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Allowance and allocation of industrial volatile organic compounds emission in China for year 2020 and 2030

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ABSTRACT

As an effective pollution control method, emission allowance and allocation just implemented in volatile organic compounds (VOCs) control strategy of China in 2016. This article presents a possible way to set the emission allowance targets and establishes an allowance allocation model for the object year, 2020 and 2030, using 2010 as the reference year. On the basis of regression and scenario analysis method, the emission allowance targets were designed, which were 17.902 Tg and 18.224 Tg for 2020 and 2030, with an increasing rate of 28.75% and 31.06% compared to 2010. From the perspective of industries, processes using VOC-containing products, like architectural decoration and machinery and equipment manufacturing, would continue to be the most significant industrial VOC emission sources in the future of China. Four allocation indicators were selected, which are per capita GDP of each province, per capita industrial VOC emission of each province, the economic contribution of industrial sector to regional economy of each province, and the emission intensity per land area of each province, respectively. Based on information entropy, the weights of the indicators were calculated and an emission allocation model was established, and the results showed that provinces like Shandong, Jiangsu, Guangdong, Zhejiang, Fujian, Liaoning, Henan and Hebei were calculated to obtain more emission allowance while burden more reduction responsibility. Meanwhile, provinces like Guangxi, Gansu, Yunnan, Beijing, Guizhou, Ningxia, Hainan, Qinghai and Xizang were on the contrary. This paper suggests governments to enhance or ease to industrial VOC reduction burden of each province in order to stimulate its economy or change its way of economy development.

Introduction

The rapid growth of China's economy has not only improved people's living standards but at the same time resulted in serious environment deterioration. In recent years, the organic aerosol concentrations and ground-level ozone concentrations are observed to be obviously elevated in key regions of China (Shao et al., 2009; Wang et al., 2014; Zheng et al., 2010; Pusheng et al., 2013; Sillman, 1999; Sun et al., 2013). Volatile organic compounds (VOCs) are identified to be one of the most important precursors

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for organic aerosols and photochemical oxidants (Atkinson, 2000; Bowman et al., 1995; Shao et al., 2009; Zhao et al., 2013). Meanwhile, researchers have proved that industrial activity is a significant source of VOCs in urban environment (Wei et al., 2008; Wei, 2009; Qiu et al., 2014). Therefore, how to reduce the industrial VOC emission becomes a crucial challenge facing Chinese government.

From the perspective of Chinese VOC control and reduction planning, legislation, policy instruments and measures, only emission concentration is taken into account at first. As a pollution control policy that can reduce pollution effectively, emission allowance and allocation just implemented in VOC control strategy in China in 2016 (Liu and Xie, 2007; Wang et al., 2010). As for national emission allowance, it is hard to set the targets based on environment capacity due to the vast territory and unbalance economic development situation of China. However, there are VOC control and reduction planning, legislation, policy instruments and measures which are about to implement in the future of China. Therefore, emission allowance can be set through emission prediction. Studies were carried out to project the VOC emission allowance for the year of 2015–2020 (Wei et al., 2011; Klimont et al., 2002; Ohara et al., 2007). But few study focused specially on the industrial VOC emission reduction. Moreover, these predictions were only updated to 2020. To meet the Chinese willing to improve the environmental air quality, a long term emission allowance planning needs to be put forward. Meanwhile, extensive studies on emission allocation have been carried out. Most of the studies are focused on the discussion of allocation method. Yi et al. (2011) developed a comprehensive index and constructed an intensity allocation method to allocate the carbon dioxide reduction target regionally, taking economic difference and reduction potential into consideration. Pan et al. (2013) assessed the effect of various initial emission allowance allocation methods of the Korean electricity market. Lin et al. (2011) compared four different allocation methods for sulfur dioxide allowance, based on an investigation of 14 power plants in Fujian province of China. Levihn (2014) provided guidelines for whether, how, and when different allocation methods should be used. Meanwhile, attentions were paid to the cost evaluation for emission allowance allocation (Fujiwara et al., 1986; Burn and Mcbean, 1985; Burn and Lence, 1992; Cui et al., 2014; Liu et al., 2012). In this work, an allocation method based on equity, development, industrial structure adjustment and environmental capacity was established to allocate the industrial VOC emission allowance in China for the period of 2020–2030, based on the emission inventory in 2010 (Qiu et al., 2014). The final outcome of this work is a detailed industrial VOC emission allowance of 31 provinces of China for 2020 and 2030, excluding Hong Kong, Macao and Taiwan.

1. Methodology

1.1. Emission allowance determination

An emission allowance is the allowed emission of the future. Based on industrial VOC emission inventory of 2010 (Qiu et al., 2014), 32 industries are included in this work, and the national emission allowance is the total of the future emissions of these industries. To calculate the future VOC emission of the 32 industries, the future activity data and emission factors of each industry were estimated by the economic model and literature survey. The emission allowance was calculated using the following equation:

$$E_y = \sum_m \sum_n A_{i,k,y} \times EF_{i,k,2010} \times f_i$$

where, i is the specific source, k is the specific raw material or product, m is the number of emission sources, n is the number of raw material or product, and y is the year, E_y is the VOC emission in the year y, A is the activity data (e.g. consumption of raw material, industrial production), $EF_{i,k,2010}$ is the basic emission factor in 2010, and f_i represents the reduction rate of source i.

1.1.1. Prediction of future activity data ($A_{i,k,y}$)

The activity data forecast is based on the GDP, population and urbanization level projection, of which GDP is the first priority. After reviewing a large number of long-term economic development studies carried out by the authoritative experts (Amann et al., 2008; Chen, 2011; ERI, 2003; Guo and Zhao, 2010; Jiang and Hu, 2006; Jiang et al., 2009; Xue et al., 2011; Zhang, 2011), we decided to derive the data from the results published by Chinese National Development and Reform Commission Energy Research Institute which were believed to be more complied with Chinese development planning. The population growth rate is 5.88% for year 2011–2020 and 2.08% for year2021–2030. The GDP growth rate is 8.40% for year 2011–2015, 7.20% for year 2016–2020, 6.60% for year 2021–2025 and 5.80% for year 2026–2030. The urbanization level is predicted to be 53.58% for 2020 and 58.89% for 2030. Moreover, we collected the historical data of GDP, population, and urbanization level for the period of 1980–2010 by surveying a large number of literatures, and the relationship between the consumption of raw material or quantities of products in various industries and the aforementioned indicators was obtained by regression analysis, the related indicators and the multiple linear regression equations of each industry are summarized in Table S1 in the supplement. The prediction method and results of each industry are listed as Table 1. The particulars of the prediction calculation can be found in Table S2 in the supplement.

1.1.2. Determination of emission factors ($EF_{i,k,2010}$)

After surveying extensive inventories (Bo et al., 2008; Cao et al., 2011; Klimont et al., 2002; Liu et al., 2008; Ohara et al., 2007; Olivier et al., 1999; Piccot et al., 1992; Streets et al., 2003; Tonooka et al., 2001; Wei et al., 2008), the emission factors applied by Qiu et al. was considered to be the most accurate and comprehensive for industries. Therefore, the $EF_{i,k,2010}$ of this study was derived from it directly.

1.1.3. Determination of reduction rate (f_i)

China has concurrently suffered from the photochemical smog and haze pollution, which is mostly occurred in Beijing-Tianjin-Hebei Region, Pearl River Delta, Yangtze River Delta and some major city clusters. The air quality of 80% cities in China could not meet the Phase I requirements of World Health Organization (WHO), and the air pollutant

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