



# COMPARISON OF PM<sub>10</sub> PATTERN AND PM<sub>2.5</sub> CARBONACEOUS FRACTION FROM EPISODIC AND NON EPISODIC PERIOD OF PEAT LAND WILDFIRE

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## ABSTRACT

The peatland wildfire in Indonesia was periodically occurs even in non-ENSO period thus may pose health risk to the inhabitants each year. During non episodic peatland wildfire, we measured PM<sub>2.5</sub> using 2 sets of PM<sub>2.5</sub> samplers combined with secondary data from fixed monitoring station for ambient PM<sub>10</sub>. We compare the data with previous study on episodic wildfire in this peatland area. EC and OC concentrations in PM<sub>2.5</sub> were determined using a thermal/optical carbon analyzer with IMPROVE-A protocol. The pattern of PM<sub>10</sub> during episodic peatland wildfire can reach more than ten times of PM<sub>10</sub> standard (24 h). This is may pose health risk since this high concentration may persist during one month or more. While during non episodic wildfire the ambient PM<sub>10</sub> showed moderate fluctuation. During episodic burning period, the ambient atmosphere are enriched by OC1 and OC2 fraction, while in non episodic burning, fraction of OC2, OC3 as well as OC4 shows higher level than OC1. Based on EC ratio analysis the char-EC in biomass burning shows higher than soot-EC leading to dominant fraction of low temperature elemental carbon originated from biomass burning.

**Keywords:** peatland wildfire, biomass burning, organic carbon, elemental carbon, char-EC, soot-EC.

## INTRODUCTION

About 2,800 ton carbon per hectare was stored in Indonesian peatland forest. Ironically, the Indonesian peatland is degraded due to deforestation and water drainage for agriculture and pulp plantation. Current data on total Indonesian peatland area (22 million ha), about 60% were deforested and drained, 5% were cultivated, while about 35% were mixed of small scale farm and destructed peatland (Hooijer *et al.* 2006). It is estimated that greenhouse gasses particularly increased of CO<sub>2</sub> concentration in the atmosphere causes rising mean global surface air temperature for about 0.2°C per decade (IPCC, 2007). The root of peatland fire generally was attributed to land clearing, cigar and matches ignition, neighboring land fire and fire from fish catchment (Rianawati, 2005). This destruction led to organic material oxidation and huge amount of greenhouse gases emission. Peat fire usually occur in smouldering combustion due peat structure have been changed by drained of soil moisture due to afforestation. The smoldering peat fires are characterized by flameless combustion with low temperature combustion (Rein *et al.* 2008). For Indonesian peat, the chemical structure of peat is governed by mineral content, depth, plant composition, mineral type in substratum in peat base and peat decomposition. Physically, peatland has high moisture content, low bulk density, low bearing capacity that land subsidence can easily take place and irreversible. Peatland moisture content is 100 – 1.300% from its dry weight (Mutalib *et al.* 1991). Based on depth, peat material has different peat enrichment i.e different clay mineral, sand and granite composition (Limin *et al.* 2000). Peatland fires occur not only on the peat surface, in its sub surface the fire take place on persistence long-term

duration therefore it needs highly effort for extinguishing it. Limin *et al.*, 2003 stated that the burnt peat on average 22.03 cm depth (0 – 42.3 cm), however on special spot the depth of peat burning can reach 100 cm deep. Compare to other emitters, peatland fire contribute the highest of greenhouse gases. During 1997 – 1998 (when El Nino phase occurred), high level of air pollution episode occurred. According to WWF research about 10 million hectares of peatland were burnt releasing greenhouse gases about 810-2.563 Megaton carbon (C) to the atmosphere (Page *et al.* 2002). About 4 million sq km surrounding of fire was affected by haze resulting adversely health effect in Southeast Asia. In this period, daily average particulate matter concentration showed very high until 4000 mg/m<sup>3</sup> (Heil *et al.* 1998). Nonetheless, it seems the periodical peatland fire was not governed by ENSO period, even in non-ENSO period the wildfire still take place in this area (Tacconi, 2003). Probably the prescribed burning for land clearing contribute much to the peatland wildfire.

## METHODOLOGY

In this research we have three measurement settings. For knowing PM<sub>10</sub> pattern during episodic and non episodic peatland wildfires we used three fix monitoring stations operated by local Environmental Protection Agency (BLH) in Siak district. These stations work automatically, so we can retrieve the data after logging to the devices. In this case, the measurement results of February – May 2014 in Siak area were collected. For characterizing episodic wildfire we measured manually in the field on June 2012. In this episodic peatland wildfire, uncontrolled burning occurred continuously. The measurement for episodic peatland fire



was fully depicted in Fujii et.al (2014). The data from this paper are compared with measurement in non episodic peatland wildfire in June 2014. Thus in the subsequent analysis we get the feature of episodic and non episodic peatland wildfire. In this non episodic peatland wildfire, the measurement of  $PM_{2.5}$  were carried out using 2 sets of  $PM_{2.5}$  samplers (ChemComb Thermo denuder model 3500, Thermo). This sampler uses Leland Legacy® sample pump at constant flowrate of 9L/m. The flowrates were calibrated pre and post-sampling against DryCal primary flow meter (Bios International, USA).  $PM_{2.5}$  samples were collected on teflon filter dia.39 mm, while for carbonaceous component analysis we used pre-fired in 600°C (4h) quartz filters (Pallflex) with diameter 39 mm. To eliminate the static charge accumulated in the filters, the filters were treated with zerostat. At least 5 weighing were employed to each teflon filter to get weight consistency using  $\pm 1 \mu\text{g}$  accuracy balance (Sartorius, ME 5-F) in a conditioned room (30 – 40%). While the quartz filter, we sent it for carbon analysis. To account the uncertainties for handling filters during measurements, field blanks also were provided for each sample

Figure-1 shows the location of measurement of episodic burning as wells as non-episodic burning.



**Figure-1.** Location of measurement.

EC and OC concentrations were determined using a thermal/optical carbon analyzer (DRI Model 2001) with IMPROVE-A protocol. In this method, organic carbon fraction evolves from the filter punch in a He-only (>99.999%) atmosphere at 140, 280, 480 and 580°C plus pyrolyzed organic carbon. While elemental carbon fraction will evolve from the filter punch in a 98% He/2%  $O_2$  atmosphere at 580, 740, and 840°C minus any pyrolyzed OC. For determining total OC, we have to get OC1 (evolved from ambient ( $\sim 25^\circ\text{C}$ ) to 140°C), OC2 (evolved

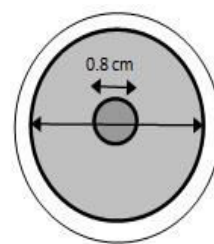
from 140 to 280°C), OC3 (evolved from 280 to 480°C), OC4 (evolved from 480 to 580°C) and OP (evolved from the time that the carrier gas flow is changed from 580 °C to the time that the laser-measured filter reflectance (OPR) reaches its initial value. While by definition, EC1 evolved from the atmosphere at 580°C, EC2 evolved from 580 to 740°C and EC3 evolved from 740 to 840°C.

We then sum up them and the following formula holds :

$$\text{OC} : \text{OC1} + \text{OC2} + \text{OC3} + \text{OC4} + \text{OP}$$

$$\text{EC} : \text{EC1} + \text{EC2} + \text{EC3} - \text{OP}$$

A punch of collected filter ( $0.503 \text{ cm}^2$ ) was used as a proxy of a whole filter area. To reach total content of OC/EC ( $\mu\text{g}$ ) in the filter, the following calculation was made :



$$\text{Mass collected in the filter : } M(\mu\text{g}) = \text{OC/EC} (\mu\text{g}/\text{cm}^2) \times 11.946 \text{ cm}^2$$

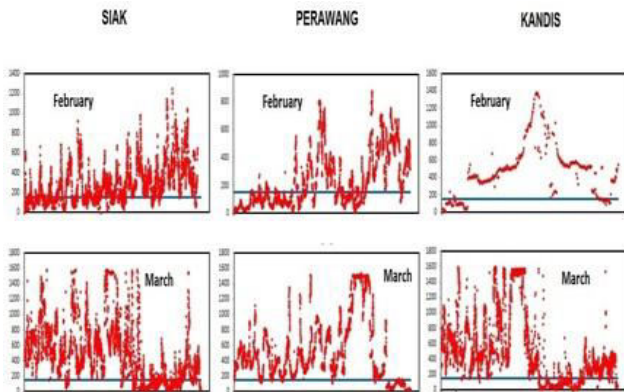
Note: 11.946 is the deposited particle area in 39 mm filter  
The calculated mass was then divided by suction air volume (standardized) to get mass concentration

**Figure 2.** Schematic view of filters with deposition area and punch area.

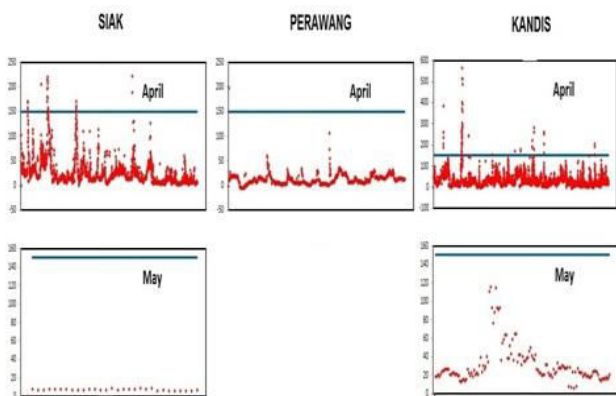
## RESULTS AND DISCUSSION

As shown in Figure-3, the pattern of  $PM_{10}$  during episodic peatland wildfire the  $PM_{10}$  concentration (in 5 minutes increments), in three sites, can reach more than 1500  $\mu\text{g}/\text{m}^3$  or ten times of  $PM_{10}$  standard of 24 h (the blue line). This is extremely high and may pose health risk since this high concentration may persist during one month or more. In this episodic period there was no rain at all, with wind speed average around 1 m/s and ambient temperature average around 29°C.

In contrast to episodic peatland wildfire (Figure-4), during non episodic wildfire and its transition showed moderate fluctuation of  $PM_{10}$  concentration i.e in several occasion the ambient  $PM_{10}$  were elevated very high as those in intensive episodic period. In the non episodic period somehow the average ambient  $PM_{10}$  concentration may fall below the  $PM_{10}$  standard. Based on this result, as long as the peatland fire is controlled, even sporadically occur widespread, then its ambient  $PM_{10}$  concentration may meet the ambient  $PM_{10}$  standard. Forbidding of prescribed burning, practicing emergency response of occurring fire for firefighters in the field may prevent uncontrolled peatland fire. Yet, the Indonesian peatland, within the recent decades, has switched from carbon sink to a significant carbon source that contributes to currently rising atmospheric  $CO_2$  concentrations (Dommain *et al.* 2014).



**Figure-3.** Pattern of PM<sub>10</sub> concentration during Episodic Wildfire.



**Figure-4.** Pattern of PM<sub>10</sub> concentration during Non-Episodic Wildfire.

Identification of organic carbon (OC) as well as elemental carbon (EC) may assist for source identification.

The PM<sub>2.5</sub> from biomass burning usually dominated by organic matter about 40 – 60% as a sources of OC and EC (Rastogi *et al.* 2014). Based on Figure-5, we can conclude that during episodic burning, fraction of OC1 and OC2 dominate in total OC, while during non episodic burning period the OC3, OC2 and OC4 dominate the fraction. High level fraction of OC1 in episodic burning period may indicate source of biomass burning. While elevated OC2 and OC3 is designated to cooking emission (Chow, *et al.* 2004). This indicates that if non episodic peatland fire occur than the carbonaceous component in the ambient air are enriched by carbonaceous component originated from cooking fire. Furthermore ratio of OC/EC from biomass burning were higher during nighttime than daytime (Higher fraction of EC1 and EC2 in PM<sub>2.5</sub> during non episodic burning indicate source high temperature burning. In this case from motor vehicle burning. Based on carbon elemental analysis i.e based on formula by Han *et al.* (2008) :

$$\begin{aligned} [\text{char-EC}] &= [\text{EC1}] - [\text{OP}] \\ [\text{soot-EC}] &= [\text{EC2}] + [\text{EC3}] \\ [\text{EC ratio}] &= [\text{char-EC}] / [\text{soot-EC}] \end{aligned}$$

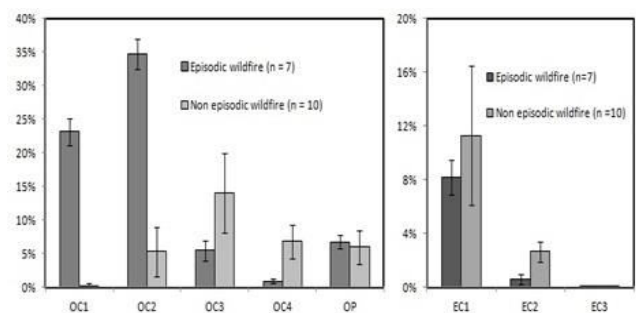
Then we get the Table-1 as below :

**Table-1.** Comparison of [EC ratio] from episodic and non episodic peatland wildfire.

Sample	[char-EC] (µg/m <sup>3</sup> )	[soot-EC] (µg/m <sup>3</sup> )	EC Ratio
Episodic burning*	94.77±44.5	38.12±20.3	3.75±3.81
Non-episodic burning	1.91±1.1	0.96±0.26	1.91±0.75

\*Data were recalculated from Fujii *et al.* 2014

Since low temperature burning exhibit char-EC than soot-EC then during episodic burning the ratio of [EC ratio] was higher than that in non-episodic burning. This EC fraction phenomenon is in agreement with that in OC fraction that during biomass burning event the ambient atmosphere are rich with low temperature level of burning carbonaceous fraction i.e OC1 and EC1. The characteristics is important to differentiate ambient atmospheric chemistry between intensive burning and non intensive burning particularly in peatland area. As the government concern about this fire that majority (85-90%) of the estimated total forest fire emission was associated with secondary forest and peatland swamp forest fires (Permadi and Oanh, 2013). High percentage of OC1 indicates smoldering burning in the peatland area. Hamada *et.al* (2013) also showed dominant smoldering combustion in Indonesian peatland fire by assessing ratio of ER<sub>CO/CO2</sub>.



Episodic data were adopted from Fujii *et al.*, 2014

**Figure 5.** Average percentage proportion of carbonaceous components to PM<sub>2.5</sub>.

## CONCLUSIONS

The pattern of PM<sub>10</sub> during episodic peatland wildfire the PM<sub>10</sub> concentration (in 5 minutes increments) can reach more than 1500 ug/m<sup>3</sup> or ten times of PM<sub>10</sub> standard (24 h). This is may pose health risk since this high concentration may persist during one month or more. In contrast to episodic peatland wildfire, during non episodic wildfire and its transition showed moderate fluctuation of PM<sub>10</sub> concentration. In the non episodic period, the average ambient PM<sub>10</sub> concentration may fall below the PM<sub>10</sub> standard. During episodic burning period,



the ambient atmosphere are enriched by OC1 and OC2 fraction, while in non episodic burning, fraction of OC2, OC3 as well as OC4 shows higher level than OC1. Based on EC ratio analysis the char-EC in biomass burning shows higher than soot-EC leading to dominant fraction of low temperature elemental carbon originated from biomass burning.

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