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Characterizations of wet mercury deposition on a remote high-elevation site in the southeastern Tibetan Plateau

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ABSTRACT

Accurate measurements of wet mercury (Hg) deposition are critically important for the assessment of ecological responses to pollutant loading. The Hg in wet deposition was measured over a 3-year period in the southeastern Tibetan Plateau. The volume-weighted mean (VWM) total Hg (Hg_T) concentration was somewhat lower than those reported in other regions of the Tibetan Plateau, but the VWM methyl-Hg concentration and deposition flux were among the highest globally reported values. The VWM Hg_T concentration was higher in non-monsoon season than in monsoon season, and wet Hg_T deposition was dominated by the precipitation amount rather than the scavenging of atmospheric Hg by precipitation. The dominant Hg species in precipitation was mainly in the form of dissolved Hg, which indicates the pivotal role of reactive gaseous Hg within-cloud scavenging to wet Hg deposition. Moreover, an increasing trend in precipitation Hg concentrations was synchronous with the recent economic development in South Asia.

1. Introduction

The special characteristics of mercury (Hg), such as, its long-range atmospheric transport, its transformation between various species, biomagnification and its role as a neurotoxin, make it a pollutant of global concern. For terrestrial and aquatic ecosystems, the main source of inorganic Hg is from the atmosphere, especially in remote areas where there are almost no local sources (Hammerschmidt and Fitzgerald, 2006). Atmospherically deposited Hg may be more available for methylation than Hg already within a system, which can be rendered less available by complexation or sorption (Mason et al., 1999, 2000; Harris et al., 2007). Methyl Hg (MeHg) is the most toxic species of Hg and a neurotoxin; the methylation of inorganic Hg in the environment and its subsequent bioaccumulation through food webs are major environmental concerns (Larson, 2014).

Anthropogenic activities have drastically altered the biogeochemical cycles of Hg, e.g., tripling atmospheric Hg concentrations and deposition fluxes compared with those of the pre-industrial period (UNEP, 2003). Asia has been estimated to have the largest amount of anthropogenic emissions of Hg and has suffered from anthropogenic Hg pollution (Pacyna et al., 2006, 2010; Burger Chakraborty et al., 2013). The Tibetan Plateau, the highest and largest plateau located in the low and mid latitudes (Yao et al., 2012), has a very unique and fragile ecosystem. As one of the most ecologically vulnerable regions on the earth (Wang et al., 2008), the Tibetan Plateau is sensitive to atmospheric composition changes due to active atmospheric exchange created by monsoon circulation and westerlies (Fig. 1). Previous research has revealed long-range transport of Hg originating from South Asia via atmospheric circulation has led to a rapid increase in the accumulation of Hg in the aquatic ecosystems of the Tibetan Plateau

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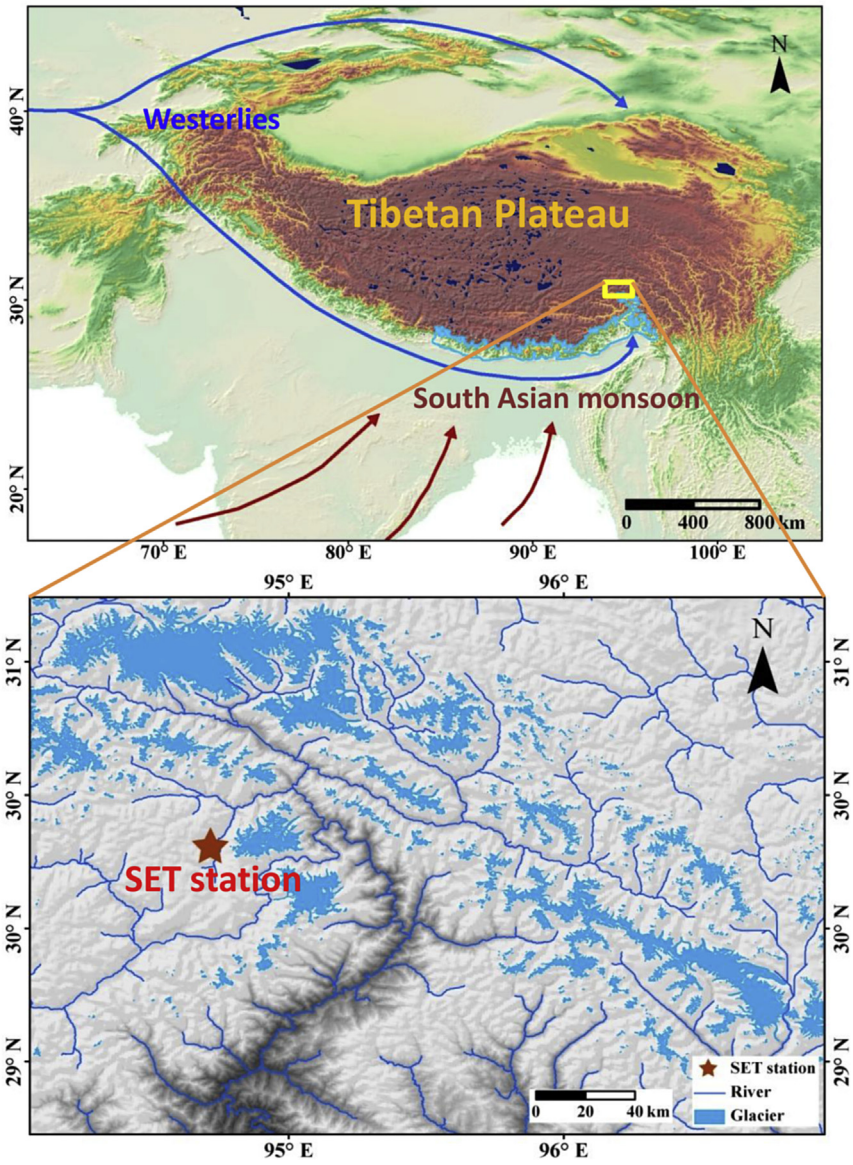

Fig. 1. Map showing the Tibetan Plateau and the location of the SET station (the Tibetan forest, like a belt, extends from the central to the eastern Himalayas).

(Loewen et al., 2007; Wang et al., 2010a; Yang et al., 2010). Atmospheric wet deposition represents an important source of Hg to terrestrial systems; theoretically, the change in atmospheric Hg deposition will have a considerable influence on the alpine ecosystem of the Tibetan Plateau because of its vulnerable biotic communities (Yang et al., 2011; Zhang et al., 2014). As a result, knowledge regarding the speciation of the Hg wet deposition is important in determining its availability to biological systems. Nevertheless, to date, very few wet Hg deposition measurements have been conducted in the Tibetan Plateau and these estimates are mainly based on very limited and short-term deposition measurements (Huang et al., 2012a, 2013). Moreover, the forest region of the southeastern Tibetan Plateau extends from the central to the eastern Himalayas (91 °E – 103 °E) (1.2 million square kilometers) (Fig. 1), which acts as a natural barrier in the southern frontier of the Tibetan Plateau. Considering that remote forests are regarded as a pool of Hg in the global Hg cycling process (Gong et al., 2014), we were motivated to investigate the current wet Hg deposition scenario in the southeastern Tibetan Plateau, which is located in front of the atmospheric Hg export from South Asia (Fig. 1). However, no long-term observations of wet Hg deposition, downwind of the South Asian subcontinent, have been conducted to examine the probable effects of anthropogenic disturbances via wet Hg deposition on the fragile ecosystem of the Tibetan Plateau. As mentioned above, long-term monitoring of wet Hg deposition in the southeastern Tibetan Plateau is therefore essential to assess the changes in atmospheric Hg deposition in this ecologically sensitive region and its implications for the high-elevation environment of this biodiversity hotspot.

In the present work, wet Hg deposition, including the concentration, speciation, and flux, was investigated at a high-elevation forest site, the Southeast Tibet Station for Alpine Environment Observation and Research (hereafter, SET station). Our data are compared with the reported data for high-elevation precipitation over the Tibetan Plateau and remote regions worldwide. Seasonal variations of Hg concentration and wet flux are discussed. In addition, long-term variations of wet Hg deposition measured in situ was first reported to compare the recent depositional trends as