Atmospheric Environment 141 (2016) 219–229

Contents lists available at ScienceDirect

Atmospheric Environment

journal homepage: www.elsevier.com/locate/atmosenv

Determination and analysis of trace metals and surfactant in air particulate matter during biomass burning haze episode in Malaysia

Manan Ahmed [a,*], Xinxin Guo [a,**], Xing-Min Zhao [b]

[a] Department of Environmental Engineering, Faculty of Engineering and Green Technology, Universiti Tunku Abdul Rahman, Kampar, 31900, Malaysia
[b] College of Resource and Environment, Jilin Agriculture University, Changchun, 130188, China

HIGHLIGHTS

- Atmospheric particulate matter investigation particularly surfactant and trace metals from biomass burning.
- Two types of particulate sample (TSP + $PM_{2.5}$) were collected.
- A cost effective and simple method used for analysis.
- Air mass backward trajectories analysis used to identify the source of PM.

ARTICLE INFO

Article history:
Received 3 May 2016
Received in revised form
24 June 2016
Accepted 25 June 2016
Available online 26 June 2016

Keywords:
Biomass burning
Trace metals
Surfactant
ICP-MS
UV/Vis spectrometer

ABSTRACT

Trace metal species and surface active agent (surfactant) emitted into the atmosphere from natural and anthropogenic source can cause various health related and environmental problems. Limited data exists for determinations of atmospheric particulate matter particularly trace metals and surfactant concentration in Malaysia during biomass burning haze episode. We used simple and validated effective methodology for the determination of trace metals and surfactant in atmospheric particulate matter (TSP & $PM_{2.5}$) collected during the biomass burning haze episode in Kampar, Malaysia from end of August to October 2015. Colorimetric method of analysis was undertaken to determine the concentration of anionic surfactant as methylene blue active substance (MBAS) and cationic surfactant as disulphine blue active substance (DBAS) using a UV–Visible spectrophotometer. Particulate samples were also analyzed for trace metals with inductive coupled plasma mass spectrometer (ICP-MS) followed by extraction from glass microfiber filters with close vessel microwave acid digestion. The result showed that the concentrations of surfactant in both samples (TSP & $PM_{2.5}$) were dominated by MBAS (0.147–4.626 mmol/m^3) rather than DBAS (0.111–0.671 mmol/m^3) and higher than the other researcher found. Iron (147.31–1381.19 μg/m^3) was recorded leading trace metal in PM followed by Al, Zn, Pb, Cd, Cr and others. During the haze period the highest mass concentration of TSP 313.34 μg/m^3 and 191.07 μg/m^3 for $PM_{2.5}$ were recorded. Furthermore, the backward air trajectories from Kampar in north of peninsular Malaysia confirmed that nearly all the winds paths originate from Sumatera and Kalimantan, Indonesia.

1. Introduction

Biomass burning has significant regional and global impacts on both chemical properties of the atmosphere and the radiative balance of the earth. Biomass burning is a particularly important source of aerosol haze, resulting from the open burning of agricultural residues, slash-and-burn practices, and grassland and forest fires. Haze is the basic forms of air pollution when tiny particles (particles in the range of sub-micron) effectively scatter and absorb sunlight, can cause significant visibility reduction in the atmosphere (Engling et al., 2014). Some haze-causing particles are directly emitted into the air; while some formed when gases emitted into the air undergo a chemicals reaction to form pollution. These emitted fine particulate matters disperse around and are transported following the general wind direction, causing trans-boundary air pollution. The fine haze-causing particulate matters are of particular health concern as they are repairable and can

* Corresponding author.
** Corresponding author.
E-mail addresses: manan_ahmed@live.com (M. Ahmed), guox@utar.edu.my (X. Guo).

http://dx.doi.org/10.1016/j.atmosenv.2016.06.066
1352-2310/

transmit many adsorbed toxic substances on the surface (Pentamwa and Oanh, 2008). Biomass combustion particulate is typically smaller than 1 μm, with a peak in the size distribution between 0.15 and 0.4 μm (Hueglin et al., 1997).

Particulate matters (PM) are involved in many atmospheric processes and play an important role in reducing visibility, acid deposition, and balance of radiation in the atmosphere, both directly and indirectly through cloud formation (Forster et al., 2007; IPCC, 2013). PM pollution is a serious environmental issue mainly due to the presence of toxic substance (organic materials, elemental carbon and crustal materials) and trace metal species in the atmosphere (Lee and Hieu, 2011). There is a general agreement that airborne PM is associated and suspected with adverse health effects on human. It is also reported that trace metal including most potentially toxic metals released by high temperature anthropogenic activities cause severe disturbance of ecosystems in the submicron particle size (Li et al., 2013; Uzu et al., 2010; Martorell et al., 2009). Some of the major sources that are released trace metals species into the atmosphere and its surrounding are combustion of fossil fuels, wood, high temperature industrial and natural processes (Hutchinson and Meema, 1987). Atmospheric trace metal species usually associated with anthropogenic activities are arsenic (As), cadmium (Cd), copper (Cu), nickel (Ni), zinc (Zn), vanadium (V), mercury (Hg) and lead (Pb) (Zheng et al., 2010). Although both natural and anthropogenic sources contribute to the distribution of trace metals into the atmosphere but the human activities play a more important role in distributions. Gravimetrically, trace metals represent a comparatively small fraction, generally less than 1% of atmospheric aerosols (Colbeck, 2008).

The growing interest stimulated by atmospheric pollution is due to its impact on human health, air quality and global climate changes. Trace metals are of primary concern for variety of human health-related and natural environment problems, includes; arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), aluminum (Al), copper (Cu), manganese (Mn), chromium (Cr) vanadium (V), and zinc (Zn) (Tchounwou et al., 2012). Dore et al. (2014) found that one of the major sources of trace metals in the atmosphere is emission of biomass particulate matter. The level of several trace metals species such as As, Pb, Cu, Ni, Cr and Cd and their potential hazards in the atmosphere are well documented and guidelines level of these species are provided World Health Organization (WHO, 2000).

Beside trace metals species, many organic materials are ubiquitous component of atmospheric particulate during biomass burning emission, making up a major fraction of fine aerosol mass but one important class of organic material generally found in atmospheric particulate (aerosol) is surface active species also known as surfactant including organic acids and diacids, proteins and humic like substance (HULIS) (Jimenez et al., 2009). The unique characteristic of surface active molecule is that they contain both hydrophilic and hydrophobic moiety in same molecule (Kumar et al., 2014). Surfactants are useful as they have aggregated structures called micelles. These compounds are best known as detergent in surface water and the foam producing layer on the ocean surface (Rub et al., 2016; Kumar et al., 2015). Sea surface microlayer and soots from combustion activities are also responsible for the surfactant in the atmospheric environment. Surfactant play a significant role in natural environmental systems as they accumulate at air-water interface and are also present in atmospheric aerosols and precipitations, influencing the surface tension of haze and cloud droplets (Guo et al., 2016). Primary studies showed that the surfactant in the atmosphere potentially influences the global climate through their ability to reduce surface tension which in turn affects the physical properties of cloud droplets and eventually leads to an enhancement of cloud albedo (Facchini et al., 2001). In term of health effect, surfactants can destabilize the mucus in the membrane which may cause asthma and allergy and also responsible to reduce surface tension of tear film, resulting in irritation and dry eyes (Wahid et al., 2013).

Air quality in Southeast Asia (SEA) is affected by trans-boundary haze pollution including combustion of fossil fuels and biomass burning (forest fires), is one of the most severe regional air pollution problems annually. Peat fires are considered one of the key sources of smoke haze among the different types of biomass burned in Indonesia. During 1997–1998, peat fire haze due to the El Nino drought has been recorded severe and most demining in the history (See et al., 2007; Page et al., 2002). The most recent serious regional biomass burning smoke haze in SEA was observed in the beginning of August 2015. The haze affected countries are Malaysia, Singapore, Brunei, Indonesia and Southern Thailand. The authorities in Malaysia issued the warning of poor visibility and respiratory difficulties. Air quality monitoring network, Department of Environment of Malaysia recorded a high concentration of potential harmful small particles in many areas. As the matter of fact, biomass burning haze caused by forest fire resulting from illegal slash-and-burn practices especially during harvesting season or in preparation for changing the use of land, principally on the Indonesian islands of Sumatra and Kalimantan, which can then spread quickly in the dry season. The haze has been particularly severe in 2015 due to the El Niño phenomenon, which has caused drier conditions, allowing the fires to spread more. The main components of biomass burning emission are water vapors, volatile organic compound (VOC), humic like substance, hydrocarbon, trace gasses and trace metal particles (Othman and Latif, 2013).

Recently, many field studies have been conducted on the analysis of trace metals and surfactant in atmospheric particulate matter in different environment compartment such as lake, sediments and atmosphere in the world. To our knowledge, studies of surfactant and trace metals in atmosphere are very limited in Malaysia (Razak et al., 2014; Jaafar et al., 2014; Othman and Latif, 2013; Wahid et al., 2013). The present study focuses on the analysis of trace metals and surfactant in atmospheric particulate matter during biomass burning haze episode. To achieve this objective, we used simple microwave-based sample preparation procedures for the determination of trace metal concentration using ICP-MS in airborne particulate matter (emitted from biomass burning) of different sizes in order to evaluate their bioavailability's which are known to pose threats to both human health and natural ecosystems. Moreover this study also quantifies the amount of water soluble organic molecule using UV–Visible spectrophotometer which behaves as surfactant in atmosphere. In general UV–Visible method for surfactant analysis is rapid and nondestructive as no sample pre-treatment is necessary. The accurate measurement of trace metal concentration and surfactant in atmospheric particulate sample is an important goal in environmental monitoring and research.

2. Experimental

2.1. Reagent and reference materials

For the preparation of reagents and standards, freshly prepared ultrapure water (18.2 MΩcm) from TKA smart2plus Ultra-Pure Water system (TKA, Germany) was used. Analytical grade reagents HNO_3 (Fluoka, France) and H_2O_2 (Merck, Germany) were used for the digestion experiment. ICP-MS multi-element standard (Purity ≥99.99%) obtained from Perkin Elmer and used for calibration of equipment. Surfactant standards sodium dodecyl sulfate (ACS reagent, purity ≥99%) and benzyldimethylhexadecyl ammonium chloride (ACS reagent, purity ≥99%) obtained from the Sigma