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Distribution Characteristics of Chemical Pollution Particulates in Oak Forest Area of Taihang Mountains

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With the development of modern industrial production and transportation, particulate matter in the chemical industry has become the main pollutant in the city, and the regulating effect of mountain forest on airborne particulate matter has become a hot issue in air pollution control research. This paper analyses the distribution characteristics of pollutants in Oak (OAK) forest area of Taihang Mountains, and then summarizes the distribution characteristics and laws of chemical particulate matters. The results showed that within one day, the air pollutant concentration in the OAK forest area is smaller at 10:00 and 13:00, and the concentration is greater at 7:00 and 16:00; located in the subtropical monsoon humid climate zone, Taihang Mountains has heavier air pollution in mountain forest areas in winter and spring, and air pollution is relatively lighter in summer and autumn due to multiple rainfalls; the air pollution index (API) in the forest area of Taihang Mountains meets the national standard, indicating that mountain forests can help improve urban ecological environment.

1. Introduction

Atmospheric pollution usually refers to the phenomenon that certain substances enter into the atmosphere due to human activities or natural processes, exhibit enough concentration within sufficient time, and thus endanger human comfort, health and welfare or environment (Heisler et al., 2003; Vanguelova et al., 2010). As long as the amount, nature, and time of certain substance are enough to exert influence on human or other biology etc., it can be called as air pollutant, and its existence is called air pollution (Pathak et al., 1986; Borrego et al., 2007; Jung et al., 2013). With the development of modern industrial production and transportation, more and more substances have been continuously discharged into the atmosphere, and the types have been increasingly more complex (such as smoke, sulphur oxides, nitrogen oxides, organic compounds, halides, and carbohydrates, etc. emitted during industrial production processes), causing a drastic change in atmospheric composition. These chemical particulate matters become the main pollutant in many cities (Francisco et al., 2009; Huttunen, 1974). Atmospheric dusts, sulphides, nitrogen oxides, and halogen compounds are indeterminate components of the atmosphere. When they enter the atmosphere, atmospheric pollution shall be caused (King et al., 2014; Mclaughlin, 1998).
In recent years, the regulating effect of mountain forest area on particulate matter has become a key and hot issue in air pollution control and chemical industry research. Mountain forest is the complex of a variety of biology and non-biology with significant ecological values and humanistic landscape values that is based on trees in cities and surrounding areas, reaches certain degree of coverage and scale, and can have a significant impact on the surrounding environment (Pandey et al., 2015). Such mountain forest areas can reduce airborne particulate matter through interception, dispersion, and absorption, thereby effectively preventing and controlling urban particulate pollution (Sastry, 2002)). Studies have shown that mountain forests can regulate urban climate, absorb pollutants, protect environment, and have significant social and ecological benefits (Taylor et al., 1994; Percy et al., 2004). This paper investigates the distribution of pollutants in mountain forest areas of Taihang Mountains, and analyses and summarizes the distribution characteristics and laws of chemical pollution particulates, in order to provide a theoretical basis for the planning and

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construction of mountain forests, and also to provide the scientific basis for further improving the ecological benefits evaluation provides scientific basis of ecological system.

2. Test overview

2.1 Chemical pollution particulates

Chemical pollutants are mainly in the form of chemical waste gas, which can be divided into three categories aOakording to the nature of the gas: (1) Chemical exhaust gas containing inorganic pollutants. The exhaust gas contains the inorganic materials such as SO_2, CO, NO_2, H_2S, HCl, HF, Cl_2, NH_3, etc., mainly from nitrogen fertilizers, inorganic acids, phosphate fertilizers, inorganic salt manufacturing; (2) organic waste gas; it contains organic substances such as benzene series, phenols, alcohols, aldehydes, acrylonitrile, cyanide, halogenated benzene, epoxy compounds, etc., mainly from the organic chemical industry, raw material manufacturing industry, and the industries of synthetic materials, pesticides, fuels, and coatings etc.; (3) Exhaust gas with both organic and inorganic waste gases, which are emitted from the petrochemical and petroleum refining industries. The types and sources of chemical pollution are shown in Table 1.

Table 1: Pollution sources and pollutants in chemical industry

Industry	Main source	Main pollutants in exhaust gas
Nitrogenous fertilizer	Synthetic ammonia, urea, ammonium bicarbonate, ammonium nitrate, nitric acid	NO_x, CO, Ar, NH_3, SO_2, CH_4
Phosphate fertilizer	Processing of phosphate rock, calcium superphosphate, calcium magnesium phosphate fertilizer, Phosphoric acid , sulphuric acid	Fluoride, dust, SO_2, acid mist, NH_3
Inorganic salt	Chromate salt, carbon disulfide, barium salt, hydrogen peroxide, yellow phosphorus	SO_2, P_2O_5, Cl_2, HCl, H_2S, CO, CS_2, As, F, S, chromyl chloride, heavy aromatics
Chlor-alkali	Caustic soda, chlorine gas, chlorine products	Cl_2, HCl, vinylchloride, mercury, acetylene
Organic materials and synthetic materials	Alkenes, benzenes, oxygen compounds, nitrogenous compounds, halides, sulphur compounds, aromatics derivatives, synthetic resins	SO_2, Cl_2, HCl, H_2S, NH_3, NO_x, CO, organic gas, hydrocarbons
Pesticide	Organophosphorus, carbamate, pyrethroid, organochlorine and so on	HCl, Cl_2, chloroethane, chloromethane, organic gas, H2S, phosgene, mercaptan, three methanol, thiophosphate pesticide
Dyestuff	Dye intermediates, primary dyes, commercial dyes	H_2S, SO_2, NO_x, Cl_2, HCl, organic gas, benzene, benzenes, alcohols, alkanes, sulphuric acid fog, SO_3
Paint	Resin lacquer, oil paint, inorganic pigment	Aromatic hydrocarbon
Coking	Cocking, gas purification and chemical product processing	CO, SO_2, NO_x, H_2S, aromatic hydrocarbon, benzopyrene, CO_2

2.2 Monitoring site

Oak is one of the main tree species in subtropical evergreen broad-leaved forests in China. It can effectively prevent co-current dust and purify the air with strong antifouling ability. In this paper, the monitoring sites of samples was selected in the oak forest area of Taihang Mountains. The test site belongs to low mountain and hilly area in the typical humid tropical climate zone; it is in a semi-natural state after afforestation.

The air and exhaust gas detection and analysis methods developed by the Chinese Environmental Protection Agency was used. Taking the sulphur dioxide, nitrogen oxides, and suspended particulate matter in the atmosphere as test object, the atmospheric pollutants at the monitoring sites were periodically tested to study the distribution characteristics of particulate matters in this forest area. The monitoring was conducted once every quarter. It’s monitored for 5 to 7 days each season, and valid data were selected for analysis and processing.

2.3 Test methods

2.3.1 Determination of sulphur dioxide

Sulphur dioxide in the air was determined by the absorption of tetra-chlorohydrin potassium (TCM) solution-pararosaniline (PRA) spectrophotometry method: after the absorption of sulphur dioxide in the atmosphere and TCM solution, stable di-chloro-sulfite complex can be formed, which then reacted together with

formaldehyde and PRA to generate the purple-red complex, and finally aOakording to the colour depth, it's determined by spectrophotometry.
The SO_2 content is calculated as (1):

$$\left(SO_2 \quad mg/m^3\right)=\frac{W}{V_n}\cdot\frac{V_a}{V_t} \tag{1}$$

where: W-the SO_2 content (μg) in the sample solution obtained during the measurement; V_t-the total volume of the sample solution (ml); V_a-the volume of the sample solution (ml); V_n- sample volume in the standard state (L).

2.3.2 Determination of nitrogen oxides NO_x

The nitrogen oxide content in the air was determined by the spectrophotometric method using n-ethylenediamine hydrochloride (NETH): the nitrogen oxides reacted with the test solution to form nitrous acid and nitric acid; then, the diazotization reaction between nitrous acid and sulfanilic acid was performed, which was coupled with the NETH to generate rose-red compounds; finally, the nitrogen oxide content was determined by spectrophotometry aOakording to the colour depth of the solution.
NOx content is calculated as (2):

$$\left(NO_x \quad mg/m^3\right)=\frac{\left(A-A_0\right)\cdot B_s}{V_r\cdot \mathbf{0.76}} \tag{2}$$

where: A-absorbance of the sample solution; A_0-absorbance of the reagent blank solution; B_s-correction factor; V_r—sample volume converted in the reference state; 0.76—conversion coefficient.

2.3.3 Determination of total suspended particulate (TSP)

The gravimetric method was used to determine the content of airborne particulates. Certain volume of air was drawn in the test area which passed through a constant-weight membrane. Then total suspended particulates (TSP) remained on the membrane. Finally, the concentration of TSP can be calculated aOakording to the weight difference of the membrane and the sampling volume before and after sampling, as shown in formula (3) and (4).

$$\left(TSP \quad mg/m^3\right)=\frac{W}{Q_n\cdot t} \tag{3}$$

$$Q_n=Q_2\sqrt{\frac{T_3\cdot P_2}{T_2\cdot P_3}}\times\frac{\mathbf{273}\times P_3}{\mathbf{101.3}\times T_3}=\mathbf{2.69}\times Q_2\sqrt{\frac{P_2\cdot P_3}{T_2\cdot T_3}} \tag{4}$$

where: Q_2-field sampling flow (m^3/min); P_2-atmospheric pressure (kPa) when the sample is calibrated on the spot; P_3-atmospheric pressure (kPa) when sampling; T_2-air temperature when the sampler is calibrated on site (K); T_3-air temperature (K) at the time of sampling.

3. Test results and analysis

3.1 Diurnal variation of pollutant concentration

AOakording to the monitoring data, the pollutants in the test area of Taihang Mountains were calculated and analysed at different time intervals within one day. Table 2 lists the results. The diurnal variation trend of pollutant concentration is shown in Fig.1.
The above results show that the concentration of pollution particulates in the test area of Taihang Mountains was highest at 16:00 and lowest at 13:00. The concentration of pollutants at the monitoring points in the test area showed a relatively high concentrations at 7:00 and 16:00, and a relatively low concentration at 10:00 and 16:00.

Table 2: Daily change of the atmospheric pollutants' concentration in Taihang Mountains

Detection project	7:00	10:00	13:00	16:00
SO_2 (mg/m^3)	0.080	0.065	0.055	0.083
NO_x (mg/m^3)	0.026	0.024	0.018	0.028
TSP	Take a sample one day, there is no mass concentration at different times.			

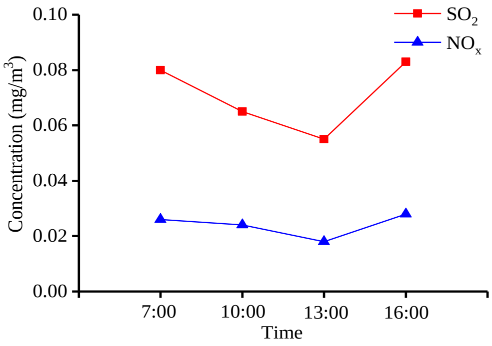

Figure 1: Diurnal variation trend of pollutant concentration

3.2 Seasonal changes in pollutant concentration

3.2.1 The concentration of SO_2

Fig.2 shows the seasonal change trend of sulphur dioxide concentration in Oak forest area of Taihang Mountains, which indicates that the concentration of sulphur dioxide in the air is higher in winter and spring, the concentration in summer and autumn is relatively low, and the concentration change in a year is slightly smaller.

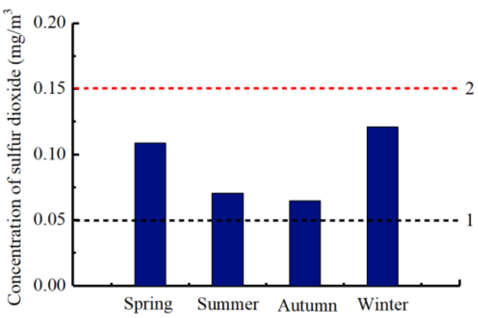

Figure 2: Seasonal changes in the concentration of sulphur dioxide

Oak forests in the test have strong absorption ability of sulphur dioxide. However, in winter, the sulphur dioxide emitted from deciduous litter and domestic waste in cities cannot be absorbed and transported by trees in time so that this pollutant will be retained in the forest, making the concentration of sulphur dioxide of forest areas higher in winter than in other seasons. In addition, due to low temperatures in winter and spring, it is easy to form radiation inversion temperature, which is not conducive to the diffusion and dilution of pollutants such as sulphur dioxide in the air, while in summer and autumn, the rainwater dilutes the sulphur dioxide, effectively reducing its concentration.

3.2.2 Concentration of nitrogen oxides

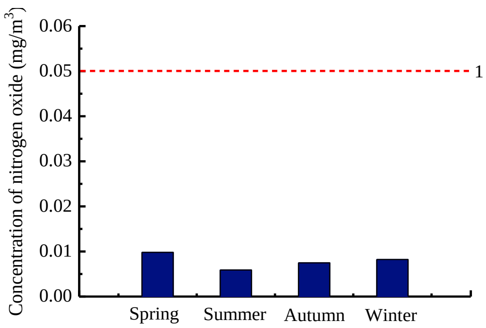

Figure 3: Seasonal changes in the concentration of nitrogen oxide

Fig.3 shows the seasonal changes of nitrogen oxide concentrations in the Oak forest area. The concentration of nitrogen oxides in the test area was higher in winter and spring, but lower in summer and autumn, with the highest concentration of nitrogen oxides in spring, reaching 0.010 mg/m^3, and the lowest concentration of nitrogen oxides in summer, 0.006 mg/m^3, which all are below the standard concentration limit of 0.05mg/m^3 in the *Ambient Air Quality Standard* in Chin. Therefore, it can be believed that the concentration of nitrogen oxides in the forest area has less impact on the environment, indicating that the Oak forest has very strong absorption and dilution capabilities against nitrogen oxides..

3.2.3 Concentration of total suspended particulates

Fig.4 shows the seasonal change trend of total suspended particulate (TSP) concentration in the test area. The TSP in the test area have the trend of higher concentration in spring and winter and lower concentration in summer and autumn. The TSP concentration in spring is the highest, up to 0.970mg/m^3, and that in summer is the lowest, only 0.315 mg/m^3, both meeting the Class I standard of environment quality evaluation. The forest area of Taihang Mountains is covered with tall trees. Suspended particulates in the air can be absorbed by leaves and trunks and retained on the branches, which in turn reduces the concentration of suspended particulates in the forest air and improves the environmental quality.

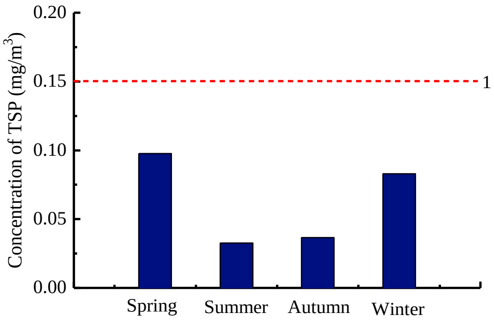

Figure 4: Seasonal changes in the concentration of TSP

3.3 Air pollution index

The Air Pollution Index (API) simplifies the concentration of several routinely monitored air pollutants into single conceptual numerical form, so as to characterize the air quality condition and degree.

Table 3: Classification limit of pollution index API

Pollution index I_n	Concentration of pollutants (mg/m^3)		
	TSP	SO_2	NO_x
500	1.000	2.620	0.940
400	0.875	2.100	0.750
300	0.625	1.600	0.565
200	0.500	0.250	0.150
100	0.300	0.150	0.100
50	0.120	0.050	0.05

Table 4: The air contamination concentration, index statistics and air quality level

	SO_2		NO_x		TSP		API	Air quality level
	Daily mean	I_{SO2}	Daily mean	I_{NOx}	Daily mean	I_{TSP}		
Spring	0.108	78.755	0.00998	9.980	0.144	56.74	78.755	II
Summer	0.0714	60.722	0.00570	5.700	0.131	53.110	60.722	II
Autumn	0.0631	56.570	0.00721	7.210	0.0829	34.529	56.570	II
Winter	0.121	85.352	0.00786	7.860	0.136	54.315	85.352	II
Annual	0.0907	70.350	0.00769	7.688	0.123	50.959	70.350	II

Based on the API of the three pollutants (sulphur dioxide, nitrogen oxides, and suspended particulates) in Table 4, the API of sulphur dioxide is the highest throughout the year. The sulphur dioxide pollution index in forest area of Taihang Mountains is rated as Class II with excellent air quality, indicating that the mountain forest area can improve the air quality of the city to a certain extent.

4. Conclusions

Based on the concentrations of sulphur dioxide, nitrogen oxides, and suspended particulate matter in the air monitored in forest area of Taihang Mountains, this paper studies the change rule of the concentration for these three pollutants over time and then evaluates the air quality. Finally, the following conclusions have been made:

(1) The air pollutants in forest area of Taihang Mountains have a significant changing trend over time. Within one day, the concentration of pollutants at 10:00 and 13:00 is relatively small, while it's relatively large at 7:00 and 16:00.

(2) The concentration of chemical pollutants in mountain forest areas has obvious seasonal changes. Specifically, in the mountain forest area, the pollution is heavy in the winter and spring seasons; while the pollution in summer and autumn is lighter, because Taihang Mountains is in the subtropical monsoon humid climate region with more rainfalls in these two seasons.

(3) The pollution index of various pollutants in forest area of Taihang Mountains has reached the national standard of Class II, indicating that mountain forests will help improve the urban ecological environment.

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