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Air Quality in Muna Valley
Some Findings During Pilgrimage, 1402 H (1982 G)

M.M. Nasralla and A. Younes

Air Pollution Laboratory, National Research Centre, Dokki, Cairo, Egypt and Hajj Research Centre, Mecca, Saudi Arabia

ABSTRACT. Monitoring programme was conducted in Muna Valley during muslims pilgrimage period, 1402 H (1982 G). Measurements of sulphur dioxide, ammonia and particulates were carried out at the middle of the most busiest place in the valley. The rate of dustfall during pilgrimage period was 294 mg m^{-2} d^{-1} while its background rate was found to be less than 90 mg m^{-2} d^{-1} Concentrations of sulphates and tarry matter in dustfall were more than three times higher than their concentrations in dustfall over the area after pilgrims departure. Sulphur dioxide and suspended particulate were found associated at high concentrations enough to create health problems for those who are suffering from bronchitis and other chest troubles. High concentrations of ammonia detected are possibly one of the prime causes of throat irritation during pilgrimage period.

The results of the present work confirm that the atmosphere of Muna Valley is favouring the accumulation of pollutants to the limits causing adverse health effects for pilgrims. Control measures should be adopted and environmental planning for Muna Valley should be considered. These measures are urgently needed to avoid air pollution episodes in the valley during the occupancy of more than 2 million persons.

Most air pollution episodes occur in valleys where pollutants accumulate to dangerous limits because of the failure of atmospheric dispersion mechanisms. The present work was conducted in Muna Valley where about 2 million muslims are gathered every year to perform pilgrimage (Hajj). Muna's area is 4 Km^2 with a general alignement along NW-SE direction, (Fig. 1). The valley is situated at about 7 Km east of the Holy city "Mecca", Saudi Arabia. The chain of mountains bordering the valley ranges in high from 400 to 900 m. The normal population of Muna is less than one thousand. Toward the muslims pilgrimage period every year, pilgrims start to move to the valley on the begining of Zul Hejjah.

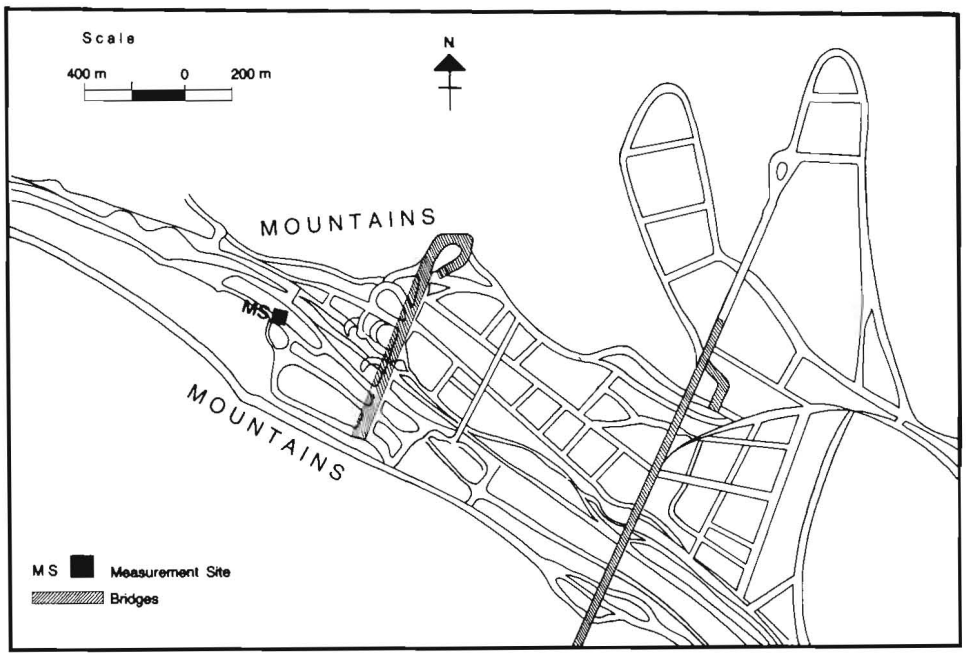

Fig. 1. Map of Muna Valley and Site of Measurements.

The performance of Hajj requires, among other physical and spiritual dimensions, the movement of all pilgrims on the 8*th* of Zul Hijjah (the last month of muslims calender year, Higry) to Muna. They may sleep at the valley for one night before they proceed to Arafat (about 12 km to the south) on the morning of 9*th*, the day of standing "Wquf". On the morning of 10*th* Zul Hijjah all pilgrims return to Muna on their way back towards Mecca. This time, they spend three days and sleep in tents at Muna during which they perform the major rites of Hajj.

The number of pilgrims reaches about 2 million and increased year after year. During the three days of staying at the valley, Muna is characterised by a compact and highly dense population. Each pilgrim has only about 2 m^2 to live on. The problem is even more striking by the fact that over 40% of the valley's area is paved for vehicles and walkways. Sources of pollution impairing air quality during Hajj sessions are mainly combusion processes in mobile and stationary sources. The number of motor vehicles working in the valley increased about 3 times within years of 1392 to 1399 H (1980 G). Although authorities put legislations to restrict the number of vehicles entering the valley since 1399 H (1980 G) the number of vehicles entered the valley during 1402 H session were more than 150,000 car. Nasralla (1982) estimated that vehicles emitted about 16 tons hydrocarbons and 238 tons CO daily in the atmosphere of Muna Valley during Hajj session of

1402 H. The next important sources of air pollution in the valley are sacrifices and rubbish incinerators located at the eastern and northern borders of the valley. These incinerators discharge 2800 kg/day SO_x, 2800 kg/day NO_x, 3000 kg/day particulate, hydrocarbons, aldehydes, ketones.. etc.. into the valley's atmosphere during the three days of pilgrims permanant staying at Muna "Tashreek days". Other pollution sources include electricity generators, cooking ovens using all kinds of fossil fuel, movements on the bottom and slopes of mountains surrounding the valley as well as aerobic and anaerobic decomposition of human and animal excreta, sacrificed animals and other organic wastes.

Congestion and high rate of pollutant emissions in a valley of small area coupled with predominant weather condition of high temperature, lack of rainfall, prevailing one wind direction (northerly), long periods of sunshine, high relative humidity, low wind speeds and the potentiality of thermal inversions make the valley an ideal situation for pollutant accumulation, atmospheric photochemical reactions and the consequence health deterioration. The problem is of concern when scavenging mechanisms fail to dilute pollutants. Pilgrims may face a disaster. The present work is the first of the outcome of a research project conducted to investigate air quality and the factors affecting pollutants concentrations during the gathering of this sort of crowdness, the only one of its kind, in a limited area under subtropical condition and has a typical topographical features for pollutants accumulation. Therefore, the present work is of a wide interest for air pollution studies.

Methodology

Air pollution station was installed at the middle of Muna Valley on the roof of "Amanat El-Asema" building. Air was sampled at 8 m above ground level. Monitoring programme was started on the arrival of pilgrims (7*th* Zul Hejjah 1402 H) and extended to the 14*th*, two days after the departure of most pilgrims and one day after departure of all pilgrims and evacuation of the valley. Therefore the survey period also includes "Tashreek" days of the full permanent residence of 2 million people in the valley of the 4 km^2 area.

Suspended particulate materials were sampled by filteration on membrane filter papers using low volume sampler. Dust fall was collected by the aid of dustfall jars similar to that used by Nasralla (1983). Dustfall was analysed for their soluble, insoluble fractions, ash, tarry, cmbustible, and sulphates according to the method described by Nasralla (1983). Sulphur dioxide was sampled in tetrachloromercurate solution and analysed coloremetrically according to West and Gaeke procedure (Stern 1968). Ammonia was sampled in diluted sulphuric acid and determined coloremetrically by Nessler reagent (Leithe 1970). Information and statistics on the valley population, traffices, topography... etc. were taken from

Hajj Research Centre Reports (Hajj Research Centre, 1402 H). Available Meteorological data are also reviewed and discussed in relation to air quality.

Results and Discussions

Particulates

Suspended particulates were measured throughout the survey period from 7*th* Zul Hijjah to 14*th* Zul Hijjah 1402 H (24*th* Sept. to 1*st* Oct. 1982) and results are shown in Table 1. These concentrations reflect the influences of population density, service activities, pilgrims movement and wind speeds. In general, particulate concentrations increased considerably during "Tashreek" days of pilgrims occupancy of Muna and related services reaching 252 $\mu g/m^3$ compared with the 89 $\mu g/m^3$ recorded on the 14*th* Zul Hijjah, after pilgrims departure from Muna Valley. However, the high concentration of particulate materials 313 $\mu g/m^3$, recorded on the 9*th* Zul Hijjah, occured in spite of the pilgrims move to Arafat. This can be attributed to the departure of the 2 million pilgrims during the morning and their return back to the valley which starts just after midnight of same day.

Table 1. Concentration of particulate materials, SO_2 and NH_3 in Muna's air during Hajj period of 1402 H.

Date, Zul Hijjah 1402 H	Time*	Concentration $\mu g/m^3$		
		Particulate materials	SO_2	NH_3
7	N	225	182	311
8	D	110	196	434
	N	88	146	427
	24h	99	171	430
9	D	—	—	—
	N	—	—	—
	24h	313	85	273
10	D	350	113	256
	N	150	166	470
	24h	250	140	363
11	D	445	171	253
	N	210	240	367
	24h	328	211	310
12	D	194	146	192
	N	274	211	—
	24h	243	179	—
13	D	190	167	489
	N	98	180	336
	24h	144	174	412
14	D	89	75	135

* D (day time 8,00-20,00 hr), N (Night time 20,00-8,00 hr), 24hr (average over 24 hr).

It is of interest to note that the concentrations of particulate materials recorded during night time are not only considered high but were of the same order of magnitude to those recorded during day time. Furthermore, 274 $\mu g/m^3$ particulate material was found in Muna's atmosphere on the night of 12*th* Zul Hijjah 1402 H while only 194 $\mu g/m^3$ particulate material was recorded during daytime. This is possibly due to the noctural formation of a stable atmosphere and the long periods of calm or light winds. The highest particulate concentration of 445 $\mu g/m^3$, 12h average, was recorded on 11*th* Zul Hijjah (28*th* Sept. 1982). On that day sacrificial incinerators worked at full capacity. Therefore, incinerators may be seen as a major source of the particulate load in the valley during the pilgrimage session. Furthermore, this is confirmed by the detection of the highest sulphur dioxide concentration in the same period. Keeping in mind that more than 250,000 out of the 2 million persons are aged over 50 years and 50,000 of age over 65 years, the high temperature and relative humidity, existance of high concentations of other air pollutants and the heavy physical activities... etc... the high pollutant concentrations are likely to cause adverse health effects during "Tashreek" days.

Table 2 shows the rates of particulate deposition over the valley and their chemical constituents during 2 periods. The rate of deposition after pilgrims departure was 87 mg m^{-2} d^{-1} which can be considered as the background dustfall rate over the area. During pilgrimage session of 1402 H (1982 G), this rate of particulate precipitation peaked to 300 mg m^{-2} d^{-1} which reflected the magnitude of atmospheric pollution with fly ash and dispersed dust due to movements of inhabitants in the valley floor and on the slopes of the mountains. The recorded rate of dustfall is not only exceed the nuisance limit of dust but could also cause several problems for pilgrims, such as soiling and skin irritation. This is aggravated by high temperature and relative humidity that causes sweating and enhances the deposition of soluble compounds. Rates of soluble particulate precipitation during the occupation of the valley was 64.7 while its background rate was less than 10 mg m^{-2} d $-^{1}$. Moreover, the particles deposited on the pilgrims contain high concentration of sulphates. Sulphates concentration in dustfall during pilgrimage period was three times higher than its concentration in dustfall outside the pilgrimage period or the soil of Muna Valley. Possible sources of these sulphates are combustion percesses and photochemical atmospheric reactions oxidising SO_2 to sulphates such as $(NH_4)_2$ SO_4 (Hidy 1978). This suggestion is strengthened by the findings of high concentrations of SO_2, ammonia (Table 1) and photochemical oxidants (Nasralla 1982) during pilgrimage period. The relatively high concentrations and rates of deposion of tarry matter (incomplete combusion products) during pilgrimage session confirm the role of incomplete combusion processes in polluting the valley's atmosphere.

Table 2. Particulate material precipitations, mg $m^{\times 2}\, d^{-1}$ over Muna Valley and chemical compositions* of dust and soil samples.

Period	Total	Solub comp	SO_4^{--}	Tarry	Comb	Ash
8-12/12/1402	294	64.7 (22%)	1.8 (0.6%)	2.6 (0.9%)	50 (17%)	179 (61%)
20/12/1402 13/1/1403	86.8	9.7 (11.2%)	0.17 (0.2%)	0.17 (0.2%)	9.4 (10.8%)	67.7 (78%)
Surface** Soil	—	(4.3%)	(0.1%)	Neg+	(7.4%)	(88.3%)

** average 4 samples, * between brakets percentage of total dust fall, + Neg, Negligible.

Sulphur dioxide

High sulphur dioxide concentrations in the valley's atmosphere were detected during "Tashreek" days. The variation in SO_2 concentrations in the valley's air follows the same pattern of suspended particulate except on *9th* Zul Hijjah "Wquf day". This can be explained on the basis of the activities taking place in the valley during pilgrimage session. On the day of *9th* Zul Hijjah pilgrims move out and back to the valley by cars, busses, lorries and on foot. Therefore, particulates and autoexhaust emitted pollutants were found at high concentrations during that day. In contrast, incinerations and other activities are at their maxima during "Tashreek" days of *10th*-*12th*, peaking on the day of *11th*. Consequently SO_2 and suspended particulate were at high concentrations during these days. It should be noted here that the concentration of 210 $\mu g/m^3$ SO_2 averaged over 24h, was associated with 328 $\mu g/m^3$ particulate. Concentrations of 200 $\mu g/m^3$ SO_2 with 120 $\mu g/m^3$ particulate material for 24h are reported to cause deterioration of patients with pulmonary disease (WHO 1972). Concentrations found at Muna are expected to cause several health problems amongst elderly people or those with respiratory complaints. This is confirmed by the high rates of mortality reported during Hajj (Pilgrimage period).

It is interest to note that the highest SO_2 concentrations were recorded during night. This is due to the discharge of SO_2 from incinerators at night when dispersion mechanisms are at their minimum because of thermal inversion and calm winds.

Ammonia in Muna atmosphere

The potential source of ammonia gas in Muna Valley are the aerobic decay of human and animal excreta and other organic waste. Ammonia is also emitted from

fuel combusion processes in vehicles and incinarators. Table 1 shows the concentrations of ammonia in the air of Muna during pilgrimage period of 1402 H. Bearing in mind the prevailing northerly wind direction, trend in daily average concentrations indicate that the major part of ammonia gas in the valley's atmosphere is locally produced from the decay of human and animals excreta and organic waste. This is apparent from (a) days of maximum NH_3 concentration did not coincide with those of other pollutants (b) the high concentrations of ammonia during "Tashreek" days and its daily cycle.

The high NH_3 gas concentrations in the air of Muna are possibly one of the reasons for a high incidence throat irritations during pilgrimage period of 1402 H. This is in line with work by Miner (1969) who reported that the exposure to 280-490 $\mu g/m^3$ NH_3 produces eye and throat irritation. Furthermore, the existence of these NH_3 concentrations with the detected high concentrations of SO_2 (Table 1), long periods of sunshine, calm to light wind and high concentration of photochemical oxidants (Nasralla 1982) lead to the production of fine $(NH_4)_2$ SO_4 particles. The presence of these fine particles of sulphates in air has a deleterious effect on the respiratory tract (Stern 1968). Hemeon (1955) suggested that ammonium sulphate aerosols played an important role as an irritant to the lungs in the Donora disaster of 1948. Consequently, control measures and environmental planning are urgently needed to avoid future severe air pollution problems (disasters) during occupation of the Muna Valley.

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نوعية الهـواء بوادي منى، دراسـة عن بعض الملوثات أثناء حج عام ١٤٠٢ هـ

محمود محمد نصر الله و أمين يونس

معمل تلوث الهواء ـ المركز القومي للبحوث
الدقي ـ القاهرة ـ مصـر
مركز أبحاث الحج ـ جامعة أم القرى ـ مكة المكرمة
المملكة العربية السعودية

يشتمـل هـذا البحث عـلى دراسـة عن غـازي ثـان أكسيـد الكبريت والأمونيا وكذلك المواد الصلبة بهواء وادي منى أثنـاء حج عام ١٤٠٢ هـ. ولقد أوضحت الدراسة دور النشاطـات المختلفة من حركـة بالـوادي وحرق للقـمامة والـذبائـح وتحلل المواد في تلويث هواء الوادي بتركيزات عالية من الملوثات مثل ثان أكسيد الكبريت والمواد الصلبة العالقة بالهـواء مما قـد ينتج عنـه أضرار صحيـة وخـاصـة لأولئـك الـذين يعـانـون من اضطرابات بـالجهاز التنفسي. كـما أن تركيـزات الأمونيـا التي وجـدت بهـواء الـوادي قـد تكـون أحـد الأسبـاب الـرئيسـة لالتهـابات الحلق أثنـاء أيام الحـج. أمـا تـركيـزات الأتـربـة المتسـاقطة فقـد وصلت إلى ٢٩٤ مجم / م^{٢} / يوم خـلال أيام الحـج بينما وجـد أن معدلهـا الطبيعي بعـد الحج هـو أقـل من ٩٠ مجم / م^{٢} / يـوم. وتشـير المحتـويـات الكيميـائيـة لهـذه الأتـربة، سـواء القطرانيـة أو غير العضـويـة إلى أن وسـائـل الاحتراق وتحلل المواد والتفاعلات الجوية تلعب دوراً رئيساً في تلوث هواء الوادي. وتؤكد الدراسـة على ضرورة العمـل على خفض الكميـات المنبعثة والعمـل على تخـطيط الـوادي بيئيـاً

بالنسبة لوضع أماكن مصادر التلوث كالمذابح والمحارق وغيرها للحفاظ على هواء الوادي عند الحدود التي لا ينتج عنها مشاكل صحية أثناء إقامة ما يقرب من ٢ مليون مسلم بوادي منى . .