxyhaemoglobine, was found at high concentrations in the valley's air during pilgrimage days. Figure 2 shows the recorded concentrations, average over 1 hr, at level of 8 m above the ground. This pattern of CO diurnal variations follows, to a great extent, the cycles of pilgrims movements for performing pilgrimage rites. The highest carbon monoxide concentrations were recorded during pilgrims movements out and back to the valley. For example 12

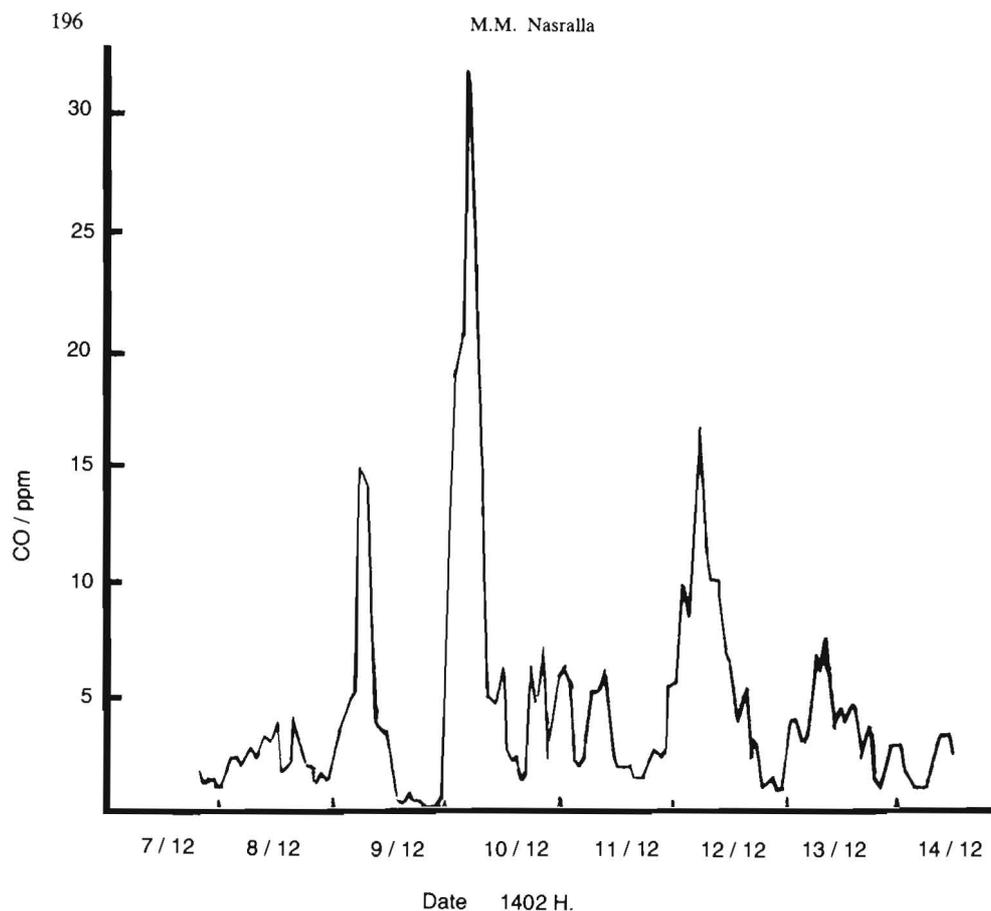


Figure 2. Diurnal cycles of carbon monoxide recorded in Muna Valley during pilgrimage days.

ppm and 26 ppm averaged over 3 hours, were detected during pilgrims movement to Arafat (about 12 km south to the valley) between 500 hr and 800 hr on 9th Zul Hijjah and their returning to the valley between 300 hr and 600 hr on 10th Zul Hijjah respectively. Movement of vehicles transporting pilgrims to Muna valley on 10th Zul Hijjah was reflected in CO concentrations which increased significantly starting from 0.00 hr peaking to 40 ppm average over 10 minutes, and 32 ppm, average over 1 hr between 400 - 500 hr. This high concentration declined, after sunrise to 8 ppm, averaged over 1 hr, at 900 hr. CO concentrations during days of semipermanent residence of the 2 million pilgrims (10th to 12th Zul Hijjah) oscillated up and down depending on pilgrims movement towards Mecca and back to the valley. Generally, high concentrations during these days were recorded during night time of 10th/11th and midday of 11th Zul Hijjah. The 14 ppm CO, average over 3 hrs, found between 600-900 hr on 12th Zul Hijjah reflect the vehicles movement during the departure of most of pilgrims out of the valley.

Variation of CO concentrations was not only dependent on vehicular movements, but reflected the prevailing meteorological condition favouring pollutants accumulation in the valley's atmosphere. For example, the maximum CO concentration of 32 ppm averaged over 1 hr, recorded during pilgrims moving back to the valley on early morning of 10th Zul Hijjah was much higher than the 15 ppm recorded during peak hours of their departure to Arafat on 9th Zul Hijjah. This can not only be attributed to the high rate of autoexhaust emission during movement back to the valley but to calm conditions (0–1 m/s) and the potential stable condition. Consequently, CO emitted into the valley's air starting from midnight accumulated in the limited volume of air and peaked to its highest value just before sunrise. On sunrise and the consequence improvement of dispersive mechanisms in the valley's atmosphere, CO concentration then declined significantly, Figure 2. This possible cycle of meteorological condition might explain the lower CO concentrations recorded during peak time of pilgrims movement out of the valley on 9th Zul Hijjah starting near sunrise. Insolation dispersed the potential thermal inversion and improved the vertical dispersion mechanism.

Table 1 summarises the significant concentrations of CO detected in the valley's air. This table shows that the USA air quality standard of 9 ppm, average over 8 hrs (WHO 1976) was exceeded several times at 8 m above the ground level during pilgrims semipermanent residence in the valley (10th-12th Zul Hijjah). CO was recorded for few periods at 1.7 m above street level adjacent to the busiest road in the valley. These measurements revealed concentrations of more than 50 ppm averaged over 1 hr, peaking to more than 70 ppm, averaged over 10 minutes during rush hours on 10th and 12th Zul Hijjah 1402 H. These concentrations are higher than those reported for the well known polluted places around the world such as central districts of Cairo (Nasralla *et al.* 1978), Chicago (Stern 1968) and

Table 1. Significant concentrations of carbon monoxide recorded in Muna valley, 8 m above the ground.

| Maximum over period | Day (Zul Hijjah 1402 H) | | | | | | USA |
|---------------------------|-------------------------|-----|-----|-----|-----|-----|------|
| | Tashreek Days | | | | | | |
| | 9 | 10 | 11 | 12 | 13 | 14 | AQS* |
| 10 min | 18 | 40 | 10 | 23 | 12 | 5 | — |
| 1 hr | 15 | 32 | 6 | 17 | 8 | 3 | 35 |
| 3 hrs | 12 | 26 | 6 | 14 | 7 | 3.5 | — |
| 8 hrs | 8 | 19 | 4 | 11 | 5 | 3 | 9 |
| 24 hr | 4 | 9.1 | 3.5 | 6.5 | 3.6 | — | — |

* AQS = air quality standard.

Fleet street, London (Nasralla 1975). Such concentrations might be considered not to be deleterious for health under normal conditions. However, it should be noted that pilgrims are exposed to these high concentrations of CO, coupled with high concentrations of other pollutants under a hot and humid climate, table 2 (HRC 1982). This sort of climate leads to several complications such as circulatory instability, water and electrolyte imbalance, heat cramp, heat stroke and heat

Table 2. Air temperature and relative humidity in Muna valley during pilgrimage period of 1402 H (1982 G)

| Date, Zul Hijjah 1402 H | 8 | 9 | 10 | 11 | 12 | 13 |
|----------------------------|----|----|----|----|----|----|
| Max temp. °C | 42 | 41 | 41 | 42 | 44 | 44 |
| Min. temp. °C | 28 | 28 | 30 | 29 | 30 | 31 |
| Max. R.H. % | 58 | 70 | 56 | 61 | 67 | — |
| Min. R.H. % | 40 | 31 | 34 | 38 | 31 | — |

hyperpyrexia. Heat stroke is a common phenomena during pilgrims residence at Muna valley. The risk of the occurrence of these symptoms is increased by a heavy physical workload. Pilgrims have to make physical efforts for performing Hajj rites under crowded conditions. Although, there is no published statistics on air pollution effect on pilgrims health, combination of these factors may result in adverse health effects, not only for those having respiratory and cardiovascular diseases, but also for healthy pilgrims especially children and old people. Consequently, alternative transport system other than vehicles should be adopted to improve environmental condition and avoid future episodes in the valley.

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أول أكسيد الكربون والمؤكسدات والكيמושوية بوادي منى خلال أيام الحج

محمود محمد نصر الله

معمل تلوث الهواء - المركز القومي للبحوث -
الدقي - القاهرة - مصر

لقد تم إجراء هذه الدراسة بوادي منى ذي المساحة التي لا تتعدى ٤ كم ٢ وذلك أثناء حج عام ١٤٠٢ هـ حيث يتجمع حوالي ٢ مليون مسلم لأداء مناسك فريضة الحج . ولقد تم اختيار غازين ملوثين للهواء لهذه الدراسة، أحدهما ينبعث مباشرة من السيارات (أولى) والآخر ثانوي ينتج عن التفاعل الكيموسوي بين الملوثات الناشئة عن احتراق الوقود، وخاصة السيارات، بعد انبعاثها إلى هواء الوادي ذلك حتى يمكن تقنين دور السيارات في تلوث هواء وادي منى وكذا احتمال تكون الضباب الكيموسوي بالوادي تحت تأثير أشعة الشمس وكميات التلوث والظروف الجوية السائدة بالوادي .

لقد أعطت هذه الدراسة نتائج تشير إلى ارتفاع تركيز غاز أول أكسيد الكربون بهواء الوادي أثناء فترات نشاط السيارات وخاصة عند العودة من عرفات حيث تساعد العوامل الجوية السائدة على تراكم هذا الغاز ليصل إلى أكثر من ٥٠ جزء في المليون (كمتوسط لفترة زمنية مقدارها ساعة). كما أن تركيزات أول أكسيد الكربون في الوادي خلال فترة القياس قد زادت عن الحدود القصوى المسموح بها

في الهواء للحفاظ على الصحة سواء لمدة ٨ ساعات أو ٢٤ ساعة متصلة . كما وجد أن تركيزات ملوثات الهواء بالوادي والعوامل الجوية السائدة كافية لإنتاج المؤكسدات الكيموضوئية بتركيزات تصل إلى أكثر من الحدود المسموح بها بالهواء . تؤكد دورة التغير في تركيزات هذه المؤكسدات بالهواء خلال اليوم الواحد أنها ناتجة عن التفاعلات الجوية بين الملوثات بهواء الوادي . تشير تركيزات هذه المؤكسدات إلى احتمال تكوين الضباب الكيموضوئي . لذا فإن هذا البحث يستخلص ضرورة العمل على الحد من انبعاث تلك الملوثات بهواء الوادي وإيجاد أسلوب يؤدي إلى سيولة الحركة بالوادي لحين التوصل إلى وسيلة نقل بديلة للسيارات ، وهو الحل الذي يجب أن يحظى بالأولوية المطلقة . ذلك حتى يمكن تجنب حدوث كارثة تنشأ عن الضباب الكيموضوئي «لا سمح الله» . كما يحتوي البحث على العديد من الاستنتاجات والتوصيات الأخرى الضرورية .