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Emissions of polychlorinated-*p*-dibenzo dioxin, dibenzofurans (PCDD/Fs) and polybrominated diphenyl ethers (PBDEs) from rice straw biomass burning

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HIGHLIGHTS

- PCDD/Fs and PBDEs concentrations were measured during rice straw burning.
- Downwind concentrations were elevated by 20 and 6 times.
- Emission factors determined using two independent methods agree well.
- The emissions of PBDEs from the biomass burning may be important.

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ABSTRACT

Biomass burning in Asia has been widely studied owing to its adverse effects on visibility, human health, and global climate. However the impact of rice straw burning on polychlorinated dibenzo-*p*-dioxin and dibenzofurans (PCDD/Fs) and polybrominated diphenyl ethers (PBDEs) concentrations is not known. In this study concentrations of these pollutants were measured at a farm site and two nearby sites during rice straw (open) burning and non-burning periods. During non-burning periods atmospheric PCDD/F and PBDE concentrations ranged from 0.0263 to 0.0329 pg I-TEQ/Nm^3 and 43.5 to 58.3 pg/Nm^3 respectively, and were similar at all of the sites. During rice straw burning periods PCDD/F and PBDE concentrations measured near the combustion (farm) site increased dramatically by six to twenty times. The strong correlation between the natural logarithm of PBDE and PCDD/F concentrations ($r = 0.949$, $p < 0.01$) at each site indicates that the elevated PCDD/Fs and PBDEs were due to emissions from the rice straw burning. The calculated emission factors, determined using the burned carbon method and the Industrial Source Complex Short-Term Dispersion Model (ISCST3), ranged from 12.6 to 14.5 ng TEQ/kg C_{burned} and 11.7 to 14.5 μg/kg C_{burned}, for PCDD/Fs and PBDEs respectively. The PBDE emission factors were at least 38 times higher than those of PCDD/Fs, revealing that rice straw burning is an important PBDE emission source.

1. Introduction

Biomass (open) burning is a rapid method used to remove post-harvest agricultural wastes, control weeds, and release nutrients for the next crop planting. Open waste burning has been prohibited in Taiwan since 1990 because of the negative impact of pollutant emissions from this poorly controlled combustion source. However,

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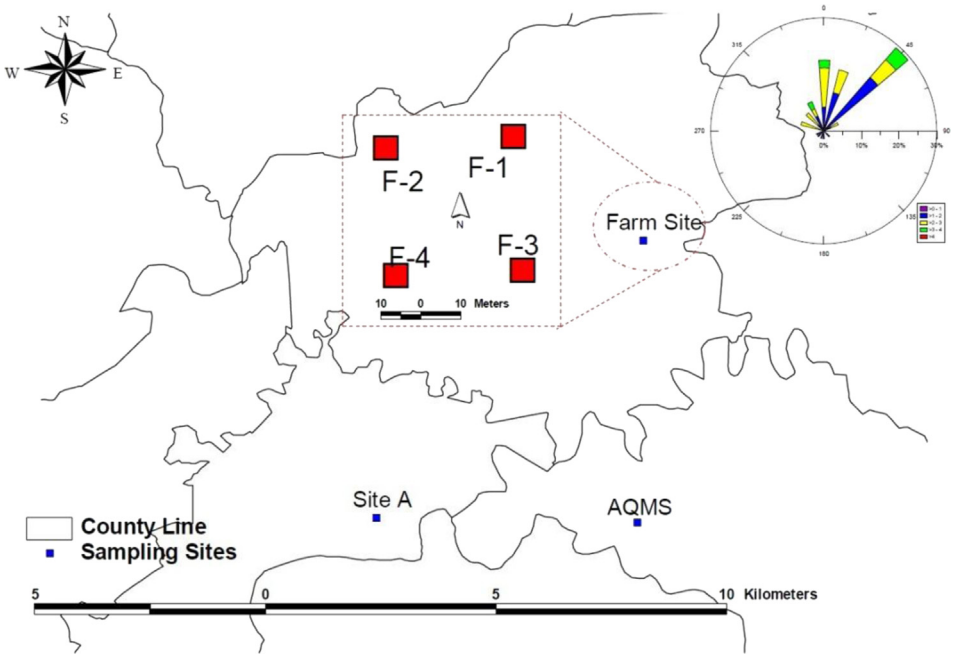

Fig. 1. Wind direction for rice straw burning period and location of the sampling sites.

this regulation is poorly enforced and open crop burning it is still commonly used to quickly remove agricultural wastes.

Air pollutant emissions from poorly controlled open burning of agricultural waste are generally greater than those from well controlled combustion sources (Lin et al., 2007; Shih et al., 2008). These emissions are not evenly distributed throughout the year and typically occur after harvest and during the dry season. Biomass burning has been found to release significant amount of incomplete combustion products such as polycyclic aromatic hydrocarbons (PAHs) and polychlorinated dibenzo-*p*-dioxins and dibenzofurans (PCDD/Fs) (Chang et al., 2013; Hays et al., 2005; Shih et al., 2008; Yang et al., 2006). Moreover, polybrominated diphenyl ethers (PBDEs), which have been found in tree bark (Salamova and Hites, 2013), might be remobilized to the atmosphere via biomass burnings.

PCDD/Fs and PBDEs can cause liver toxicity, developmental neurotoxicity, and may be related to the onset of diabetes (Arisawa et al., 2005; Wang et al., 2011). Combustion processes are the primary sources of PCDD/Fs which formed via de novo synthesis and/or the thermolysis of precursor compounds with metallic catalysts (Wang et al., 2003a, 2003b). PCDD/Fs have been found in stack flue gases of waste incinerators, metallurgical processes, and vehicles (Chang et al., 2014; Olie et al., 1977; Wang et al., 2010b).

Concerns about PBDEs from combustion sources have increased since they were recently found in the stack flue gases (Batterman et al., 2009; Wang et al., 2010a, 2010b, 2010c). They were found to be formed in combustion sources such as power plants and vehicles where the feedstock or fuel contains bromine (Chang et al., 2014; Wang et al., 2010b). Batterman et al. (2009) found that US combustion sources (1260 kg/year) contribute more PBDEs to the atmosphere than emissions from materials found in houses and garages (722 kg/year). Others (Chang et al., 2014; Wang et al., 2010b) reported that PBDEs have similar emission sources with PCDD/Fs and might be synthesized from the bromine content in the feedstock based on the highly correlated concentrations between PBDEs and combustion-originated PCDD/Fs.

To date there are no published results on PBDE emissions from agricultural biomass (open) burnings, although Gullett et al. (2010)

Fig. 2. Photos of (a) air sampling and (b) rice straw burning plume.