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Biomass burning in Indo-China peninsula and its impacts on regional air quality and global climate change-a review

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ABSTRACT

Although, many biomass burning (BB) emissions products (particulate matter and trace gases) are believed to be trans-boundary pollutants that originates from India and China (the two most populous countries in Asia), the information about BB emission and related contents is limited for Indo-China Peninsula (ICP) region. This motivated us to review this region pertaining to BB emission. The main objective of the review is to document the current status of BB emission in ICP region. In order to highlight the impact of BB on regional air quality and global climate change, the role of BB emission in ICP region is also discussed. Based on the available literature and modeling simulations studies, it is evidenced that ICP is one of the hotspot regional source for aerosols in terms of BB emissions. In addition, regional emissions through BB have significant implications for regional air quality especially in the neighboring countries such as China, Taiwan and India. Our assessment highlight that there is still a general lack of reliable data and research studies addressing BB related issues in context of environmental and human health. There is therefore a critical need to improve the current knowledge base, which should build upon the research experience and further research into these issues is considered vital to help inform future policies/control strategies.

1. Introduction

Biomass Burning (BB) refers to the burning of living and dead vegetation, including grassland, forests, and agricultural lands after harvesting and subsequently for land clearing and land use change (Levine, 1991). BB also includes fuel wood burning (such as charcoal, chips, pellets and sawdust) for cooking and/or heating (Roden et al., 2006). It is not restricted to one geographical region, but is rather a truly global phenomenon (Bond et al., 2004; Yang et al., 2008; Ding et al., 2013; Jain et al., 2014; Zhu et al., 2015). BB is an important global source of gaseous and particulate emission to the atmosphere, thereby contributing as much as 48% CO_2 emission and 38% of tropospheric O_3 which is more common in tropical and subtropical regions (Vermote et al., 2009; Chang and Song, 2010; Costa et al., 2012; Lin et al., 2013). Greenhouse gases (GHG) such as CO_2, CH_4 and N_2O emission from BB leads to global warming by inhibiting heat loss from surface. They have also a profound effect on the oxidizing capacity of troposphere leading to the photochemical production of O_3, while methyl chloride (CH_3Cl) is the source of chlorine to the atmosphere, and has significant impact on stratospheric O_3 depletion (Levine, 1985).

Also, bromine compounds especially methyl bromide is emitted to the atmosphere when biomass is burnt (Mano and Andreae, 1994; WMO, 2003; Gebhardt et al., 2008). Methyl bromide plays an important role as a catalyst in chemical destruction of stratospheric O_3. It is about 40 times more efficient in destroying O_3 than chlorine. Particulate produced by BB perturb the transfer of incoming solar radiation through troposphere, thereby influencing climate (IPCC, 2007). Besides their direct effects on the atmospheric composition and chemistry, BB may also perturbs the components and process (biogeochemical cycling of nitrogen and carbon,

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hydrological cycle, climate and biological diversity) of the earth's system. Hence, BB is an important driver for global climate change (Levine et al., 1995; Daniau et al., 2012).

Over the past 100 years, various anthropogenic activities significantly enlarged the amount of BB emission in atmosphere and are attributing more frequently and extensively in recent days than it was thought previously (IPCC, 2007). Annually, about 8700 Tg of dry matter are burnt worldwide (van der Werf et al., 2010; Giglio et al., 2013). Majority of the burned biomass matter come from Savannas (Africa) and is now recognized as burnt center on the planet. Every year, the burning of the tropical savannas may destroy dry matter three times more than the burning of tropical forests (Hao et al., 1990; Andreae, 1991). Savannah fires are the largest source of BB emission worldwide, accounting for an average 43% of total global emissions (Sinha et al., 2003; van der Werf et al., 2010). Agricultural fire and forest fire contribute 23% and 18% of the total BB emission worldwide, respectively (Fig. 1 and Table S1). Most often BB is the most easiest and inexpensive method for eliminating or reducing of combustible materials (eg. stalks, grasses, leaves and husks) of agricultural activities and is widely practiced in many countries.

Natural fire of Savannas and forest fire induced mainly by lightning and accounts only small fraction of total world burning, while in majority of cases (>90%), BB is human initiated (Andreae and Merlet, 2001: van der Werf et al., 2006). Subsequently, combustion of biomass releases gases and particulates into the atmosphere (Levine et al., 1995). The burning of forest can destroy an important sink for atmospheric CO_2 (Levine et al., 1995). BB emission has both short and long term impact on the global budget of CO_2 in atmosphere (Levine et al., 1995). If the burnt ecosystem regrows, the amount of CO_2 gets removed from atmosphere ultimately through photosynthesis mechanism, which can assimilated later into new vegetative growth (Levine et al., 1995). However, if the burnt ecosystem is not regrown, the liberated CO_2 remain in atmosphere for long time, thereby affecting the global CO_2 budget (Levine et al., 1995). Due to long range atmospheric transport, these emissions may also impact the budget of organic trace gases in the tropical marine atmosphere (Swap et al., 1996; Szopa et al., 2007; Hu et al., 2013; Wai et al., 2014), as well as the remote troposphere (Pickering et al., 1996; Chatfield et al., 2002; Pak et al., 2003; Honrath et al., 2004). The formation of O_3 and other photochemical oxidants resulting from BB emission not only affect human health and regional environment in the vicinity of BB events but also significantly influence the region thousands of miles away from source through long range atmospheric transport mechanism (Jaffe et al., 2004).

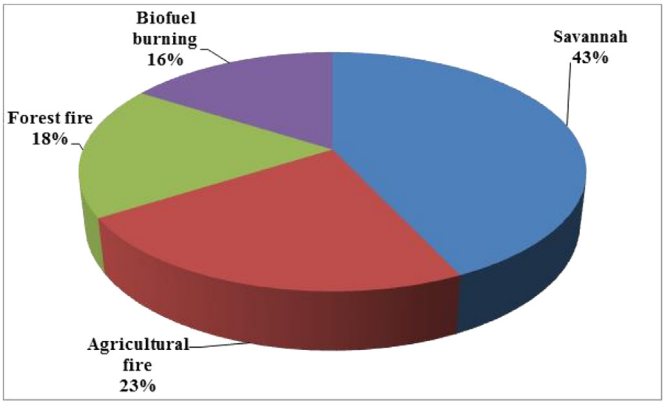

Fig. 1. Worldwide source categories of biomass burning.

BB has for some time been known to influence both human wellbeing and global climate (IPCC, 2007; Jacobson, 2014). The particulates emission from BB may affect global climate by inhibiting solar albedo from surface, while it can cause severe respiratory problems in human when inhaled (Smith et al., 2013). For example, CO when inhaled, it is capable of developing carboxy-hemoglobin after binding with blood hemoglobin and ultimately reduces the capacity of the red blood cells (RBCs) to absorb oxygen. It also result in disorientation or fatigue in the exposed population (WHO, 1999). Breathing high level of CO also creates acidity in the blood causing death of tissues and even cancer in later stage (Rozenberg, 2002).

BB derived PM has been known to affect human health and is interconnected with morbidity and mortality (Johnston et al., 2007, 2011, 2012a,b; Delfino et al., 2009; Hanninen et al., 2009; Morgan et al., 2010). Atmospheric PM causes cardiovascular and respiratory diseases in human (Pope and Dockery, 2006; Naeher et al., 2007; Sanhueza et al., 2009). Epidemiological and toxicological studies suggest that exposure to high concentration of ultrafine particles could adversely affect the cardiovascular system (Delfino et al., 2005). More than hundreds traces compounds of BB emissions have been known as toxic and carcinogens and are hazardous for human health.

Understanding the impact of fire emission on global climate is complex phenomenon and is especially true in case of BB emission, because of spatial and seasonal variation in intensity of fire (Gustafsson et al., 2009). Elevated levels of GHG could favor vegetation fire by creating conducive climatic conditions (Running, 2006), thereby further releases of carbon compounds. A positive feedback study related to release of GHG and climate derived using complicated model, indicated that the emissions of particulates primarily scatter solar radiation would enhances radiatively-forced climate (dimming) and cooling (Ramanathan et al., 2005). Increased concentration of both organic and black carbon aerosols in atmosphere would also result in negative radiative forcing (Forster et al., 2007; Menon et al., 2002). Burning emission can also affect the radiative balance of the atmosphere directly by scattering or absorbing solar radiation (Hobbs et al., 1997), and indirectly by acting as cloud condensation nuclei (CCN) (Reid et al., 2005) and ice nuclei (Petters et al., 2009).

Although most global fires are limited to Africa and South America, but evidence suggests that Indo-china peninsula (ICP; the continental portion of South East Asia which extend over 93°–109° E, and from 10° to 25° N comprising mainly of Myanmar, Thailand, Laos, Cambodia, and Vietnam) (Fig. 2) is one of the most active fire hotspot in the world and is matter of great concern because of high population densities near high fire zone (Lin et al., 2009; Johnston et al., 2012a,b; Chuang et al., 2013, 2014; Gautam et al., 2013; Shi et al., 2014). Also, it is an important source region for gaseous and particulate emissions (Streets et al., 2003a). Evidence suggests that the trace gases, non-methane hydrocarbons, and aerosols emitted from these regions not only boost the regional contamination levels (Wang et al., 2003; Chan et al., 2006; Tang et al., 2007), but also could reach up to troposphere, and transported through the western Pacific and ultimately to North America via Pacific Ocean (de Gouw et al., 2004; Lin et al., 2009; Sahu and Sheel, 2014).

Although, many BB emissions products (particulate matter and trace gases) are believed to be trans-boundary pollutants that originates from India and China (Ramanathan et al., 2005; Deng et al., 2008; Lin et al., 2010; Ghude et al., 2013; Jena et al., 2015), the information about BB emission and related contents is limited for ICP region. Hence, the present review highlights the current status of BB emission in the ICP region together with the role of BB emission influencing regional air quality and global climate change.