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Factors influencing polychlorinated dibenzo-*p*-dioxin and polychlorinated dibenzofuran (PCDD/F) emissions and control in major industrial sectors: Case evidence from Shandong Province, China

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ABSTRACT

Analyzing determinants that influence polychlorinated dibenzo-*p*-dioxin and polychlorinated dibenzofuran (PCDD/F) emissions is helpful for decision-makers to find effective and efficient ways to mitigate PCDD/F emissions. The PCDD/F emissions and the contributions of the scale effect, structure effect and technology effect to emissions from eight main industrial sectors in 2006, 2008 and 2010 in Shandong Province, were calculated in this article. Total PCDD/F emissions in Shandong increased by 52.8% in 2008 (614.1 g I-TEQ) and 49.7% in 2010 (601.8 g I-TEQ) based on 2006 (401.9 g I-TEQ). According to the decomposition method, the largest influencing factor on PCDD/F emission changes was the composition effect (contributed 43.4% in 2008 and 120.6% in 2010 based on 2006), which was also an emission-increasing factor. In this case, the present industrial restructuring policy should be adjusted to control the proportion of production capacities with high emission factors, such as iron ore sintering and steelmaking and the secondary non-ferrous metal sector. The scale effect increased the emissions in 2008 (contributed 21.9%) and decreased the emissions in 2010 (contributed –28.0%). However, as a source control measure, the excess capacity control policy indeed had a significant role in emission reduction. The main reason for the technology effect (contributed 34.7% in 2008 and 7.4% in 2010 based on 2006) having an emission-increasing role was the weakness in implementing policies for restricting industries with outdated facilities. Some specific suggestions were proposed on PCDD/F reduction for local administrators at the end.

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Introduction

Polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) are a group of related chlorinated organic compounds of unintentionally produced persistent organic pollutants (UP-POPs). Due to their persistent adverse effects on ecosystems and human health at trace levels, many countries have made efforts to reduce PCDD/F emissions, such as the application of best available techniques (BAT) and best environmental practices (BEP) (UNEP, 2006). Industrial activities, including waste incineration and secondary non-ferrous metal production, are the main PCDD/F emission sources (UNEP, 2001). In China, a preliminary estimation of PCDD/F emissions revealed that three kinds of industrial sectors contributed about 81% to the total emissions: ferrous and non-ferrous metal production, heat and power generation, and waste incineration (NIP, 2007). The remarkable growth and high detection values in sensitive areas of PCDD/F emissions posed major challenges to policymakers in China (Gao et al., 2011; Li et al., 2009; Sun et al., 2006). Thus, the reduction of PCDD/Fs emissions is an extremely urgent environmental issue for China.

In this context, understanding the determinants that influence PCDD/F emissions is helpful for decision-makers to find effective and efficient ways to reduce or eliminate them. Many studies have been carried out to identify the factors influencing PCDD/F emissions, such as studies on PCDD/F emission character analysis (Antunes et al., 2012), on the PCDD/F formation mechanism in industrial production processes (Dickson et al., 1992), and on technology improvements in production and air pollution control equipment (Kulkarni et al., 2008). However, most of those studies are microscopic studies. Besides these technical factors and mechanisms, macro factors, such as industrial scale and structure, can also affect PCDD/F emissions by changing industrial production or emission factors. Although some macro-level research has already been carried out to understand PCDD/F emissions control, such as the effects of energy conservation policy (Geng et al., 2010), of human activities (e.g., population and GDP) (Ren and Zheng, 2009), and of national strategies (Cheng and Hu, 2010; Lu et al., 2007; Lu and Giesy, 2005; Shi et al., 2005; Zhang et al., 2005), there is still a lack of knowledge on, for instance, how (much) these macro factors contribute to emission change and which policy instruments at regional level are suitable to control emissions. This work aims to fill this knowledge gap and attempts to provide some macro-level PCDD/F emission reduction suggestions to regional policy-makers in China.

In this article, an approach to find out the key factors influencing the PCDD/F emissions was provided, the prior control sectors were analyzed, and the effective policy instruments in emission control at the regional level were identified. PCDD/F elimination is a long and tough task for the Chinese government, since the variances of industrial emission sources distributed in different regions. The approach presented here offers useful lessons to other regions to design specific measures for PCDD/F emissions control.

1. Method and data

1.1. Decomposition analysis method

The economic activity scale of PCDD/F emission of industry, the industrial structure, and the conditions of production and

pollution control technology can directly or indirectly affect PCDD/F emissions. In order to assess the relative magnitude of these influencing factors, a decomposition analysis method, as initially proposed by Grossman (Grossman, 1995; Grossman and Krueger, 1991), was adopted in this article. Grossman and Krueger (1991) first suggested the decomposition analysis method and apply it to environmental studies. They decomposed the change of pollutant emissions into three mechanisms: scale effect, composition effect, and technology effect. This method has become a widely accepted tool for decomposition studies on national energy and environmental issues (Ang, 2004), and has been frequently used to decompose the contributions of various determinants, such as production activity (i.e., scale effect), industrial structure changes (i.e., composition effect), and pollutant emission ratio reduction or energy intensity reduction (i.e., technology effect), in the emission change analyses of CO₂, SO₂ and other air pollutants (Ang, 1994; Ang and Choi, 1997; Ang and Pandiyan, 1997; De Freitas and Kaneko, 2011; Diakoulaki and Mandaraka, 2007; He, 2010; Selden et al., 1999; Stern, 2002).

Although PCDD/Fs are different from CO₂ and SO₂ in many properties, all the variables used in the decomposition analysis method have nothing to do with pollutants' properties. Only the macro activities of industrial sectors and the total pollutants' emissions are considered, including the total production, production share, and emission intensity of the sector. Meanwhile, all the transformations of equations below are a purely mathematical process, which is not related to the pollutants' properties either. Therefore, it is reasonable to apply the decomposition analysis method to analyze the PCDD/F emission changes.

Three emission determinants are contained in Eq. (1): scale, composition and technology effects (Grossman, 1995).

$$E_t = \sum_{j=1}^n Y_t I_{j,t} S_{j,t} \quad (1)$$

where, E_t stands for the total emissions in year t ; $j = 1, 2, \dots, n$ represents the different sectors; Y_t is the total production of selected sectors in year t , which is equivalent to the sum of production of all the n sectors ($Y_t = \sum Y_{j,t}$); $I_{j,t}$ is the emission intensity of sector j in year t , and $S_{j,t}$ is the production share of sector j in year t . Eq. (1) is an identity, because of $I_{j,t} = E_{j,t}/Y_{j,t}$ and $S_{j,t} = Y_{j,t}/Y_t$.

The scale factor (Y_t) is positively related to pollutant emissions. Grossman (1995) notes that, under the condition of "all else being equal", an increase in production results in an increase in pollutant emissions. The "all else being equal" condition could be violated by changes in the industrial structure and changes in technology (De Bruyn, 1997; Grossman, 1995).

The composition change ($S_{j,t}$) in economic activities influences the proportion of high emission intensity sectors, which can positively or negatively affect emissions. If high emission intensity sectors grow faster than low emission intensity sectors, structural change results in an increase in emissions. Meanwhile, total emissions will grow faster.

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