Science of the Total Environment 650 (2019) 2545–2558

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Pollution characteristics in a dusty season based on highly time-resolved online measurements in northwest China

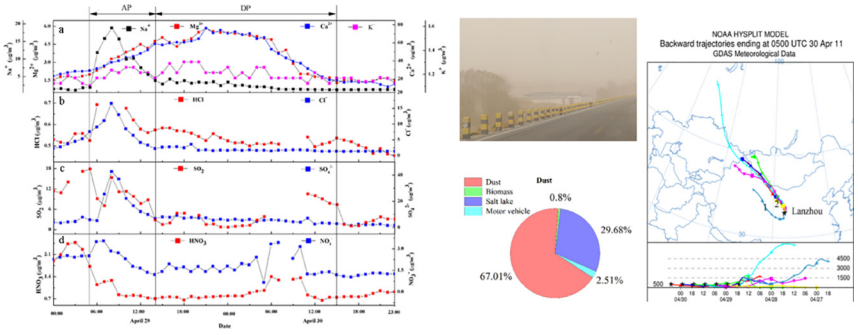
Fanglin Wang [a], Yunlong Sun [a], Yan Tao [a,*], Yongtao Guo [b], Zhongqin Li [c], Xiuge Zhao [a,d,**], Sheng Zhou [a]

[a] Key Laboratory of Western China's Environmental Systems (Ministry of Education), College of Earth and Environmental Sciences, Lanzhou University, Lanzhou 730000, China
[b] College of Atmospheric Sciences, Lanzhou University, Lanzhou 730000, China
[c] State Key Laboratory of Cryospheric Science/Tien Shan Glaciological Station, Northwest Institute of Eco-Environment and Resources, Chinese Academy of Sciences, Lanzhou 730000, China
[d] State Key Laboratory of Environmental Criteria and Risk Assessment, Chinese Research Academy of Environmental Sciences, Beijing 100012, China

HIGHLIGHTS

- Trace gases and water-soluble ions in PM_{10} were measured based on an online analyzer.
- Pollution characteristics were analyzed in the dust and non-dust period.
- Mixing mechanism was conducted by equivalent ratio analysis in the dust event.
- Sources were identified and quantitated by PMF.
- Potential source-areas were explored by HYSPLIT and CWT.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 24 July 2018
Received in revised form 28 September 2018
Accepted 30 September 2018
Available online 02 October 2018

Editor: Jianmin Chen

Keywords:
PM_{10}
Dust event
Water-soluble ion
Trace gas
Source apportionment
Potential source-area analysis

ABSTRACT

To investigate the pollution characteristics and potential sources in a dusty season, an online analyzer was used to measure trace gases and major water-soluble ions in PM_{10} from April 1st to May 29th, 2011 in Lanzhou. The average concentrations of HONO, HNO_3, HCl, SO_2 and NH_3 were 0.93, 1.16, 0.48, 9.29 and 5.54 μg/m^3, respectively, and 2.8, 2.76, 8.28 and 2.48 μg/m^3 for Cl^-, NO_3^-, SO_4^{2-} and NH_4^+. In the non-dust period, diurnal variations of SO_4^{2-}, NO_3^- and their gaseous precursors showed similar change trend. NH_4^+ showed unimodal pattern whereas NH_3 illustrated a bimodal pattern. HCl and Cl^- showed an opposite diurnal pattern. In the dust event, temporal profiles of HCl and Cl^-, SO_2 and SO_4^{2-} all presented similar change trend, and SO_4^{2-} and Cl^- preceded dust ions (Ca^{2+} and Mg^{2+}) 13 h. The ratios of NO_3^- to SO_4^{2-} were 0.65 in the non-dust period and 0.31 in the dust event. In the dust event, the sulfur oxidation ratio (SOR) was a factor of 1.33 greater than that in the non-dust period, and $[SO_4^{2-}]/[SO_2]$ was 2.31 times of that in the non-dust period. The source apportionment using Probabilistic Matrix Factorization (PMF) suggested that fugitive dust (58.09%), secondary aerosols (33.98%), and biomass burning (7.93%) were the major sources in the non-dust period whereas dust (67.01%), salt lake (29.68%), biomass burning (0.8%), and motor vehicle (2.51%) were the primary sources in the dust event. Concentration weighted trajectory (CWT) model indicated that NO_3^-, Cl^- and K^+ could be regarded as local source species, the potential sources of Na^+, Mg^{2+} and Ca^{2+} concentrated in the two large areas with the one covered in the junction areas of Xinjiang, Qinghai and Gansu and another one covered the places around in Lanzhou, the potential sources of SO_4^{2-} were mainly localized in the areas adjacent to Lanzhou.

* Corresponding author.
** Correspondence to: X. Zhao, State Key Laboratory of Environmental Criteria and Risk Assessment, Chinese Research Academy of Environmental Sciences, Beijing 100012, China.
E-mail addresses: taoyan@lzu.edu.cn (Y. Tao), hkyzhaoxg@163.com (X. Zhao).

https://doi.org/10.1016/j.scitotenv.2018.09.382
0048-9697/

1. Introduction

Particulate matter (PM_{10}) is an important indicator of air condition and emitted from various natural and anthropogenic activities. PM pollution has aroused the public concerns because it can cause adverse effects on the atmospheric environment, public health, and climate change (Cao et al., 2012a,b; Fang et al., 2016; Hu et al., 2015; Kim et al., 2015; MR et al., 2012; Sun et al., 2014; Ye et al., 2016; Zhang et al., 2015).

Water-soluble ions in PM have been regarded as a crucial factor for its significance in aerosol-phase chemistry reactions and adsorptions of trace gases by particles (Ocskay et al., 2006; Shon et al., 2012; Xue et al., 2011). These major ions include those primary species directly released into the atmosphere and secondary ions formed by oxidation of their corresponding gaseous precursors (SO_2, NOx, and so on) and neutralization with other primary compounds (ammonia, volatile organic compounds, et al.) (Koçak et al., 2015). As an important component of atmospheric aerosols, water-soluble ions affect not only the acidity and formation of aerosols (Han, 2014; Kunwar et al., 2016; C.S. Liang et al., 2016), but also the ecosystems and architectural heritage (T. Liang et al., 2016; Nava et al., 2016). Extensive studies have demonstrated that water-soluble ions occupy a large proportion of PM (Cao et al., 2012a,b; Dao et al., 2014; Du et al., 2011; Tan et al., 2009). In European urban areas, the most abundant water-soluble ions were sulfate and nitrate which could account for 20–30% of PM_{10} mass concentration (Galindo et al., 2013; Putaud et al., 2010; Tolis et al., 2014) whereas in Chinese urban regions, the ratio could be as high as 33% or more (Shen et al., 2011).

Trace gases generally are emitted from natural and anthropogenic sources (Bari et al., 2003; Derwent et al., 2009). It is well-recognized that trace gases like HNO_3, NH_3, HCl, and H_2SO_4 can be converted into aerosols by neutralization and reversible phase equilibrium reactions (Koçak et al., 2015; Seinfeld and Pandis, 2006). HONO also plays an important role in aerosol chemistry as it can be served as a source of OH radicals and its photolysis can lead to 34% comprehensive OH yield in the daytime (Kleffmann et al., 2003; Su and Pöschl, 2011). Previous studies have shown that SO_2 is the most abundant trace gas whereas HCl has the lowest level in the atmosphere (Behera et al., 2013; Kirkby et al., 2011; Kulmala et al., 2000). The average concentrations of N-containing gases (NH_3, HONO and HNO_3) contribute the most in summer and little in winter (Makkonen, 2014).

To identify potential sources of pollutants, several practical receptor models have been developed (Keeler, 1987; Poirot and Wishinski, 1986; Zeng and Hopke, 1989). The most commonly used receptor models are trajectory cluster (Harris and Kahl, 1990; Sirois and Bottenheim, 1995), potential source contribution function analysis (PSCF) (Cheng et al., 1993; Hopke et al., 1993), and concentration weighted trajectory analysis (CWT) (Hsu et al., 2003; Seibert et al., 1994). These models have been widely used by combining meteorology factors, backward trajectories, and concentrations measured at a sampling site. Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) (Draxler and Hess, 1998) is also frequently used in basic air masses trajectory calculation. A tool named TrajStat has been developed by Wang et al. (2009) which implements cluster calculation, cluster statistics, PSCF, and CWT models into this modeling tool to identify source-receptor relationships.

Lanzhou (35.95° N, 104.14° E), the capital of Gansu Province, is located in a narrow (2–8 km width) and long (40 km) valley basin in Loess Plateau (Fig. 1), which is the home of a large-scale oil refinery and petrochemical industrial base and a key transportation hub in northwestern China. Over the past decades, Lanzhou has been one of the most heavily polluted cities by PM in China and even in the world (WHO, 2014). The severer PM contamination is attributed to frequently occurring stable atmospheric boundary layer and calm winds induced by the mountain-valley topography, arid environment (annual precipitation <300 mm), and massive petrochemical and oil refinery industries. The poor ecological environment and complex topography are uniquely susceptible to the atmospheric pollution, especially high ambient suspended particulate loadings which often take place in spring. The rapid increasing number vehicles in Lanzhou in the past decade further deteriorates the air quality in Lanzhou (Ta et al., 2004; Wang et al., 2006; Wang et al., 2016; Han, 2013). Previously, the investigations into the PM pollution in Lanzhou mostly focused on the pollution levels of PM and its compositions, chemical characteristics, and daily changes in PM concentrations (Pathak et al., 2009; Wang, 2014), there are large knowledge gaps about the relationships between trace gases and water-soluble ions in PM_{10} in a dusty as compared with other cities (Ding et al., 2017; Kulshrestha et al., 2009; Li et al., 2012). Few studies have been carried out to measure trace gases and their related water-soluble ions in PM_{10} during spring, and the temporal variations of water-soluble ions, potential sources, mixing mechanisms and chemical compositions have not been characterized in dust event.

In this article, the observation of trace gases (HCl, HONO, SO_2, HNO_3, and NH_3) and major water-soluble ions (NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+}, SO_4^{2-}, NO_3^- and Cl^-) in PM_{10} were performed simultaneously in Lanzhou from April 1st to May 29th, 2011. The present study intends to

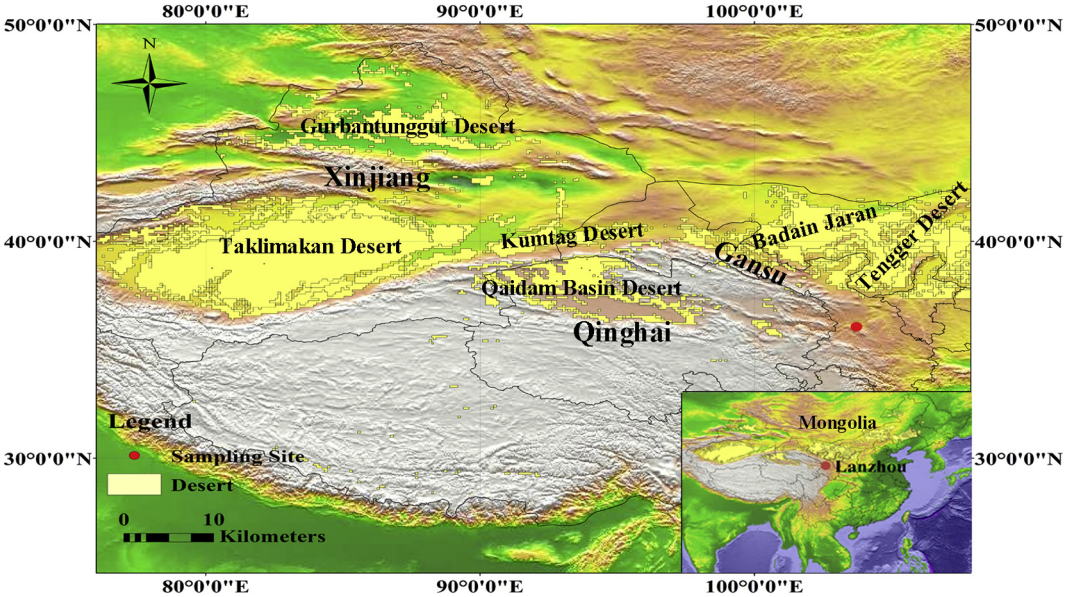


Fig. 1. A map description for locations of sampling site, related Deserts and toponymies.