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Refining mercury emission estimations to the atmosphere from iron and steel production

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Due to its long-range transport in the atmosphere, mercury is a pollutant of global concern with health risks to humans and ecosystems worldwide (Li et al., 2012; Lindqvist et al., 1991; Liu et al., 2012a; Tang et al., 2016; Wang et al., 2015; Shao et al., 2016). Atmospheric mercury, mainly from emission from various natural and anthropogenic sources and re-emission of previously released mercury built up in surface soils and oceans, may undergo long-range transport and enter into aquatic and terrestrial ecosystems through wet and dry deposition (Liang et al., 2014; Liu et al., 2012b; Quan et al., 2008). Atmospheric deposition has been confirmed to be the main source of inorganic mercury in open ocean systems, and anthropogenic mercury emissions have impacted ocean ecosystems at varying levels globally (Kang and Xie, 2011; Mason et al., 2012). Thus, a global mercury emission inventory is needed for quantitative assessment of its effect on ecosystems.

The United Nations Environment Programme (UNEP, 2013) estimated that global anthropogenic emission of mercury to the atmosphere in 2010 was 1960 tons (Fig. 1) or about 30% of total annual emission of mercury to air (including anthropogenic, natural, and re-emission), significantly higher than natural sources (600 tons or 10% of mercury emission to air). The major anthropogenic sources of mercury are artisanal and small-scale gold mining and coal combustion, accounting for about 35% and 25% of global anthropogenic emissions, respectively, followed by production of ferrous and non-ferrous metals and cement production (Kumari et al., 2015). Asia has been regarded as the world's largest emission source (Jiang et al., 2006; Kumari et al., 2015; UNEP, 2013), contributing 56% of the worldwide mercury emission (Pacyna et al., 2010). The majority of Asian emissions are from East and Southeast Asia, and China accounts for three-quarters of East and Southeast Asian emissions, or about one third of the global total (UNEP, 2013).

Large uncertainties remain in global estimates of mercury emissions to the atmosphere, *e.g.*, 1010–4070 tons for the global annual emission in 2010 according to UNEP estimation (UNEP, 2013). These uncertainties are mainly caused by assumptions and generalizations employed during estimation, due to, for instance, the lack of information on mercury contents of some raw materials and non-quantified potentially important emission sectors in the emission inventory (Liu et al., 2012b; UNEP, 2013). In some cases, emission factors from studies conducted in Europe and North America have been adopted for the global emission estimate, despite the fact that processes and pollution-control techniques used in developing countries (*e.g.*, China) may differ dramatically from those used in developed countries (Ancora et al., 2015; Jiang et al., 2006; Wang et al., 2011). More field studies are needed to determine mercury emission characteristics from different types of sources in order to more accurately estimate mercury emissions.

A recent study (Wang et al., 2016) indicated that a single emission factor of 0.04 g Hg/ton steel, which has long been used for estimating mercury emission from iron and steel production, could provide inaccurate information on mercury emission from this type of source (Pacyna et al., 2010; Pirrone et al., 2010; UNEP, 2013). The estimation using this single

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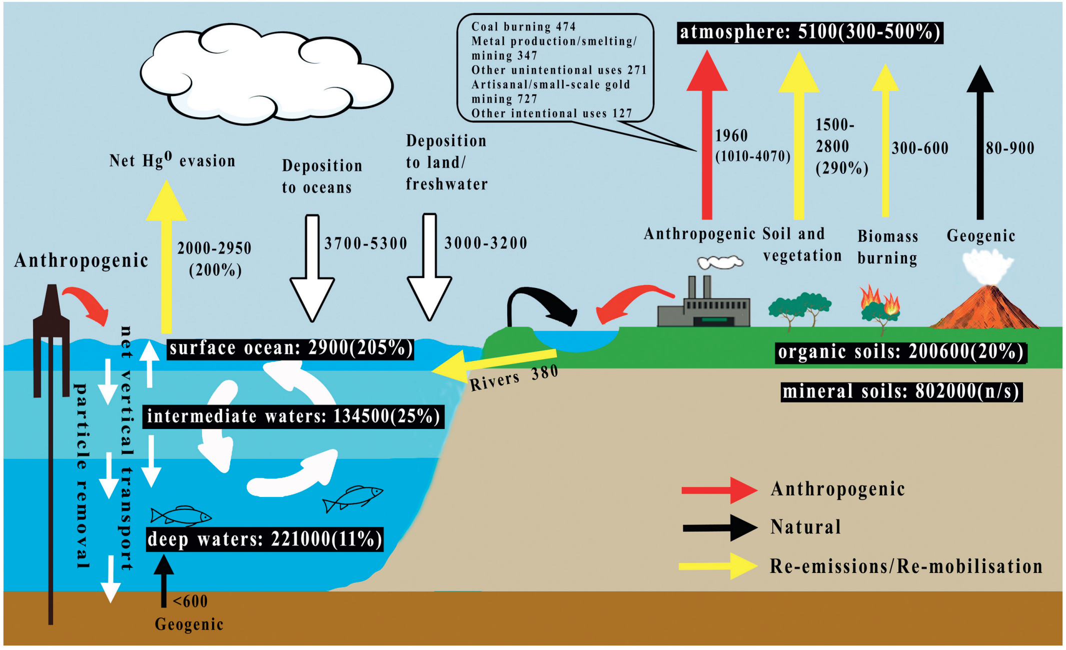

Fig. 1 – The global mercury budget, modified from Mason et al. (2012) with additional data from Selin et al. (2007), Holmes et al. (2010), Soerensen et al. (2010), and UNEP (2013). Total inventories (numbers in black boxes) are in tonnes, and fluxes (numbers accompanying arrows) in tonnes per year. The percentage values in brackets are the estimated increase in inventories in the past 100 years due to anthropogenic activities.

emission factor ignored the variations in the mercury contents of the raw materials and in the production processes. Thus, Wang et al. (2016) conducted field tests at two typical iron and steel plants in China, representing two different conventional steel production processes, to investigate mercury emission characteristics through a mercury mass balance method. The flue gases from all stacks, raw materials, products and by-products of different facilities were sampled and analyzed to understand the mercury mass flows in the iron and steel production process.

Wang et al. (2016) showed that the largest mercury emissions were from the sintering machine and coal gas burning, contributing 46%–50% and 17%–49% of the total mercury emissions from the iron and steel plants. The preparation of the raw materials (limestone and dolomite production) and the electric furnaces, not considered in previous estimations, could significantly influence the emission estimation. The mercury emission factor increased from 0.047 to 0.068 g Hg/ton crude steel when considering the emissions from the production of limestone and dolomite, suggesting that previous estimations using a factor of 0.04 g Hg/ton steel could underestimate mercury emission from this source (Pacyna et al., 2010; Pirrone et al., 2010; UNEP, 2013). The emission factor for the electric furnace, which is used during 10% of all the steel production in China (and 30% worldwide) (Lu and Zhang, 2012), was 0.021 g Hg/ton crude steel (Wang et al., 2016), suggesting that this process could not be ignored when estimating the mercury emission inventories, in particular in view of its increasing use in steel production. In addition, Wang et al. (2016) showed that low-sulfur fuel gas from the sintering machine could be a significant contributor of mercury emission (accounting for up to 40% of total mercury emission), and suggested that desulfurization devices should be installed in iron and steel plants to reduce mercury emissions.

The study conducted by Wang et al. (2016) provides a good example of the necessity of refining mercury emissions from different types of sources and further reducing uncertainties in global mercury emission estimation, through more detailed, in-depth field investigations into mercury emission characteristics in different regions. Through field studies of the emission characteristics of mercury in iron and steel plants, the research could be used for more accurate estimations of mercury emissions from iron and steel production. Similar work should be conducted toward different types of emission sources in different regions in the future to ensure the validity of generalizations and assumptions employed to estimate mercury emissions and to minimize the uncertainties associated with global mercury emission estimation.

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