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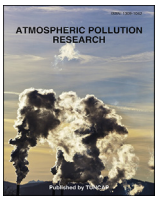

Assessment of national emissions of air pollutants and climate forcers from thermal power plants and industrial activities in Vietnam

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ABSTRACT

This study developed a comprehensive emission inventory (EI) for thermal power plants (TPPs) and industrial activities in Vietnam for 2010. A combined top-down and bottom-up EI was conducted using fossil fuel consumption data of TPPs and industrial activities collected at the provincial level. Emission factors (EFs) were selected from literature considering the relevancy to the country emission sources. The best emission estimates, collectively from TPPs and industry activities, in Gg, was: 361 CO, 320 NO_x, 529 SO_2, 52 NMVOC, 13 NH_3, 266 PM_{10}, 79 $PM_{2.5}$, 2.6 BC, 4.7 OC and 105,856 CO_2, which were mainly contributed by the industrial activities. The range between low and high emission estimates were determined for each species and the largest ranges were found for BC and SO_2. Spatial emission distributions showed higher intensities over major economic zones of the country. The lowest monthly emissions were seen in February coinciding with the Lunar New Year holiday which were followed by the peaks in March when the economic activities resumed. The net GWP of the emissions in 20-yr CO_2 equivalent was 59.7 Tg with CO_2 emissions having the largest share (87%) followed by BC (6%), whereas sulfates were the main cooling agent. Fuel switching to natural gas would significantly reduce emissions from TPPs while better combustion and emission control technologies applied in small and medium industries would reduce emissions of PM species including BC. The emission database developed in this study can be used in dispersion modeling for air quality management studies in Vietnam.

1. Introduction

High levels of air pollution observed in many places in Vietnam have raised a serious public concern due to the potential adverse effects on human health and crops (Mehta et al., 2013; Van et al., 2009; Hai and Kim Oanh, 2013; Danh et al., 2016). Similar to other developing countries in the region, rapid industrialization and urbanization in Vietnam have caused the environment deterioration. The high rates of fuel consumption, fossil and non-fossil, in Vietnam for transportation, cooking, energy production, industry and other activities, release large emissions of toxic air pollutants and greenhouse gases (GHGs) to the atmosphere (MONRE, 2009; MONRE, 2010; MONRE, 2013a). Fuel combustion in industrial installations with backward technologies would release more pollutants that are associated with incomplete combustion such as black carbon (BC), an important short-lived climate forcing pollutant (SLCP) (Bond et al., 2013), and other toxic gases of carbon monoxide (CO), volatile organic compounds (VOCs) and semi-VOCs.

The rapid growth rate of the industrial sector in Vietnam is associated with its increased energy consumption, e.g. in 2010 the industrial sector shared 53% of the national energy consumption, as reported by the Institute of Energy (IE, 2011). Consequently, this requires more electricity generation, mainly thermal power energy that leads to high emissions of air pollution and GHGs, both directly from the industrial processes and indirectly from the increased thermal power generation. As of 2010, there were totally 293 industrial zones (IZs) which were more concentrated in the South with 65% (50% in the Southeast and 15% in Mekong River Delta), as compared to 21% in the North and 14% in the central region of the

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country (Vietnam Industrial Park and Investment Information Consulting Portal, VIIPIP, 2010). In the Northern Vietnam, as compared to other provinces, Hanoi, Bac Ninh and Hai Duong had more IZs, i.e. 14, 15 and 9 zones, respectively. In the central region of Vietnam, most of industrial activities were located in Quang Nam, Binh Dinh, Quang Ngai and Da Nang, i.e. with 8, 7, 6 and 6 IZs, respectively. In the Southern Vietnam, the highest concentrations of the industrial activities were observed in Long An, Dong Nai, Binh Duong and Ba Ria–Vung Tau provinces with 34, 31, 28 and 13 IZs, respectively. Ho Chi Minh City alone had 19 IZs while Can Tho City was the hub of industrial development in the Mekong River Delta with 10 IZs.

The Government of Vietnam approved one master plan for the industry sector development (Decision 879/QĐ–TTg, 2014) with an expectation of an annual growth rate of 6.5–7.0% until 2020 and 7.0–8.5% afterward (2021–2035). Accordingly, the increase of GHGs emission from the industrial sector was projected to increase by 4–4.5%/yr. The coal-fired thermal power generation was estimated to contribute 46.8% of the total electricity production in 2020 (with 67.3 million metric tons of coal consumption) and 56.4% in 2030 (with 171 million tons of coal consumption) (Decision 1208/QĐ–TTg, 2011). Some preliminary emission estimates showed that in 2006 the thermal power plants (TPPs) contributed 19% of nitrogen oxides (NO_x) and 30% of sulfur dioxide (SO_2) emissions, whereas the industry, service and domestic sectors collectively accounted for 15% of CO, 50% of NO_x and 66% of SO_2 in the national total emissions, respectively (CAI–Asia, 2010).

The annual average levels of the total suspended particles (TSP) at monitoring sites in many IZs exceeded the National Ambient Air Quality Standard (NAAQS) of 100 μg/m^3 by 3–4 times. Normally, SO_2 and NO_2 levels in the surrounding areas of IZs were found lower than the NAAQS (both 24 h and annual average) (MONRE, 2013a). However, SO_2 levels measured at some big industrial facilities, such as the oil refinery factory (Dung Quat), large industrial plants with boilers or near TPPs, were reported exceeding the annual NAAQS of 50 μg/m^3 (MONRE, 2013a).

The current environmental management status of many IZs, especially related to air pollution, in Vietnam is still not yet fully characterized. The air quality management in areas surrounding IZs therefore has recently gained increasing attention from the governmental authority (VEA, 2015) hence several policies/decisions directly or indirectly addressing the air quality management topics have been introduced, such as the issuance of the revised ambient air quality standards (QCVN 05: 2013/BTNMT) (MONRE, 2013b), the climate change mitigation and adaption decision (Decision 9792/QĐ–BCT, 2014), the waste management decree (Decree 38/2015/NĐ–CP, 2015). Specifically for air pollution control purposes, Decision 22: 2009/BTNMT, 2009, has been issued to provide the national technical regulations on the emissions from the thermal power production. However, the implementation of the regulations was not progressing as required and the roles of related parties have not yet been clearly defined. According to MONRE (2013a), there are several existing issues of the environmental management for IZs in Vietnam, such as the lack of clear responsibilities assigned to the related management offices of the environmental protection agencies and IZ authorities at provincial level.

A comprehensive emission inventory (EI) database is required to clearly show the contributions of the industrial sources (power generation and manufacturing industries) to the national emissions so as the priority can be set for the emission control efforts. Emissions from the industrial sector in Vietnam have been reported in several regional or global EI databases, such as the Global Atmospheric Research (EDGAR) available for 2008–2010 (EC-JRC/PBL, 2013), the Center for Global and Regional Environmental Research (CGRER) available for 2000–2006 (Streets et al., 2003; Zhang et al., 2009) and the Regional Emission Inventory in Asia (REAS) available for 2000–2008 (Ohara et al., 2007; Kurokawa et al., 2013). The top-down approach was mainly applied in producing these regional and global EI databases. Improvement of the EI databases for a more recent base year and with the use of local activity data collected at the national level is always strongly desired for the air quality management purposes.

In Vietnam, there were several efforts, mainly through the academic research, to produce EI at urban scales, but not specifically for the industry sector, e.g. for Hanoi by An (2005) and for Ho Chi Minh City by Tuan (2003). The emissions in IZs in 2009 were also estimated by MONRE (2013a) for four key pollutants of NO_x, SO_2, non-methane VOC (NMVOC) and TSP. Therefore, in this study we aimed to develop a national EI of TPPs and industrial facilities for Vietnam for the base year of 2010. Multiple species were considered, including toxic gases of CO, SO_2, NO_x, ammonia (NH_3), NMVOC, and aerosol species of PM_{10} (particulate matter with aerodynamic diameters ≤10 μm), $PM_{2.5}$ (diameters ≤2.5 μm), BC and organic carbon (OC). Major GHGs of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) were also included in this EI work.

2. Methodology

This study considered emissions from the TPPs (fuel combustion only) and industry (fuel combustion, non-fuel combustion and manufacturing/process activities). The emission factors (EFs) used in this study were extracted from the compiled database presented in the Atmospheric Brown Cloud–Emission Inventory Manual (ABCEIM) by Shrestha et al. (2013). ABCEIM has included EFs from several databases including the AP-42 (USEPA, 1995), EMEP/CORINAIR (2006) and IPCC (1997), as well as available measurement data reported for various sources in Asia. For TPPs and the industrial fuel combustion, ABCEIM has extracted the relevant EFs from IPCC (1997, 2006), AP-42 (USEPA, 1995), Bond et al. (2004), Kato and Akimoto (1992), Battye et al. (1994), Hangebrauck et al. (1964) and APEG (1999), EMEP/CORINAIR (1992), Streets et al. (2001), Reddy and Venkataraman (2002), Ge et al. (2001), and Kupiainen and Klimont (2007). For industrial non-fuel combustion and process activities, beside the above mentioned data sources, ABCEIM also compiled the available EFs measured in Asia, e.g. brick kiln emissions in Vietnam measured by Le and Kim Oanh (2009). Our EI results were compared with those extracted for Vietnam from the available EI databases of EDGAR in 2008–2010, CGRER in 2006 and REAS 2.1 in 2008. The specific emissions from TPPs in Vietnam, in g/kWh, were also estimated and compared with the international emission norms.

2.1. Economic zones in Vietnam

Vietnam covers a total area of 331,690 km^2 (http://www.chinhphu.vn/portal/) and had a population of about 90.7 million in 2014, with 67% living in rural areas (General Statistics Office of Vietnam, GSO, 2014). Vietnam has 58 provinces and 5 large cities that are considered equivalent to provinces (Hanoi, Hai Phong, Da Nang, Ho Chi Minh and Can Tho). There are 8 major geographical regions and 3 key economic zones in the country (detailed in Fig. S1, Supporting Material (SM)). The northern key economic zone includes Hanoi and Hai Phong cities, and 5 provinces of Quang Ninh, Hai Duong, Bac Ninh, Hung Yen and Vinh Phuc. The central Vietnam key economic zone includes Da Nang city and 4 provinces of Thua Thien Hue, Quang Nam, Quang Ngai and Binh Dinh. The southern key economic zone includes Ho Chi Minh City and 7 provinces of Dong Nai, Binh Duong, Ba Ria–Vung Tau, Binh Phuoc, Tay Ninh, Long An and Tien Giang.

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