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Effects of dust storm on public health in desert fringe area: Case study of northeast edge of Taklimakan Desert, China

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ABSTRACT

This study investigated the effects of dust storms in Bugur County, northeast part of Taklimakan Desert, China, on public health using the hospital records and questionnaire survey for 100 days in February–May 2013. Four types of dust weather were considered: normal day, suspended dust, blowing dust and sand storm. The time series analyses (simple regression, cross–correlation for lag effects, Poisson regression with generalized additive model) were applied together with principal component analysis (PCA) to reveal the association between the daily numbers of inpatients/outpatients, air pollutants (TSP, SO_2 and NO_2) and meteorology (temperature and wind speed). Primary data, collected in the questionnaire survey from 810 respondents for 10 health symptoms, was analyzed to reveal the association between dust weather and occurrence frequency of symptoms with different severity degrees using PCA. Results of both secondary and primary data analyses showed strong associations between dust weather and the health effects. Levels of the pollutants were higher in dust weather days than in normal days. Diseases related to the respiratory system and ENT (Ear, Nose, Throat) were more susceptible to dust weather conditions and air pollution levels than other diseases. SO_2 had a stronger influence on increase in likelihood of hospital visits than NO_2 and TSP (total suspended particulate matter). Elder people of above 60 and young children of below 15 were more sensitive to dust storms than others.

Keywords: *Dust storm, air pollution, hospital record, health survey, Taklimakan Desert*

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1. Introduction

Dust storms are the atmospheric phenomena that have been recognized as having a very wide range of environmental and climate impacts. During a dust storm period, strong wind raises rough sand and fine particles, and forms a storm which is transported over a large distance. Dust storms are considered to be a natural hazard that can affect daily life of people in downwind areas (Maghrabi et al., 2011). The dust storms possibly also carry heavy metal, bacteria, virus, and poisonous minerals that, once inhaled by people, can cause adverse health effects (Huang and Wang, 2001; Geng, 2006; Wu et al., 2010). The effects of dust storms or dust weather on human health have drawn an increasing concern from the environmental health research community, government, society, industry, and the general public. However, there are still a limited number of studies in the world reporting the association between dust storms and human health. The epidemiologic studies on the possibility of respiratory diseases caused by sand–dust fine particles are still in the preliminary stage although it is generally perceived that dust storms greatly deteriorate air quality hence would influence human health (Englert, 2004; Curtis et al., 2006; Jimenez et al., 2009; Ueda et al., 2010; Lim et al., 2012; Park et al., 2013).

In China, dust storms mostly occur over the northwest part of the country in the spring. This is the transitional period of the atmospheric circulation when synoptic–scale cold air mass is prevalent while soil is relatively dry (Quan et al., 2001; Wang et al., 2004). Taklimakan Desert is the largest desert in China, situated in the middle of the Tarim River Basin, in Xinjiang Uyghur Autonomous Region, as seen in Figure S1, Supporting Material (SM). This is reputed to be the world's second largest shifting–sand desert covering an area of over 337 000 km^2. Because of the wind, the sand dunes are always moving and statistical data suggest that each year these sand dunes move toward the oasis area by about 150 m, which seriously threatens the existence of oasis and the life of local residents (Qian et al., 2002). Dust storm has already become one of the most serious environmental problems in the northeast edge of Taklimakan Desert because of its high occurrence frequency, especially in spring. The springtime peak of dust storms in northeast edge of Taklimakan Desert is consistent with the seasonality of dust storms activity in arid and semi–arid regions in Northwestern China (Wang et al., 2004). The northeast edge of Taklimakan Desert, which plays an essential role on the regional economic development, has already become one of the vulnerable areas to dust storm impacts.

A limited number of studies have been conducted to investigate dust storm impacts in Taklimakan Desert and its surrounding areas but they mostly focused on the environmental impacts (Wang et al., 2006; Tao et al., 2012). There has yet been a comprehensive study reporting the impact of dust storms on public health in the region. This study therefore was designed to partly fill in this information gap. The primary data on health symptoms were collected during a door–to–door survey in February–May 2013 and were analyzed together with the secondary data of hospital records and air pollution levels. The principal component analysis (PCA) and Poisson regression with generalized additive model (GAM) were conducted along with simple time–series analyses to reveal relationships between the dust weather, air pollutants (TSP, SO_2 and NO_2), and daily number of outpatient/inpatients. The severity of ten (10) different health symptoms in response to dust storms, obtained from the questionnaire survey, was comparatively analyzed for different age groups in urban and rural areas, respectively. PCA was applied to reveal multivariate associations between severity of the health symptoms, pollutant levels and meteorology (wind and temperature).

2. Materials and Methods

2.1. Study area

The northeast edge of Taklimakan Desert includes Bugur County and Korla City of the Xinjiang Uyghur Autonomous Region. The Bugur Country, geographically stretched between 83°38′–85°25′E and 41°05′–42°32′N, has a total area of 14 789 km^2 and 11 town/townships with a total population of 113 000. The Korla City, geographically stretched between 85°25′–86°75′E and 41°08′–41°92′N, has an area of 13 345 km^2 and includes 16 town/townships with a total population of 452 000 (Kahar et al., 2010). This region has a cold desert climate with extreme seasonal temperature variations. The monthly average of temperature ranges from −7.0 °C in January to 26.4 °C in July. The annual temperature mean is 11.66 °C, which however is still warmer than most locales at the same latitude in further east of the country. The precipitation in the area is only 57 mm annually, and mostly occurs in summer, which is much lower compared to the annual evaporation rate of about 2 800 mm. There are about 3 000 hours of sunshine annually. The frost–free period is averaged at 210 days in a year. This area is considered as a region with a frequent occurrence of dust storms in Xinjiang (Lai et al., 2002; Liu et al., 2004). Dust storm weather in this study was classified using the criteria given by AQSIQ/NSC (2006). Accordingly, there are 3 types of dust weather depending on the severity. The least severe type is called the suspended dust weather and refers to the suspending dust in the air under calm or low wind conditions with the atmospheric visibility below 10 km. The medium severe dust weather is called the blowing dust and refers to the lower horizontal visibility, 1 km–10 km. The most severe/strong dust weather is called sand storm (sometimes is also simply called the dust storm) which refers to such phenomena when the instantaneous wind velocity is over 25 m/s and horizontal visibility is below 1 km (Qian et al., 2002; AQSIQ/NSC, 2006). Dust storm mostly occurs in spring, the average annual frequency during the period of 1958–2008 was 17.5 times for suspended dust events, 6.1 times for blowing dust events and 1.4 times for the sand storm events (Aili, 2010).

Since the discovery of oil in the Taklimakan Desert in 1990s, this area is now both more populated and far more developed than other parts of Southern Xinjiang. It is an important economic center of Southern Xinjiang and serves as the home to a huge operational center for Petro China's exploration in Xinjiang. It can be described as the “economic strategic zone and traffic center of southern Xinjiang” and “ecological fragile region” (Chen et al., 2009). However, due to its direct contact with the desert and its location in dust storm tracks, this region is vulnerable to dust storm effects. In fact, most parts of the region are desert and barren mountains, only around 10% of total areas are habitable (Lei and Zhang, 2005). This study only focused on the habitable areas which are located between desert and mountains of Bugur County.

2.2. Data collection

Primary data. To examine the health symptoms induced by different dust weather conditions on people living in the study area, a questionnaire survey was conducted. The questionnaires were delivered to the respondents in their homes around 20 February 2013. The questionnaire listed ten (10) types of health symptoms, including cough, expectoration, shortness of breath, chest oppressed, dry throat with a bitter taste, dry eyes, tears, runny nose, sneeze, and depressed mood, and the respondents were instructed to fill in the symptoms that they experienced each day with 4 levels of severity (negligible, somewhat, medium and serious). The forms were collected from the respondents by the end of May 2013 hence the data collection period was 100 days, from 21st February to 31st May 2013, which covered the storm season. During the data collection period, in order to ensure the accuracy and completeness of the survey data, about 20 volunteers from different areas were recruited who were responsible for distribution and collection of filled questionnaire forms at the end of each month. For young respondents of less than 15 years of age, parents and school teachers were requested to help them to fill the forms.

In order to produce representative survey data, a multistage statistical sampling design was used. First, the total population of Bugur County of 113 000 was divided into two strata, namely, the urban population of 46 735 (people living in cities) and rural population of 66 265 people. Second, in each stratum the cluster sampling was used and the clusters (communities) were selected for a more detail study. Further, in each commune the stratified sampling was again applied for different age layers: children (<15 years), young (15–25), working/employee (25–60) and elderly/retirees (≥60).

The sample size, refers to the number of respondents to be included in the survey was calculated using four steps as applied in Magnani (1997) and presented in Table S1 (see the SM). First, the base sample size was estimated which was then adjusted for the designed effect (increased by 2 times) and for contingency (increased by 5%). The number of respondents within the urban and rural stratum was estimated based on the population distribution between rural and urban areas, and the number of respondents in each age stratum was estimated using the shares of the population of particular age group/stratum in the total population.

The final number of respondents selected for the survey in the study area was 810, including 475 respondents for the rural area and 335 for the urban area. For the age distribution, 243 respondents (n_1) were selected for children, 152 respondents (n_2) for the young, 281 respondents (n_3) were for the working/employee, and 134 respondents (n_4) for the elderly/retirees, as seen in Table S1 (see the SM).

Secondary data. (1) Hospital record: Three general hospitals of the Bugur County, the Public hospital, the Uyghur medicine hospital and the Maternal and Child health hospital, were selected to collect secondary data on daily number of outpatients and inpatients during the same period as the questionnaire survey, 21st February to 31st May 2013. The data were obtained from all departments, including the Internal Medicine (respiratory system diseases, digestion system diseases, and neurology system diseases), Gynecology, Pediatrics, ENT (Ear, Nose and Throat), Traditional Chinese Medicine and the Genitourinary Division. Because of the overall small numbers of patients of departments of Traditional Chinese Medicine and Genitourinary, as well as from Neurology sub–department, the data from these 3 units were not included in further analyses. The collected information included the name, gender, birthday of patient, and the name of diseases and symptoms and so on. Totally, 6 types of diseases were selected for further statistical analysis which, based on the International Classification of Diseases of the 10th edition (ICD–10) by of WHO (1998), were classified as follows: respiratory diseases (code: J00–J99), digestive diseases (code: K00–K93), circulatory system diseases (code: I00–I99), gynecology diseases (no coding), pediatrics diseases (no coding) and ENT (otolaryngological) diseases (code: H00–H95).