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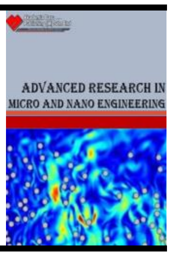

Surfactants and Microbial Aerosol of Urban Particulate Matter (PM_{10}) in Kuala Lumpur City Centre

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ABSTRACT

Surfactants in the atmosphere potentially influence the global climate and may affect human health. This study aims to determine the compositions of surfactants extracted from urban particulate matter (PM_{10}) and motor vehicle exhaust soot. In addition, microbial aerosol was also determined. A high-volume air sampler (HVAS) has been used to collect PM_{10} samples in Kuala Lumpur urban area. Meanwhile, the vehicle exhaust soot was collected randomly from the exhaust pipes of various types of diesel and petrol vehicles, using a soft brush during dry days. The concentration of anionic surfactants as Methylene Blue Active Substances (MBAS) was determined by the colorimetric method using a UV-Vis Spectrophotometer. The presence of microorganisms such as bacteria and fungi were investigated by colony count. In addition, the correlation between surfactants and traffic-related air pollutants has also been investigated. Results revealed that the average concentration of MBAS in particulate matter is 107.68 ± 7.91 μgm^{-3}. Diesel vehicles demonstrated higher surfactant concentration in exhaust particulate matter with an average value of 0.227 ± 0.006 $\mu molg^{-1}$ compared to petrol vehicles (0.146 ± 0.003 $\mu molg^{-1}$). Based on this study, various mitigation procedures can be implemented to reduce the impacts of PM and exhaust soot for a better future.

1. Introduction

Particulate matter (PM_{10}) is one of the most common air pollutants and as such is used to monitor the level of environmental pollution [1-3]. Recent findings on the health problems experienced following exposure to PM_{10} include a decline in lung function and an increase in respiratory symptoms, chronic pulmonary disease, heart disease and premature death, along with a rise in

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mortality. The concentration of PM itself is dependent on several factors which include climate, season, land use and geographical location. Tsitouridou *et al.,* [4] have found that the concentration of PM was higher during the cold season. A higher traffic density and the use of fossil fuel for combustion was found as the reason for higher PM in the atmosphere [5-10].

One of the organics species that can be determined from the PM is surfactant. Surfactants (surface active agents) are able to affect the fate of other organic and inorganic pollutants [11,12]. Surfactants are amphipathic molecules with both hydrophilic and hydrophobic (generally hydrocarbon) moieties that partition preferentially at the interface between fluid phases with different degrees of polarity [13]. Surfactants in the environment can originate from natural and anthropogenic sources such as degradation of humic substances, biomass burning, sea surface microlayer and soot from combustion activities [14-16].

Previous studies of surfactants showed that their presence in the atmosphere potentially influences the global climate through their ability to reduce surface tension, which in turn leads to an enhancement of cloud albedo [17,18]. Furthermore, surfactants can also increase the solubility of aerosol compositions [19]. In terms of health, surfactants may destabilize mucus in the membrane, which may lead to asthma and allergy and may cause irritation and dry eye [18,20,21].

According to a study by Abd Wahid *et al.,* [12], three main sources of surfactants were identified from PCA-MLR analysis for MBAS in fine mode samples in Kuala Lumpur, dominated by motor vehicles, followed by soil/road dust and sea spray. Motor vehicles are expected to be the principal source of aerosols in the urban atmosphere due to urbanization, rapid economic growth and a resulting growth in population which in effect has resulted in an increase in the volume of traffic in developing countries [5,22].

National Policy on the Environment (DASN) has been established for continuous economic, social and cultural progress and enhancement of the quality of life of Malaysians through environmentally sound and sustainable development. One of the objectives of DASN is to achieve a clean environment, safe, healthy, and productive environment for present and future generations. Although many previous studies on air quality have been conducted, studies involving microbial aerosols have not yet been studied. Therefore, this research focuses on surfactants and their characteristics in ambient PM, particularly in urban areas, as well as from motor vehicle exhaust particulate matter. In addition, the relationship between surfactants and other traffic-related gaseous pollutants will also be identified. As Kuala Lumpur is known as one of the megacities in Malaysia, with urbanization and abundance of vehicles every day, this area is chosen as the sampling site for this research.

2. Methodology

2.1 Sampling Area

The sampling of PM_{10} was conducted at Kuala Lumpur, one of the megacities in Malaysia. Kuala Lumpur recorded the highest number of vehicles registered every year and also gives the highest value of road traffic volume almost every day including weekends (Malaysian Ministry of Works) [23]. Due to urbanisation, a modern transportation system and an increase in population and migration, this area has become one of the busiest areas for human activity and some areas of business and industry. The sampling station is located at Setapak Jaya (N 3.188370, E 101.729725), near to Universiti Teknologi Malaysia (college) and a residential area located in the close vicinity of the sampling station. Figure 1 shows the sampling location of this study.

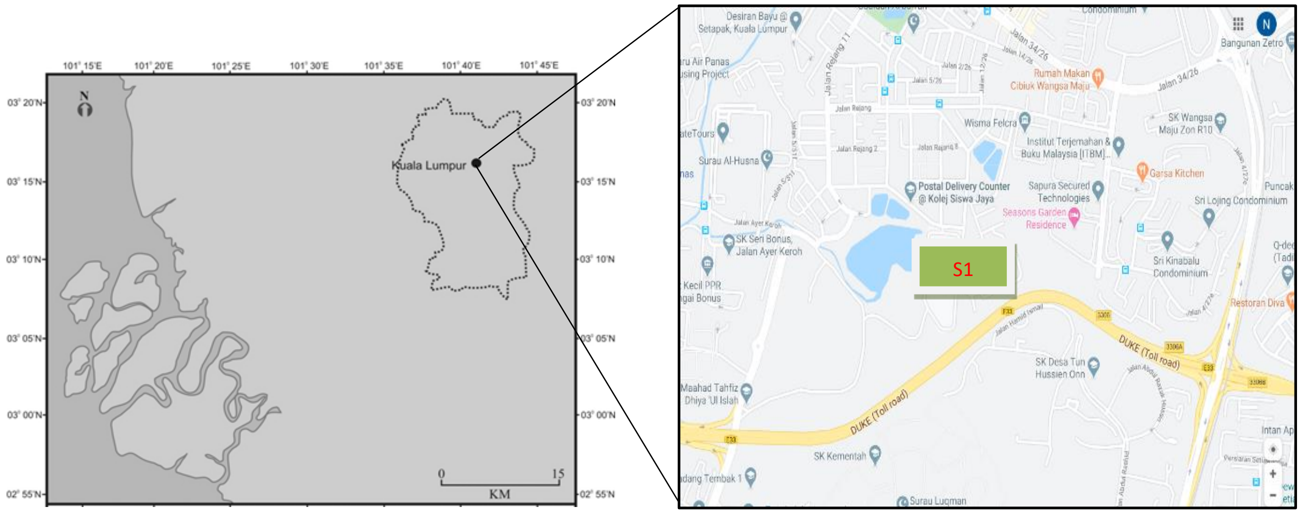


Fig. 1. Sampling station in Kuala Lumpur, S1 (N 3.188370, E 101.729725)

2.2 Sampling Procedures

Particulate matter samples were collected by using a high volume air sampler (HVAS). Whatman EPM 2000 fiber-glass filter papers (20.3 cm x 25.4 cm) were used to collect the sample. All the filter papers were packed in aluminium foil and heated at 500°C for 5 h in order to remove organic species prior to sampling. After sampling, all the filter papers were placed in a desiccator for 24 h, before being weighed and stored in a refrigerator until further analysis. The HVAS was turned on for 24 h each day during the sampling activities. The soot samples were collected from the exhaust pipes of petrol and diesel vehicles. A number of different circulating motor vehicles were selected randomly in this study involving cars, motorcycles, buses, lorries and big lorries of variable age. Dust from the inside of the exhaust pipes of each type of vehicle was directly collected, in a sealed plastic bag, by using a soft brush on hot and sunny days. The sample collected was stored in a glass vial screwed cap until further analysis.

2.3 Surfactant Analysis

For surfactant analysis, the principle of anionic surfactant, as Methylene Blue Active Substances (MBAS) was based on the formation of a chloroform extractable ion-association complex between the anionic surfactants and anionic (methylene blue) dyes. In this analysis, the chloroform layer was measured based on the light absorbance by using a UV-vis spectrophotometer at a wavelength of 650 nm. The calibration curve was established in the range of 0.05 – 2.00 µM for MBAS using Sodium Dodecyl Sulphate (SDS).

2.4 Microbial Aerosols and FESEM Analysis

The biological composition of the bioaerosol sample was analysed using a petri dish containing Trypticase Soy Agar (TSA) treated with chloramphenicol antibiotic that was a medium for bacterial growth and Malt Extract Agar (MEA) treated with cycloheximide antibiotic as a medium of growth of fungi. TSA plates were incubated for 24 – 48 h at 35°C to enhance the bacterial growth while MEA plates were incubated at 25°C for 5 d to enhance the growth of fungi before the colony forming unit was counted as suggested by NIOSH Manual of Analytical Method (NMAM) 0800.

Then, the surface morphological and elemental composition of particulate matter extracted from filter paper and petrol and diesel exhaust PM were examined using Field-emission Scanning Electron Microscopy (FESEM, Hitachi, SU 8020) coupled with Energy Dispersion System (EDS, Horiba Xmax Model) microanalysis. The filter paper was cut about 0.5 cm while the soot sample was attached directly to aluminium SEM stubs, using a two-sided adhesive film to adhere the filter to the stub, and covered by a thin film of platinum (Pt) coating. The microscope was operated at an accelerating voltage of 5 kV, while the images were adjusted using a high contrast-to-brightness ratio to obtain the best visualization of the particle.

2.5 Traffic-Related Gaseous Pollutants

The data on gaseous pollutants was obtained from the air monitoring stations managed by the Department of Environment, Malaysia (DoE). The data was utilized by β-ray attenuation mass monitor (BAM-1020) as manufactured by Met One Instruments Inc. To analyse the results of this study, several statistical analyses were used such as descriptive statistic and Pearson correlation analysis after all the data was found in normal distribution. The data collected was analysed using the XLSTAT 2017 software.

3. Results and Discussion

3.1 Composition of Surfactants in PM_{10}, Diesel and Petrol Soot

The average concentration of PM_{10} recorded in Kuala Lumpur was 107 ± 7.91 μgm^{-3}, with the minimum and maximum values of 102 μgm^{-3} and 123 μgm^{-3}, respectively. This level of PM_{10} was well below the 150 μgm^{-3} recommended by the Malaysian Government in the Recommended Malaysian Air Quality Guidelines (RMAQG). Table 1 shows the overall composition of surfactants (MBAS) in atmospheric PM_{10}, petrol-vehicle and diesel-vehicle exhaust PM. The average concentration of anionic surfactants as MBAS in atmospheric PM_{10} was 105 ± 48.8 $pmolm^{-3}$. These results were similar to the previous studies, which found that the level of surfactants in urban areas was high, as the result of traffic vehicles and urbanization [9,24]. The surfactant concentrations in Kuala Lumpur were probably influenced by anthropogenic sources during the sampling campaign. The PM_{10} sampling was located near college and residential areas with busy traffic, which may result in the accumulation of surfactants in the atmosphere possibly generated by motor vehicles [9,25,26].

Table 1
Average concentration of surfactants in atmospheric PM_{10}, diesel and petrol soot

	MBAS Average concentration	Minimum	Maximum
Particulate matter (PM) ($pmolm^{-3}$)	105 ± 48.8	67.9	206.42
Diesel Vehicles ($\mu molg^{-1}$)	0.227 ± 0.006	0.146	0.309
Petrol Vehicles ($\mu molg^{-1}$)	0.146 ± 0.003	0.107	0.185

For soot samples, diesel vehicles show a greater amount of surfactant concentration compared to petrol vehicles. Soot sample collected from diesel vehicle (buses and lorries) have recorded average surfactants value of 0.227 ± 0.006 $\mu molg^{-1}$ while petrol vehicles (cars and motorcycle) show the average of 0.146 ± 0.003 $\mu molg^{-1}$. The use of bus as the public is most likely the reason bus is the major contributor of surfactants' concentration in an urban area. In addition, the typical driving behaviour of accelerating and braking has also influenced the concentration of exhaust particles in the atmosphere [27]. Incomplete combustion of a hydrocarbon in fuel is possibly the reason for the high emission of surfactants in the urban atmosphere mainly in busy traffic area [24,28]. Moreover, frequent use of surfactants in engine oil can contribute to the high amount of surfactants in the busy traffic of urban areas [9,29].

To determine the relationship of surfactants as MBAS in PM_{10} with traffic emission, the correlation analysis was conducted using XLSTAT. Table 2 shows the correlation between MBAS with traffic-related gaseous pollutants such as SO_2, NO_x, O_3 and CO. Results indicate that surfactants as MBAS have significantly correlated (positive correlation) with CO ($p < 0.05$). This correlation indicates that the combustion process and motor vehicles influence the level of surfactants in atmospheric aerosol with a strong correlation (r value of 0.671). However, MBAS was negatively correlated ($p < 0.05$) with O_3 with the r value of -0.612. Based on this result, O_3 seems to act as the agent to destroy surfactants through the oxidation process [25]. In addition, O_3 also might be reduced from NO_x in the atmosphere, particularly through interaction with nitrous oxide. Therefore, the positive correlation of anionic surfactants with NO_x has indicated a reverse correlation between surfactants and O_3 [9,30-32].

Table 2
Correlation of MBAS with traffic-related gaseous

Variables	MBAS	SO_2	NO_x	O_3	CO
MBAS	1				
SO_2	0.326	1			
NO_x	0.245	0.788	1		
O_3	-0.612*	-0.622	-0.437	1	
CO	0.671*	0.635	0.935*	0.312	1

*indicated p<0.05

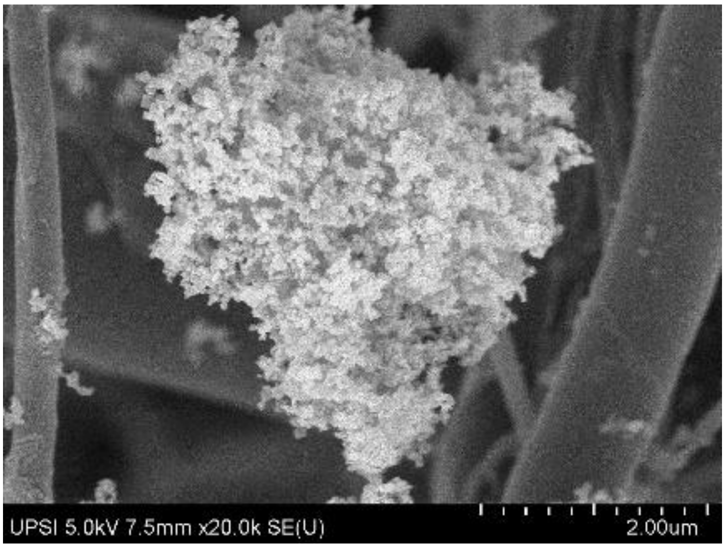
Table 3 shows the correlation of MBAS with meteorological factors in the study area. Results show a positive correlation between MBAS with wind speed, and humidity but a negative correlation with temperature. However, this relationship is not significant ($p > 0.05$).

Table 3
Correlation of MBAS with meteorological factors

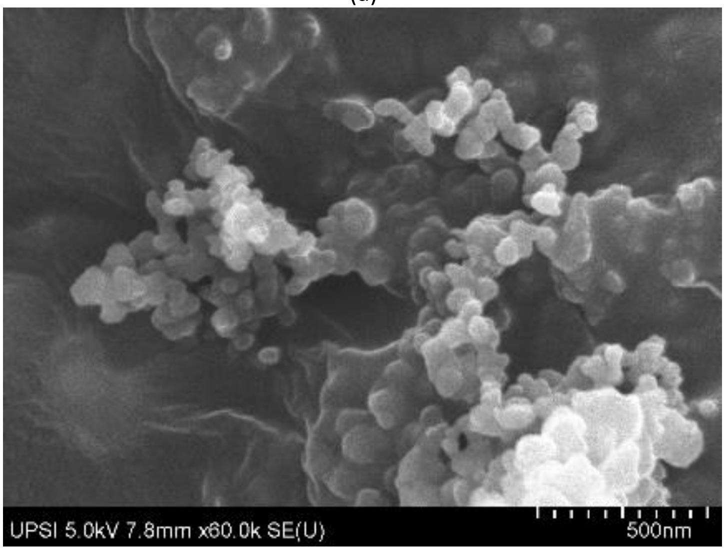
Variables	MBAS	Wind speed	Humidity	Temperature
MBAS	1			
Wind speed	0.156	1		
Humidity	0.047	0.301	1	
Temperature	-0.112	-0.219	-0.971*	1

*indicated p <0.05

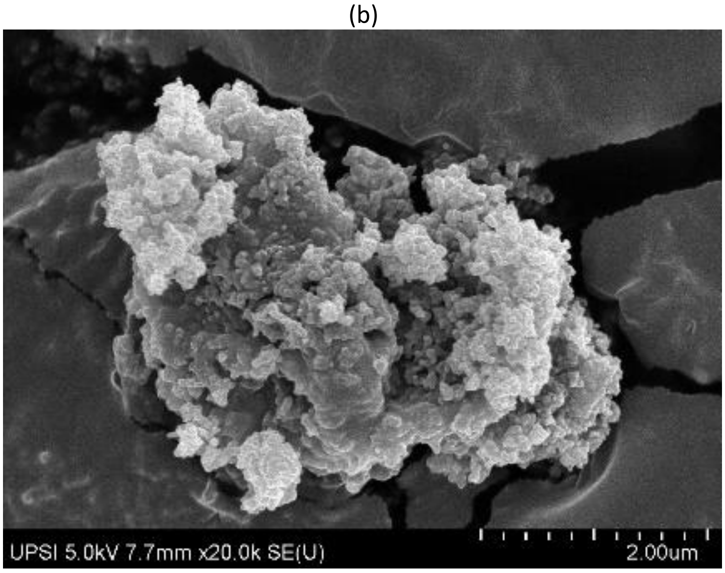
For bioaerosol, the average total bacterial count (TBC) and total fungal count (TFC) from particulate matter are 225 cfu m^{-3} and 250 cfu m^{-3}, respectively. This result indicated that fungi are higher than bacteria in ambient PM_{10} of the study area. Figure 2 shows the FESEM image of filter paper (atmospheric PM_{10}), as well as diesel and petrol exhaust soot. These results probably confirmed that most of the PM_{10} in urban areas is generated from vehicular emissions such as diesel and petrol vehicles, as the similarity of morphological image of PM_{10} with those diesel and petrol soot. This result is in line with the studies by Wahid *et al.,* [9], Anake *et al.,* [33], Reşitoğlu *et al.,* [34], and Nor *et al.,* [35].



(a)



(b)



(c)

Fig. 2. FESEM image for (a) Particulate matter, (b) Diesel vehicles soot, (c) Petrol vehicles soot

4. Conclusions

As a conclusion, in this study, the composition of surfactants in atmospheric PM_{10} and exhaust particulate matter was determined in Kuala Lumpur, Malaysia. Results indicated that the anionic surfactants as MBAS were between 67.9 to 206.42 pmolm^{-3}. The location of the sampling station was near a busy traffic area, which may contribute to a high concentration of surfactants in the atmosphere. The surfactant analysed from exhaust particulate matter clearly showed the presence of a large amount of surfactant in diesel engines compared to petrol engine vehicles. This is probably due to the irregular operating condition of diesel vehicles mainly heavy-duty vehicles, compared to petrol vehicles, which are regularly serviced for better performance. The mean of total bacterial counts and total fungal counts were at a moderate level. This study suggests that anthropogenic sources such as combustion activities and motor vehicle emission are probably contributed to the quantity of surfactants in urban area of Kuala Lumpur, Malaysia. Due to the high contribution of surfactants in urban areas, the management and emissions of motor vehicles also need to be reconsidered to develop a better urban environment in the future.

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