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SIZE SEGREGATED OF ATMOSPHERIC SULPHATE AEROSOLS IN JOHOR BAHRU

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Abstract

The measurement of atmospheric aerosols samples segregated into six sizes using a cascade impactor was performed at the Air Quality Research Station, University of Technology Malaysia, Johor Bahru. The samples were collected from July to November 1996 and analysed for sulphate ($\text{SO}_4^{=}$) using an ion chromatography. Results showed that the average $\text{SO}_4^{=}$ concentration at the site was $5.58 \pm 3.41 \mu\text{g}/\text{m}^3$ which is below the concentration observed in other cities of the world such as those in the Europe and Japan (range $6 \mu\text{g}/\text{m}^3$ - $14 \mu\text{g}/\text{m}^3$). The size distribution of $\text{SO}_4^{=}$ showed a strong concentration peaks at both $1.32 \mu\text{m}$ and $4.5 \mu\text{m}$ which can be attributed to non-sea salt and sea salt $\text{SO}_4^{=}$ origin respectively. The non-sea salt $\text{SO}_4^{=}$ which was found to be predominantly in the fine size fraction is an anthropogenic related pollutant. While the sea salt $\text{SO}_4^{=}$ aerosol was found to be transported from the nearest marine environment (i.e from the S-SE wind sector). Evidently, sea salt $\text{SO}_4^{=}$ aerosol concentration was consistently showed a positive correlation with wind speed term throughout the study.

Introduction

A study on the atmospheric sulphate ($\text{SO}_4^{=}$) aerosol concentration in different particulate sizes is reported in this paper. The samples were collected using a 5 staged cascade impactor which segregates atmospheric aerosols into various particulate size fractions. Sulphates of anthropogenic origin are known to be predominantly in the fine size fraction whilst natural occurring sulphate is in the coarse size fraction. For example, the combustion of fossil fuel and the formation of secondary $\text{SO}_4^{=}$ due to the oxidation of sulphur dioxide (SO_2) are characterised as anthropogenic origin. The $\text{SO}_4^{=}$ pollutants from anthropogenic origin generally remain in atmosphere for several days due to its sub-micron size. Natural occurring $\text{SO}_4^{=}$ is mainly contributed by sea salt sprays.

Thus, this study is an attempt to scrutinise the anthropogenic and the natural occurring $\text{SO}_4^{=}$ collected at the Air Quality Research Station, University of Technology Malaysia (UTM), Johor Bahru.

Materials and Methods

Sampling Site

The Air Quality Research Station of UTM is located *ca* 20 km northwest of Johor Bahru and 40 km to the east of Pasir Gudang industrial estate. The site is surrounded by rubber and oil palm trees plantation to the north-east. The location of the research station is shown in Figure 1.

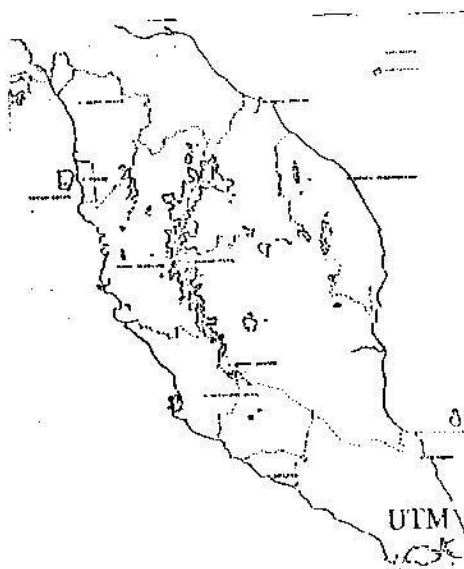


Figure 1 Location of Air Quality Research Station, UTM.

Sample Collection

The size segregated atmospheric sulphate aerosol samples were collected by using a five staged cascade impactor placed on a standard high volume air sampler. The aerodynamic cut-size diameter of each stage of the impactor and its backup filter is presented in Table 1. The samples were collected on cellulose membrane type filters which were kept in a dessicator at room temperature of 25 °C and relative humidity < 50%. The particulate mass was determined gravimetrically and the samples were analysed for $\text{SO}_4^{=}$ using ion chromatography (Dionex, Model ED40). One third of each cascade filter stripes and one tenth of backup filter were utilised for the analysis. Twenty five millilitre of deionised distilled water was added into each sample which was then vibrated ultrasonically for half an hour. The sample was then filtered and the filtrate was analysed for $\text{SO}_4^{=}$. A detailed analysis procedure have been described elsewhere (Yaaqub *et al.*, 1991; Watts *et al.*, 1987).

Table 1 Aerodynamic cut-size diameter of the cascade impactor

Stage	Particle cut size, μm
1	9.4
2	4.5
3	1.7
4	1.32
5	1.11
backup	< 1.11

Meteorological Parameter

The meteorological parameters (i.e wind speed and wind direction) were collected by a wind anemometer installed at the sampling site. The wind speed and wind direction were compiled every ten minutes and the daily vector average of wind speed and wind direction was then computed.

Results and Discussion

Total Sulphate

The mean and the range of the measured total $\text{SO}_4^{=}$ concentration (i.e sum of $\text{SO}_4^{=}$ concentrations in all size fractions) for the five months study period was $5.58 \pm 3.41 \mu\text{g}/\text{m}^3$ and 0.97 to $16.4 \mu\text{g}/\text{m}^3$, respectively. Table 2 presents the comparison of $\text{SO}_4^{=}$ concentration found at various cities of the world which shows that the $\text{SO}_4^{=}$ concentration measured at the site was lower compared to other places especially those of Europe and Japan. The variability of the $\text{SO}_4^{=}$ concentration at the site was quite high (coefficient of variation = 61%) during the study period. The daily $\text{SO}_4^{=}$ concentration at the site illustrated in Figure 2. A high $\text{SO}_4^{=}$ concentration was observed during the southwest monsoon season (July - September) with an average concentration of $6.68 \pm 3.91 \mu\text{g}/\text{m}^3$ compared to $4.16 \pm 1.81 \mu\text{g}/\text{m}^3$ during the transition period (October - November). The $\text{SO}_4^{=}$ size distributions showed a strong concentration peaks at both 1.32 and $4.50 \mu\text{m}$ which clearly indicates the anthropogenic and non-anthropogenic $\text{SO}_4^{=}$ origins. The latter is as a result of sea salts intrusion to the site. Similarly, increased in the sea salt $\text{SO}_4^{=}$ concentration in the higher size fractions of larger than $4.5 \mu\text{m}$ in Barbados and Miami had been reported by Savoie and Propero (1982).

Sea Salt Sulphate and Non Sea Salt Sulphate

An attempt was made to account for the sea salt and non-sea salt $\text{SO}_4^{=}$ using the following equations (Galloway *et al.*, 1993; Savoie and Propero, 1982):

$$\text{ssSO}_4^{=} = [\text{Na}^+ \times 0.06029] \dots\dots\dots \text{Eq.1}$$

$$\text{nssSO}_4^{=} = [\text{total SO}_4^{=}] - [\text{Na}^+ \times 0.06029] \dots\dots\dots \text{Eq.2}$$

Table 2 Comparison of $\text{SO}_4^{=}$ concentration found in various cities of the world

City	Concentration, $\mu\text{g}/\text{m}^3$	Reference
Southeast England	5.22 ± 4.65	Yaaqub <i>et al</i> (1991)
Vista, Los Angeles	8.30 ± 6.20	Henry and Hidy (1979)
Riverhead, New York	7.20 ± 4.70	"
Seoul, Korea	12.8	Wakamatsu <i>et al</i> (1996)
Tsushima, Japan	14.5	"
Ogori, Japan	6.69	"
Netherland	9.90	Janssen <i>et al</i> (1989)
Luebeck, Germany	7.85	Stoffregen and Dannecker (1990)
Preila, Lithuania	11.0 ± 9.48	Sopauskiene and Budvytyte (1994)
Leeds, England	7.6	Willison <i>et al</i> (1985)
Johor Bahru, Malaysia	5.58 ± 3.41	This work

where $\text{ssSO}_4^{=}$ and $\text{nssSO}_4^{=}$ is the sea salt and non-sea salt sulphate respectively; 0.06029 is the molar $\text{SO}_4^{=}/\text{Na}^+$ ratio in bulk sea water. Table 3 presents the calculated monthly average $\text{ssSO}_4^{=}$ and $\text{nssSO}_4^{=}$ concentrations which shows that $\text{nssSO}_4^{=}$ accounts between 85% and 95% of the total $\text{SO}_4^{=}$ aerosols at the site. The $\text{nssSO}_4^{=}$ was mostly found in the lower size fractions conforming its predominance as anthropogenic related aerosols. Table 3 also showed that both sulphate aerosols were high in the beginning of southwest-monsoon months i.e in July and August. The hot and dry weather conditions in these months may have been the reasons for the findings. The formation of $\text{nssSO}_4^{=}$ is expected to be accelerated during hot and humid weather conditions. Meanwhile, sea salts aerosols are easily evaporated in hot weather conditions.

Table 3 Monthly average total $\text{SO}_4^{=}$, non sea salt $\text{SO}_4^{=}$ and sea salt $\text{SO}_4^{=}$.

Month	Total $\text{SO}_4^{=}$	$\text{nssSO}_4^{=}$	$\text{ssSO}_4^{=}$
Jul	8.77 ± 3.12	8.28 ± 3.06 (93.93)	0.50 ± 0.41 (6.07)
Aug	7.89 ± 4.49	7.50 ± 4.31 (94.69)	0.38 ± 0.57 (5.31)
Sep	4.53 ± 2.31	4.16 ± 2.33 (90.34)	0.37 ± 0.22 (9.66)
Oct	4.50 ± 1.61	4.10 ± 1.73 (89.60)	0.40 ± 0.36 (10.40)
Nov	3.77 ± 1.93	3.31 ± 1.87 (85.28)	0.46 ± 0.22 (14.72)

note: concentration in $\mu\text{g}/\text{m}^3$; () = % contribution.

Figure 3 presents the monthly $\text{nssSO}_4^{=}$ and $\text{ssSO}_4^{=}$ size distribution which showed that the aerosol was predominantly in the fine and large particle size fractions, respectively. Both of the sulphate aerosols registered high concentrations in July and August but gradually decreased towards the transitions monsoon period (i.e October to November). The $\text{nssSO}_4^{=}$ and $\text{ssSO}_4^{=}$ aerosol concentration was found to peak at the particulate size range of 1.11 - 1.32 μm and within 9.0 - 10 μm , respectively. The high concentration of $\text{ssSO}_4^{=}$ aerosols in the beginning of the southwest monsoon season was attributable to the intrusion of fresh sea salt aerosols from the nearest sea mainly from the Straits of

Tebrau located in the south of Johor Bahru. On the contrary, the low concentration of $\text{ssSO}_4^{=}$ towards the end of southwest monsoon and during the transitional monsoon period (i.e October and November) was probably due to the variability or changes in wind pattern that reduced the amount of marine aerosols being transported to the sampling site. A positive correlation coefficient between the $\text{ssSO}_4^{=}$ aerosol concentrations in all particle sizes and wind speed term, as found in this study, clearly indicates the influence of wind speed (besides wind direction) on the concentration of $\text{ssSO}_4^{=}$ at the site.

Conclusions

The investigation on the segregated atmospheric sulphate aerosols measured at the Air Quality Research Station, University of Technology Malaysia, Johor Bahru revealed that the average concentration of total $\text{SO}_4^{=}$ aerosols concentration for the five months study period was $5.58 \pm 3.41 \mu\text{g}/\text{m}^3$. The measured $\text{SO}_4^{=}$ concentration was lower than those found in other cities of the world such as in Europe and Japan. The total $\text{SO}_4^{=}$ concentration was found to peak during southwest monsoon season with non-sea salt $\text{SO}_4^{=}$ and sea salt $\text{SO}_4^{=}$ aerosol concentration concentrating within the particle size range of $1.11 - 1.32 \mu\text{m}$ and $> 9.0 \mu\text{m}$, respectively. In this study, the $\text{nssSO}_4^{=}$ was found to account between 85% - 95% of the total $\text{SO}_4^{=}$ aerosol concentration at the sampling site. While wind direction and wind speed can play a role in influencing the $\text{ssSO}_4^{=}$ aerosol concentration at the sampling site.

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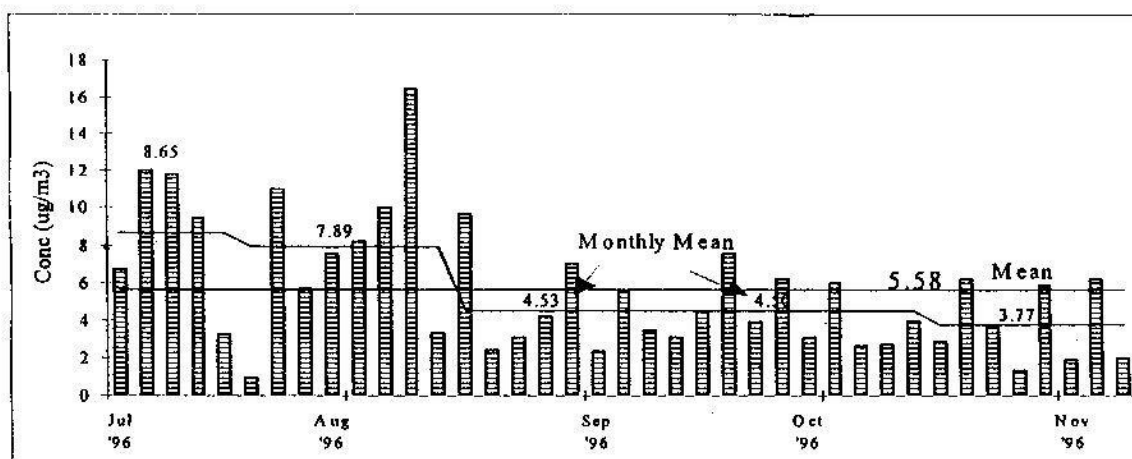


Figure 2 : Trend of Sulphate in UTM

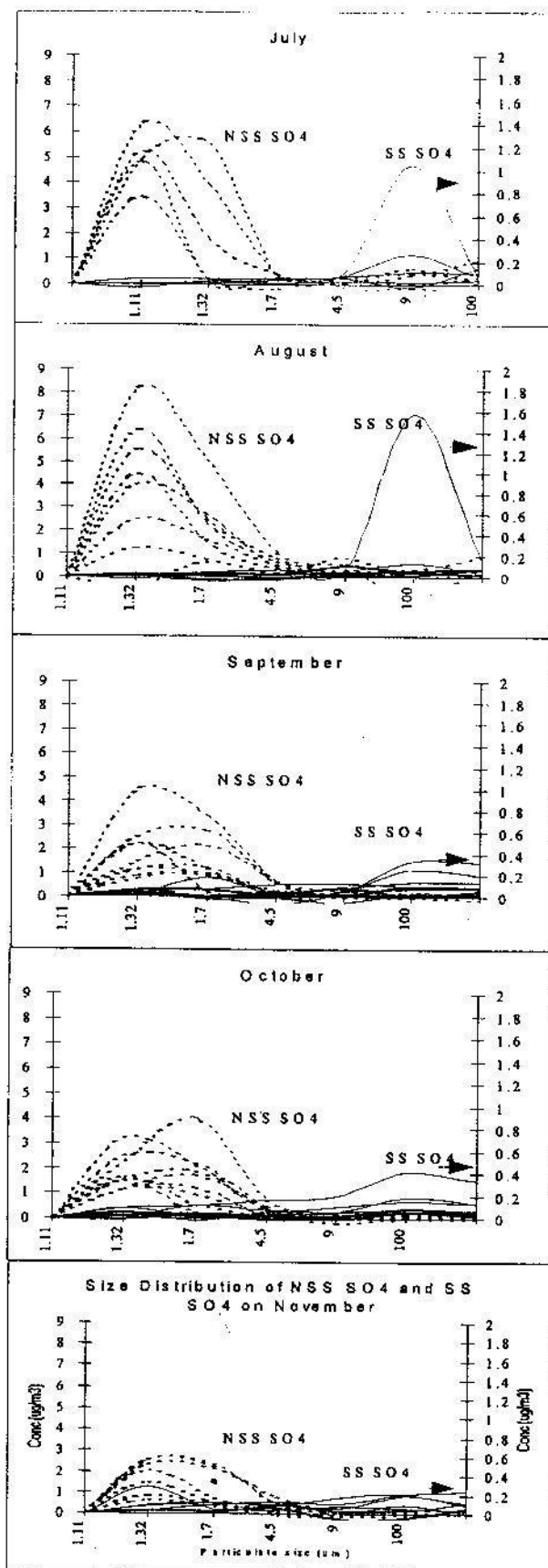


Figure 3 : Particulate Size Distribution of nss SO4 and ss SO4