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Future trends of global atmospheric antimony emissions from anthropogenic activities until 2050

Junrui Zhou [a, b], Hezhong Tian [a, *], Chuanyong Zhu [a], Jiming Hao [c], Jiajia Gao [a], Yong Wang [a], Yifeng Xue [a, d], Shenbin Hua [a], Kun Wang [a]

[a] *State Key Joint Laboratory of Environmental Simulation & Pollution Control, School of Environment, Beijing Normal University, Beijing 100875, China*
[b] *Wuhan Environmental Protection Sciences Research Institute, Wuhan 430015, China*
[c] *State Environmental Protection Key Laboratory of Sources and Control of Air Pollution Complex, School of Environment, Tsinghua University, Beijing 100084, China*
[d] *National Engineering Research Center of Urban Environmental Pollution Control, Beijing Municipal Research Institute of Environmental Protection, Beijing 100037, China*

HIGHLIGHTS

- Global Sb emission until 2050 is projected with 3 scenarios based on 2013 EIA outlook.
- World countries are divided into 4 regions with similar technology development level.
- We use transformed normal distribution function to reflect emission factor variation.
- Future Sb emission will peak at 2020–2025 and then decline under 2 control scenarios.
- Control of Sb from MSW incineration and coal burning in top 10 countries is critical.

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ABSTRACT

This paper presents the scenario forecast of global atmospheric antimony (Sb) emissions from anthropogenic activities till 2050. The projection scenarios are built based on the comprehensive global antimony emission inventory for the period 1995–2010 which is reported in our previous study. Three scenarios are set up to investigate the future changes of global antimony emissions as well as their source and region contribution characteristics. Trends of activity levels specified as 5 primary source categories are projected by combining the historical trend extrapolation with EIA International energy outlook 2013, while the source-specific dynamic emission factors are determined by applying transformed normal distribution functions. If no major changes in the efficiency of emission control are introduced and keep current air quality legislations (Current Legislation scenario), global antimony emissions will increase by a factor of 2 between 2010 and 2050. The largest increase in Sb emissions is projected from Asia due to large volume of nonferrous metals production and waste incineration. In case of enforcing the pollutant emission standards (Strengthened Control scenario), global antimony emissions in 2050 will stabilize with that of 2010. Moreover, we can anticipate further declines in Sb emissions for all continents with the best emission control performances (Maximum Feasible Technological Reduction scenario). Future antimony emissions from the top 10 largest emitting countries have also been calculated and source category contributions of increasing emissions of these countries present significant diversity. Furthermore, global emission projections in 2050 are distributed within a $1^\circ \times 1^\circ$latitude/longitude grid. East Asia, Western Europe and North America present remarkable differences in emission intensity under the three scenarios, which implies that source-and-country specific control measures are necessary to be implemented for abating Sb emissions from varied continents and countries in the future.

* Corresponding author. School of Environment, Beijing Normal University, No. 19 Xinjiekouwai St., Beijing 100875, China.
E-mail address: hztian@bnu.edu.cn (H. Tian).

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1. Introduction

Antimony is a global hazardous air pollutant with an atmospheric residence time of 1–2 weeks, and it's observed obviously to enrich on the surface of fine particulate matters (Shotk et al., 2004; Gao et al., 2014). So far, antimony and its compounds have been listed into priority pollutants by the U.S. Environment Protection Agency (US EPA) (USEPA, 1979) and the European Union (EU) (Council of the European Communities, 1976). In previous study, we have established a comprehensive global antimony emission inventory for the period of 1995–2010 and investigated the temporal trend and spatial variation distribution characteristics (Tian et al., 2014). Nevertheless, with the rapid development of some emerging economies such as BRICS countries (Brazil, Russia, India, China and South Africa), the distribution pattern of world economy and energy consumption will experience a profound transition in the future, which will accordingly alter the global Sb emissions and its geographical distribution characteristics. Thus, it is of great necessity to investigate and assess the possible future emission trends as well as the variation of contribution from different source categories and countries, so that we can prepare and adopt possible adequate mitigation options in advance.

On the basis of global environmental conventions and protocols (the EU Long-range Trans-boundary Air Pollution (LRTAP) Convention Heavy Metals Protocol, Intergovernmental Panel on Climate Change (IPCC) Kyoto targets etc.), some international official organizations have developed predictions on international energy consumption and global environment changes like EIA international energy outlook, EU ESPREME projects, EU Drought-tolerant yielding Plants (DROPS) project and United Nations Environment Programme (UNEP) global environment outlook (EIA, 2013; EU-Project ESPREME website; EU DROPS project website; UNEP website). However, little information on future global antimony emissions prediction has been provided so far.

The purpose of this study is to establish a systematic way to assess the global anthropogenic antimony emissions in the future as a continuation of our previous work (Tian et al., 2014). The possible ranges of global antimony emissions up to the year 2050 as well as the characteristics of country and source contributions are forecasted under 3 different control scenarios.

2. Projection of activity levels

On a global scale, it is quite difficult and even impossible to obtain the detailed information for each country. In this study, by referring to the global Hg emissions study of Streets et al. (2004, 2011) and our previous study (Tian et al., 2014), we have divided the whole world into 4 different regions and assumed average activity level intensities and dynamic emission factors for countries in each region. It should be noted that this simple classification and average method will inevitably introduce some large uncertainties in the emission estimates, which may overestimate or underestimate the future emissions in some specific countries. However, these assumptions and the associated results are meaningful for source identification and pollution control on a global scale.

Anthropogenic atmospheric antimony emissions can be assessed by 5 primary source categories: fuel combustion (FC), nonferrous metals production (NMP), pig iron and steel production (PISP), waste incineration (WI), and vehicle brake wear (VBW). Considering the influence which brought from the difference and transition of industry technology development and pollution control levels among worldwide countries, global Sb emissions are calculated for 4 ascending world regions according to our previous study (see Table S1 in the separate Supplementary Information (SI) file) (Tian et al., 2014).

For all regions in the world included, available national perspectives on the sectoral economic and energy development up to the year 2040 are directly collected and compiled from EIA (U.S. Energy Information Administration) research report (EIA website). The reference case up to 2040 in international energy outlook 2013 is adopted and further projected to the end year 2050 by using trend extrapolation in this study. With regard to fuel combustion, projection of activity levels (electricity generation and coal consumption) for all countries has been involved. For the source category of nonferrous metals production, pig iron and steel production, brake wear and waste incineration, decomposition analysis specified with countries is employed to forecast the future trend of activity levels (see Eq. (1)).

$$M_{m,n,t} = I_{m,\,n,t} \times A_{m,\,n,t} \tag{1}$$

where $M_{m,\,n,\,t}$ is the projection of activity level in country m for emission source n in future year t, $I_{m,n,\,t}$ is the projection of indicator index in country m for emission source n in future calendar year t, and $A_{m,\,n,\,t}$ is the projection of activity level intensity in country m for emission source n in future year t.

Detailed decomposition parameters of various emission source categories are listed in Table 1 (Ang and Zhang, 2000; Schipper et al., 2001; Streets et al., 2004). Projections of indicator indexes are adopted directly from the reference case reported in international energy outlook 2013. Projections of activity level intensities are calculated according to their historical trends of various world regions (see Fig. 1). Regression curves are used to fit the historical data and estimate future scenarios by trend extrapolation method (UN data website, Tian et al., 2014).

Notably, vehicles per capita of countries in region 1 and 2 have stayed steadily to the approximate saturation since 2005, indicating these countries have entered into the post-industrialized development phases. Therefore, we assume that vehicles per capita in these regions in constant for the projected years. Similarly, municipal incineration per capita of some developed countries in region 1 (the United States, Japan, France and Spain) nearly reach saturation according to the historical trend and we presume that they will continue keeping this general trend in the future.

However, the waste in developing countries is always contain high organic fraction and moisture content, as well tends to be low in calorific, which makes incineration to be a poor option (Barton et al., 2008). Till now, incineration is not wide-spread in developing countries due to higher costs and unsuitable waste composition (Dedinec et al., 2015). The historical trend of waste incineration per capita served in region 4 present small values and poor degree of fitting. Nevertheless, under the global urbanization progress and land use pressure, promoting waste incineration is a corollary in developing countries in the future. Since 2001, incineration in region 3 (China) has witnessed a rapid development, and the incineration disposal rate has increased from 2% in 2001 to 18% in 2010 (OECD statistics, 2015). Here, we make the assumption that waste incineration per capita served in region 4 will follow the

Table 1
Decomposition parameters of emission source categories.

Emission source category	Indicator index	Activity level intensity
Nonferrous metals production	GDP	Nonferrous metals production/GDP
Pig iron and steel production	GDP	Pig iron and steel production/GDP
Brake wear	Population	Vehicles ownership/capita
Waste incineration	Population	Municipal waste incineration/capita served