COMPOSITION OF SURFACTANTS AND BIOAEROSOLS IN AMBIENT PARTICULATE MATTER FROM SELECTED AREAS IN PERAK, MALAYSIA

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ABSTRACT

Surfactants and bioaerosols are components of air pollutants in the atmospheric particulate matter (PM) that significantly contribute to the level of air pollution. This study was conducted to determine the composition of surfactants and bioaerosols in the atmospheric PM from urban area (Ipoh), sub-urban (Tanjung Malim) and marine area (Manjung) at Perak. Atmospheric PM samples were collected using a high-volume air sampler (HVAS) with a flow rate of 1.13 m^3 min^{-1} in 24 h basis. Samples were collected based on size fraction of fine (< 1.5 µm) and coarse (>1.5 µm) mode particles. The concentrations of anionic surfactants as Methylene Blue Active Substances (MBAS) were determined by using colorimetric method. Principal component analysis (PCA) with multiple linear regressions (MLR) was used to identify the possible sources of MBAS based on the ionic composition. For bioaerosols analysis, samples were collected in Tanjung Malim only and cultured by spread-plate technique on selective media followed by colonies counting (CFU/m^{-3}). Results from this study indicated that Manjung has the highest average concentration of MBAS compare to Tanjung Malim and Ipoh (188.62 ± 13.73), (159.95 ± 12.65) and (151.29 ± 12.30) pmol m^{-3} respectively. Overall, the concentration of surfactants at all sampling location was dominated by fine mode (< 1.5 µm) rather than coarse mode (>1.5 µm) particles. For bioaerosols composition, fungal shows higher mean concentration than bacterial with (111.23 ± 100.64) $CFUm^{-3}$. FeSEM image show majorly the pollutants had different particles shape and size that might represent the origin of those particulate. This can be concluded that the composition of surfactants and bioaerosols in atmospheric PM were varies based on the studied location. This finding of chemical characterization and sources identifications are useful in planning the effective control strategies to reduce the emission of surfactants in atmosphere.

KOMPOSISI SURFAKTAN DAN BIOAEROSOLS DALAM BAHAN ZARAHAN ATMOSFERA DARI KAWASAN TERPILIH DI PERAK, MALAYSIA

ABSTRAK

Surfaktan dan *bioaerosols* adalah komponen pencemar udara dalam bahan zarahan atmosfera (PM) yang telah dikenalpasti sebagai penyumbang kepada pencemaran udara. Oleh itu, kajian ini dijalankan bagi menentukan komposisi surfaktan dan *bioaerosol* di PM atmosfera dari kawasan bandar (Ipoh), separa bandar (Tanjung Malim) dan kawasan marin (Manjung) di Perak. Sampel PM atmosfera dikumpulkan dengan menggunakan alat pensampelan udara berisipadu tinggi (HVAS) dengan kadar aliran 1.13 m^3 min^{-1} dalam masa 24 jam. Sampel dikutip mengikut saiz berbeza yang terdiri daripada zarah mod halus (< 1.5 μm) dan mod kasar (> 1.5 μm). Kepekatan surfaktan anionik sebagai *Methylene Blue Active Substances* (MBAS) dikenalpasti dengan menggunakan kaedah kolorimetrik. Analisis komponen utama (PCA) dengan pelbagai regresi linear (MLR) digunakan untuk mengenal pasti sumber kemungkinan MBAS berdasarkan komposisi ionik. Untuk analisis *bioaerosols* pula, sampel dikumpulkan dari Tanjung Malim sahaja dan dikultur dengan teknik penyebaran berlimpah pada media tertentu diikuti oleh penghitungan koloni ($CFUm^{-3}$). Keputusan menunjukkan bahawa Manjung mempunyai kepekatan purata tertinggi MBAS berbanding Tanjung Malim dan Ipoh masing-masing dengan nilai (188.62±13.73), (159.95±12.65) dan (151.29±12.30) pmol m^{-3}. Secara keseluruhannya, kepekatan surfaktan di semua lokasi persampelan didominasi oleh mod halus berbanding mod kasar. Untuk hasil komposisi *bioaerosols*, kulat menunjukkan kepekatan lebih tinggi daripada bakteria dengan (111.23 ± 100.64) $CFUm^{-3}$. Gambar FeSEM menunjukkan kebanyakan bahan pencemar mempunyai bentuk dan saiz yang berbeza kemungkinan mewakili asal jisim tersebut. Ini dapat disimpulkan bahawa komposisi surfaktan dan *bioaerosols* dalam PM atmosfera berbeza-beza berdasarkan lokasi yang dianalisis. Penemuan pencirian kimia dan pengenalan sumber ini berguna dalam merancang strategi kawalan yang berkesan untuk mengurangkan pelepasan surfaktan di atmosfera.

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LIST OF ABBREVIATIONS

DoE	Department of Environment
FeSEM	Field Emission Scanning Electron Microscopy
HYSPLIT	Hybrid-Single Particle Lagrangian Integrated Trajectory
HVAS	High-Volume Air Sampler
MBAS	Methylene Blue Active Substance
MLR	Multiple Linear Regression
PCA	Principal Component Analysis
PM	Particulate Matter
SE	Standard Error
SML	Sea-Surface Microlayer
SPSS	Statistical Packages for the Social Science
TSP	Total Suspended Particulate
WHO	World Health Organization

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CHAPTER 1

INTRODUCTION

1.1 Overview

This whole chapter discusses the research that has been carried out and the discussion is broken down into several sections, namely background of this research, rational of study, problems statement, conceptual frameworks, objective of studies, importance of studies, research interests and study limitations. Besides, this chapter also discusses the overall research design and thesis outline.

1.2 Research Background

The issue of air pollution is not a recent phenomenon since it is widespread all around the world. Mcgranahan and Murray (1999) defined air pollution as any substances emitted to the air at concentrations, durations and frequencies that adversely affect human health, human welfare or the environment. Air pollution occurs as a consequence of natural processes as well as anthropogenic activities including volcano eruption, forest fires, automobile emission and open burning (Latif et al., 2005; Rhind, 2009). The rapid advancement of industrial activities and population concentration also pose a serious threat to atmospheric air quality and well-being as cited by Ramanathan and Feng (2009). In addition, air pollution in Malaysia is also affected by haze derived from long-range transport and pollutants from biomass burning activity in some areas (Abas, Oros & Simoneit, 2004; Othman, Sahani, Mahmud, & Sheikh, 2014; Lee et al., 2016).

Monitoring data and studies on ambient air quality showed that some of the air pollutions in several huge cities of Malaysia are increasing with time (Latif et al., 2005; Ahmat, Yahaya, & Ramli, 2015). According to Othman, Sahani, Mahmud & Sheikh (2014) and Lee et al. (2016), particulate matter (PM) is believed to be one of the major air pollutants that lead to air pollution. Atmospheric PM consists of minuscule particles of solid and liquid suspended in air and most of them are hazardous with diameter ranging from 0.001 μm to 100 μm (Mohapatra & Biswal 2014; Ismail, Yuen & Abdullah, 2015). Adverse health effect had been documented after exposure to ambient PM including respiratory and cardiovascular diseases (Pražnikar & Pražnikar, 2012; Gabriela et al., 2014). PM also plays an important role in greenhouse effect and global warming where it directly scatters and absorbs the incoming solar radiation and

indirectly affects the climate system by changing the cloud composition in many ways (Lohmann & Feichter, 2005; Pöschl, 2005; Schwier, 2012). Hence, particulate matter is crucial to study for its effect on global climate.

Surfactants or surface active agents are one of the organic substances that is present in PM which can affect the global climate system by reducing the surface tension of activating cloud droplets (Facchini, Mircea, & Fuzzi, 1999; Vejrup & Wolkoff, 2002). Desai and Banat (1997) had stated that surfactants are amphiphilic organic species with two defining moieties which are the hydrophilic head group and hydrophobic carbon chain (generally hydrocarbon). Depending on the charge of their head group, surfactants are generally classified as anionic, cationic, amphoteric and nonionic (Ivanković & Hrenović, 2010). This characteristic of molecules may cause these surfactants to accumulate toward the surface easily and within matter surface of a material (Myers, 1988). The study conducted by Wahid et al., (2013b), Alsalahi et al., (2014) and Jaafar et al., (2016) had concluded that surfactants emissions in the atmosphere are dominated by anionic group because maybe it represented approximately 65% of total production of surfactants compound.

Previous studies showed that surfactants had participated in several atmospheric processes such as visibility reduction, forming cloud condensation nuclei (CCN) and acidification of cloud, rain and fog (Khan et al., 2010; Prisle et al., 2012). Surfactants affect the climate system by concentrating itself in the cloud surfaces and reduce the surface tension of activated cloud droplets which lead to the enhancement of cloud albedo (Facchini et al., 2001; Vejrup & Wolkoff, 2002). Moreover, surfactants are also able to increase the solubility of PM composition (Kiss et al., 2005). In terms of health,

surfactants may destabilize mucus in membrane, which may lead to asthma and allergy (Cserhati et al., 2002), irritation and dry eyes (Vejrup & Wolkoff, 2002). The composition of surfactants might vary widely and depends on the emission source, geographic location and meteorology in certain location since different area has different environmental conditions (Kiss et al., 2005; Gabriela et al., 2014). According to Latif and Brimblecombe (2007) and Beaver (2008), surfactants have been observed to be present on both terrestrial and marine PM particles. Thus, this study focused on the composition of surfactant samples collected at selected area in Perak including the urban, sub-urban and marine environment.

Atmospheric pollutants are also comprised of microbiological component called bioaerosols. These biological origins typically consist of bacteria, fungi and their spores, pollen, viruses, plant debris and their derivatives (Huffman et al., 2012; Polymenakou, 2012). Bioaerosols can colonize soil, plant surfaces, water bodies and are readily released to the air by wind erosion and splashing water which can influence the atmospheric chemistry, physics and climate (Griffin et al., 2004; Kuske, 2006). They are also of anthropogenic origin such as sewage treatment, agricultural activities, exhaust emission and fermentation processes (Manchinelli & Shulls, 1978; Fang et al., 2007; Smets et al., 2016). Other study conducted by Pastuszka et al. (2000) had stated that the bioaerosols concentration in motor vehicles also produce bacteria and fungi, which exist in the environment as unicellular or multicellular. Rapid population growth and increasing number of vehicles on the road has induced high bioaerosols emissions to the atmosphere.

Organic compounds including the ones from biogenic or non-biogenic origin in the PM can affect global climate change through the modification of clouds lifetime, size distribution of clouds droplets, distribution of water mass in different atmospheric layers and the glaciation rates (Andrews et al., 1997; Sun & Ariya, 2006; Mason et al., 2015). In term of human health, small-sized particles of bioaerosols can easily travel in the atmosphere where humans are easily exposed to these airborne microorganisms resulting in public health problem including respiratory diseases, infection diseases and cancer (Hinds, 1999; Zain, 2011; Pyankov, Pyankova & Agranovski, 2012; Hansell, 2015). Furthermore, bioaerosols mainly bacteria and fungi spread diseases through wind along the process of food production resulting in spoilage and defect in raw materials and food products (Jay, 1996; Tournas, 2005; Akyar, 2015; Munthali et al., 2016). Food shortage and great economic losses due to bioaerosols attack are among the matters to be avoided for our mutual comfort.

In these growing years, awareness of atmospheric pollutants has gained the attention of many researchers especially in the environmental field. This is because PM has been the reason for many studies to be conducted on atmospheric pollutant since it is well addressed to have significant relation with health impacts (Pöschl, 2005; Gabriela et al., 2014; Khan et al., 2016). Since surfactants and bioaerosols affect the climate, environment and human health negatively, an urge for the investigation of their composition is needed in order to better understand their composition and interaction in the atmosphere. Furthermore, according to Jimoda (2012), meteorological factors like ambient temperature, humidity, rainfall and wind speed were also reported to affect PM emission, transportation and chemical reaction which are also important to be examined in this study.

1.3 Problem Statement

Recently, many field studies have been conducted on the analysis of surfactants in the atmospheric particulate matter (PM) around the world due to their effect on climate, environment and human health. In Malaysia, researches on surfactants analysis from ambient PM are also getting more attention due to the increase in air pollution problems. There are several studies conducted on surfactants analysis in different environment compartment in Malaysia such as in coastal area (Jaafar et al., 2016; Roslan et al., 2010), river (Hanif et al., 2012) and lake (Hanif, Latif and Othman, 2011; Razak et al., 2013a). Meanwhile, in main busy areas such as Kuala Lumpur and Selangor, the studies focused more on the urban and sub-urban area as per conducted by Latif et al., (2005), Wahid, Talib, & Suratman, (2013a) and Ahmed, Guo, and Zhao, (2016a).

Nevertheless, these following studies are more focused on surfactants properties at specific place only. In other words, detailed information regarding surfactants properties will reflect on that particular area only. It became evident that without inclusive input data, the composition of atmospheric surfactants is difficult and inadequate to be analyzed comprehensively. Therefore, a more specific study covering a variety of backgrounds done at the same time should be implemented in order to better understand their role in the climate system as well as to draw a general conclusion on surfactants analysis in Malaysia. Thus, this study presents to investigate the composition of surfactants from urban, sub-urban and marine environment in atmospheric PM at the same time in Ipoh.

Meanwhile, PM was also affected by the presence of bioaerosols in the atmosphere. The studies of airborne microbes' interaction in the environment are getting more interest from local researcher especially in the field of air quality. Several studies have been conducted in indoor areas such as classroom, hospital, nursery, library and restaurant (Kumari, Shravanthi & Reddy, 2015; Hizrri et al., 2014; Maryam et al., 2015; Che Noraini et al., 2016; Khamal et al., 2016). However, very few of them conducted studies in the ambient environment. According to Oh et al., (2015), the air in the outdoor environment greatly influences the indoor air circulation resulting in individuals being exposed while indoor. Moreover, to the knowledge of the author, there is a lack of investigations done on ambient inhalable bioaerosols as well as little attention has been paid on the interrelationships between bioaerosols and ambient air pollutants relevant to human health and meteorological factors in Malaysia. Thus, the specialty of this study was an assessment on the relationship of atmospheric PM with the concentration of bioaerosols in the ambient environment.

The distribution pattern of atmospheric pollutants is believed to be affected by meteorological factors as stated by Wahid et al. (2014) and Noor et al. (2015). This is because, weather plays a very important role in the presence, formation and behavior of ambient surfactants in the atmosphere. High concentration of surfactants was frequently recorded to exceed the safe value of Recommended Malaysia Ambient Air Quality Guideline (RMAAQG), especially during the dry season that occurs during summer monsoon (June until September) (Wahid et al., 2013a; Ahmed, Guo, & Zhao, 2016b).

Hence, this study aims to determine the composition of atmospheric surfactants in the urban, suburban and marine environment in Perak, Malaysia. In order to

determine the composition of surfactants, their source identification needs to be done. Possible sources collected from road dust and exhaust soot were also analyzed by using multivariate analysis. Thus, in this study, the relationship between surfactants' concentrations and bioaerosols with three weather parameters which are ambient temperature, humidity and wind speed were also studied.

1.4 Importance of The Study

In this study, the composition of surfactants and bioaerosols in the selected area of Perak is investigated. This study focused more on the comprehensive data of surfactants analysis collected from various background areas. Most of the atmospheric researchers focused more on the concentration of surfactants at a certain area at one time only. This is different from this study where the level of air quality in the urban, sub-urban and marine environment can all be predicted at once. Furthermore, the source apportionments of surfactants and its characterization in atmospheric PM can also be understood more through the morphological result in this study, where it is less investigated by other atmospheric researchers in this country. Hopefully, the result from this finding can be used for further study in understanding the role of surfactants and bioaerosols in affecting climate system and cloud formation.

There is a great concern about the potential health hazards of bioaerosols in ambient PM particularly about the levels of toxigenic fungi and their association with outdoor air quality. The quality of outdoor air is crucial since we want to breathe fresh air with no contamination. In addition, the level of air quality in the indoor environment is also influenced by the quality of air from the outdoor environment. For that reason,

the specialty of this study is to gather as much information as possible on microbial community in the ambient environment in order to serve a better understanding as it can lead to various health problems such as infectious disease, allergy, asthma and cardiovascular diseases (Xu et al., 2011; Madsen, 2012, Jacob et al., 2016, Kallawicha et al., 2016).

It is expected that the results of this study will provide comprehensive information for the study of surfactants and bioaerosols in atmospheric PM. Results from this study can also contribute as the reference for other researchers and stimulate further studies to address their nature and environmental impacts, especially in atmospheric air quality research. This research is also important in providing information for the government agencies to produce high-quality mitigation procedures involving air-quality control. Moreover, preserving and maintaining good air quality can serve our future generation a better quality of life as well as it helps in the development of Malaysian tourism industry as it attracts domestic and foreign tourists to Malaysia.

1.5 Research Objectives

The objectives of this research are:

i. To determine the concentration and possible sources of surfactants in the atmospheric particulate matter from the urban, semi-urban and marine environment.
ii. To investigate the composition of bioaerosols in the atmospheric particulate matter.

1.6 Thesis Outline and Research Guideline

This thesis consists of eight chapters which explained in detail on the whole process of this research. Chapter 1 is the introduction of this study in which basic things conducted in this study is clarified. It includes research background, problem statement, significance of study and objectives of this study. Chapter 2 is comprised of the literature review of this study. In this chapter, a detailed explanation regarding particulate matter (PM), characterization and relationship of PM with climate change (albedo cloud). Clarification of surfactants, types of surfactants, the characterization and its effect are also discussed. A specific description of bioaerosols, its classification, characterization in the atmosphere, and effects are also discussed in this chapter. Factors of meteorological and gaseous pollutant in affecting surfactants' concentration are also clarified. Review of the previous study regarding surfactants and bioaerosols are also discussed.

Chapter 3 includes materials, apparatus and methodology used in this study. Starting from explanation of the study area, this chapter clarified how the process of collecting data from different location is done. Next, sample processing was discussed which involved several different processes according to the types of sample and analysis done. Principal of instruments used and statistical analysis as well as quality control while conducting this research were also discussed in this chapter. A comprehensive description of methodology of each surfactants and bioaerosols extraction, analysis and test was also elaborated in this study.

In chapter 4, the results of surfactants' concentration from three different background environments was measured and compared. The results from surfactants

analysis in atmospheric PM was discussed in details based on the different between fine and coarse mode particles. This chapter also discussed the difference of surfactants' concentration in each sampling location based on the topography. Next, Chapter 5 focused on the characteristics of anionic surfactants in the atmospheric PM. The interaction between water-soluble ionic elements as well as the sources of surfactants was defined using statistical analysis of principal component analysis (PCA) and multi linear regression (MLR). The characterization of surfactants was analyzed and compared with ionic composition, meteorological factors and gaseous pollutants.

Chapter 6 focuses on the results and discussion of possible sources for surfactants. The relationship between road dust and exhaust soot as reference of possible sources with surfactants was discussed in details in this chapter. In Chapter 7, the results of preliminary data of composition of bioaerosols in atmospheric PM are discussed. The concentration of airborne microbe-associated PM present in the atmosphere of sampling location was described in colony-forming units (CFU). A closer look at particulate morphology collected from PM, road dust and exhaust soot were scanned by using field emission scanning electron microscope (FeSEM). Chapter 8 is the last chapter discussed in this study. In this chapter, all of the findings were summarized. Next, several recommendations as well as improvements that could be done in future work were also discussed.

1.7 Conclusion

As a conclusion, this chapter had described an overall summary of this study. It involved the importance, significance and objectives that are discussed in the following chapters.