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Review

Inorganic pollution around the Qinghai-Tibet Plateau: An overview of the current observations

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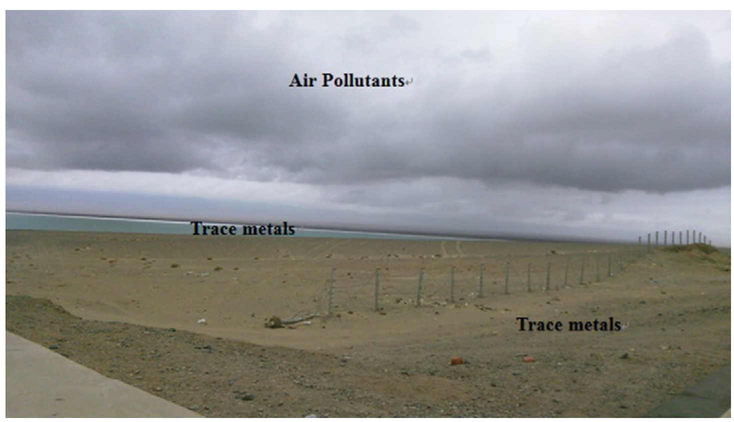
HIGHLIGHTS

- Relatively high metal concentrations around the Qinghai-Tibet Plateau
- Non-negligible air pollution around the Qinghai-Tibet Plateau
- High soil heavy metal contamination degree of the Qinghai-Tibet Plateau
- High water heavy metal hazard index of the Qinghai-Tibet Plateau

GRAPHICAL ABSTRACT



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ABSTRACT

The Qinghai-Tibet Plateau is the highest geographical unit in the world. Thus, it serves an important role in evaluating long-term ecologic conditions and environmental status and changes over time. This study summarizes major and trace element concentrations in biota and in water and soil. It also pays attention to gaseous pollutant and particle concentrations in air around the Qinghai-Tibet Plateau. The degree of soil heavy metal contamination and the water heavy metal hazard index were respectively evaluated. The contamination degrees of two sampling areas around the Qinghai-Tibet Plateau reached extremely high levels with soil mC_d (modified degree of contamination) values exceeding 20. Surprisingly, over 54% of sampling areas showed moderate or more serious soil contamination degree ($mC_d > 1.5$). Moreover, the hazard indexes of two important rivers were 1.56 and 7.59, reaching unacceptable level. The potential risk might be beyond our expectation. Therefore, it should be an urgent and top priority to identify and confirm possible pollution sources around the Qinghai-Tibet Plateau. Then, it is imperative to implement feasible and effective environmental quality control strategies.

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Contents

1. Introduction

The Qinghai-Tibet Plateau, known as the third polar and roof of the world, is a unique geographical unit to attract increasing attentions all over the world. The Qinghai-Tibet Plateau covers a total area of nearly 3.0×10^6 km^2 (about 2.5×10^6 km^2 in China) with an average altitude of over 4000 m. It serves as the source of several important rivers including: Yangtze, Lancang, Nujiang, Senge Tsangpo (also known as Shiquan River), Yarlung Zangbo (also called Brahmaputra River) and Tarim.

Major and trace elements, especially heavy metals, play important role in the environment. Heavy metals generally refer to metals or metalloids with a specific density of greater than 5 g/cm^3 (Järup, 2003; Oves et al., 2012). Heavy metals exert a serious threat to human health and well-beings, living organisms, and local environment due to their bioaccumulation characteristics, persistence, and toxicity (Laskowski et al., 1995; Cheng, 2003; DeForest et al., 2007; Nabulo et al., 2010). Heavy metals naturally exist in the environment and enter the water, air, and soil by ways of natural and anthropogenic activities (Clark, 1981; Förstner, 1989; Valipour et al., 2012, 2013a, 2013b; Zukal et al., 2015). It is possible for heavy metals to travel long distances by bonding to particles in air.

Composed of solid and liquid particles suspended in the air (Kokhanovsky, 2008), atmospheric aerosols have aroused global attention due to their significant effects on climate, atmospheric chemistry and visibility, precipitation, clouds, and human health (Boucher et al., 2013). Gaseous pollutants are also important for air quality and human health (Cox, 2003) and deserve extensive study on the Qinghai-Tibet Plateau.

The Qinghai-Tibet Plateau is least disturbed by human activities in China. Thus, it is regarded as "the last pure land" with the least pollution in China. However, the observations obtained in recent years have provided different and thought-provoking facts. To the current state of knowledge, previous research paid more attention to concentrations of a few pollutants (metals, aerosol, etc.) in a certain media (biota, soil, water, or air) around one or several sites of the Qinghai-Tibet Plateau. The published results are diverse and fragmented to make it difficult to obtain the comprehensive information on contamination degree of the Qinghai-Tibet Plateau. Therefore, this study compiled the previously published data and evaluated the contamination degree of the Qinghai-Tibet Plateau, aiming at providing thorough insight for the inorganic pollution around the Qinghai-Tibet Plateau so as to provide the basis for environmental protection policies for this unique area.

2. Materials and methods

All concentration data were collected from the published research articles. The sampling sites were also marked in Fig. S1.

Due to the limitation of background/baseline data of air/aerosol metal contents and gaseous pollutant/particle concentrations, this study only evaluated the heavy metal contamination degree of soil/sediment and heavy metal hazard index of water.

The heavy metal contamination degree of soil/sediment was described as mC_d (modified degree of contamination), calculated using the following equation:

$$mC_d = \frac{\sum_{i=1}^{n} \frac{C_x^i}{C_b^i}}{n} \quad (1)$$

where C_x^i and C_b^i refer to the concentration of the ith pollutant in the contaminated soil/sediment (mg/kg) and the background concentration of the ith pollutant in the soil/sediment (mg/kg), respectively; n refers to the number of pollutants. More detailed information of this method were described by Hakanson (1980) and Abrahim and Parker (2008). Background concentrations were determined from the reference (MEPC, 1990). This studied used maximal concentrations as C_x^i to obtain the possibly maximal contamination degree.

Water hazard index (HI) caused by heavy metals was calculated using the following equation (Park and Choi, 2013; Adamu et al., 2015):

$$HI = \sum_{i=1}^{n} \frac{C_i \times IR \times ED \times EF/(BW \times AT)}{RfD_i} \quad (2)$$

where C_i is the concentration of a pollutant in water (mg/L); IR is the ingestion rate (2 L/d); ED is the exposure duration (30 years); EF is the exposure frequency (350 d/year); BW is the body weight (60 kg); AT is the average time ($ED \times EF$ days); RfD_i is the reference dose of the ith pollutant for non-carcinogen characterization. More detailed information refers to research articles written by Park and Choi (2013) and Adamu et al. (2015).

3. Results

3.1. Trace elements in biota of the Qinghai-Tibet Plateau

Due to bio-magnifications and bio-concentration effects, pollutants in the organisms attract more attentions from the researchers (Table 1). Yang et al. (2007) analyzed heavy metals in fish from two high mountain lakes (Nam Co Lake and Yamdro Lake) and Lhasa River in the Qinghai-Tibet Plateau. Heavy metals were relatively high in fish liver, eggs and gill, and generally low in brain and muscle. Maximal Cu and Zn concentrations reached 2.0 and 6.9 mg/kg (wet weight), respectively. Yang et al. (2007) speculated that the study on the metal pollution source or bioaccumulation mechanism by fish could obtain useful information from the correlations among metal concentrations in biota samples. Later then, the concentrations of total mercury (Hg_T)