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Vertical Distribution of Urban Near-surface Pollutant PM2.5 Based on UAV Monitoring Platform

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In this work, the differences among the vertical distribution of pollutant PM2.5 concentration of three urban land types near the ground were analyzed to get the data on pollutant PM2.5 concentration of urban water, green space and road in Xi'an. The Guang Yuntan waters of Ba River, the green space of Binhe Park in western bank of Ba River, the roadside that is 400 m away from western bank of Ba River was selected as the monitoring points among which four monitoring periods were set and pollutant PM2.5 concentration data were collected with UAV (unmanned aerial vehicle) monitoring platform between 0m to 100 m. The experimental results show that pollutant PM2.5 concentration data is different in the vertical distribution of PM2.5 near the ground. The changes of the vertical distribution of PM2.5 concentration existing in such three types of land as waters area, green space and roads are also different at the same time, especially at 8:00 am. The same monitoring point during different periods differs in a tendency of high value in the morning and low in the afternoon to analyze from the perspective of different monitoring points at the same time, there exists difference between the vertical distribution of pollutant PM2.5 near the ground impacted by different urban land types.

1. Introduction

The rapid development of China's economy has led to a sharp increase in energy consumption. More and more pollutants have caused frequent haze and a series of environmental problems (Zhang et al., 2012). A large amount of studies have been done on the cause and distribution of haze, but most of them focus on the horizontal direction (Chang et al., 2009; Che et al., 2009; Ma et al., 2017; Hesam Kamyab et al., 2018). Now, more and more scholars pay attention to the vertical distribution of PM2.5 concentration. Extensive research has been carried out in various ways, such as UNA monitoring, CFD simulation, satellite remote sensing technology and so on through the installation of PM2.5 measuring instruments outside the building and the meteorological iron tower, the vertical distribution law of PM2.5 has been grasped in a certain extent (Han et al., 2008; Yang et al., 2005; Ma et al., 2016; Guo et al., 2017). The UAV monitoring platform, as a technical mean, has the advantage of strong mobility and large selection range, which can monitor the PM2.5 concentration at any height in different regions so as to realize the continuous monitor (Niu and Wang, 2014; Peng et al., 2015; Lu et al., 2017). The urban underlying surface plays an important role in the diffusion and transportation of pollutants. The urban underlying surface causes the differences between horizontal distribution of PM2.5 (Dong, 2014; He et al., 2017). At present, some scholars have studied the differences of vertical distribution of PM2.5 caused by the single type of urban land use but there is still a lack of comparative study on the differences of vertical distribution of PM2.5 concentration near the ground of different urban land use (Yu et al., 2016; Huo, 2012).

UAV monitoring technology has given us the possibility of studying differences between the vertical distribution of PM2.5 concentration near the ground in different urban land types. We select the day that has the most serious haze in Xi'an, monitor the concentration changes of 0-100 m PM2.5 data in the selected waters, roads and green space of the appendix of Guang Yuntan in the Ba River, and explain the difference between vertical distribution of PM2.5 concentration in different urban land types near the ground by analyzing the experimental data.

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2. Experiments

2.1 Experimental design

In order to obtain the PM2.5 concentration data at different heights near the ground in Xi'an waters, green space and road, the difference between the vertical distribution of PM2.5 concentration near the ground was analyzed. The Guangyuntan waters of Ba River, the green space of Binhe Park in the western bank of Ba River, the roadside that is 400m away from the western bank of Ba River were selected as the monitoring points, to determine four monitoring periods, 8:00. 11:00. 14:00. 17:00 on January 21,2018, and the monitoring height 0-100m. Using UAV from the monitoring site vertically rise, every 10m hovering in one minute to collect 60 PM2.5 concentration data, which includes 3 flights in all (See Fig.1).

Figure 1: Location of monitoring station

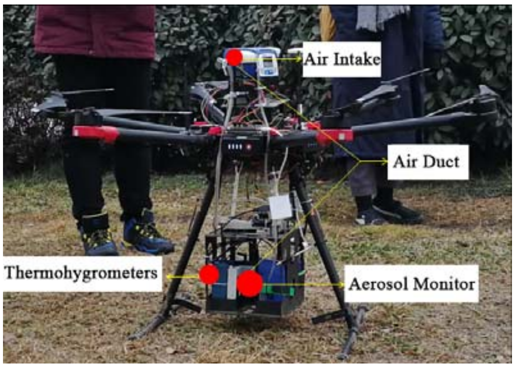

Figure 2: UAV monitoring platform

The UAV used in the experiment is M600 six rotors unmanned aerial vehicle produced by the Da Jiang company. It carries the PM2.5 concentration data with the Side Park TM AM520 individual dust meter produced by the TSI company of the United States. To avoid the influence of the tail flow of the wing, the air enters the instrument through sampling tube locating on the aircraft top (as shown in Fig.2). Before the experiment, the instrument cleaning equipment was installed to the instrument inlet and adjust PM2.5 monitor to zero.

2.2 Meteorological condition as background

The weather was stable on January 21, 2018 and meteorological conditions were not conducive to pollutants' dispersion. The height studied in this study is 0-100 m, so the influence of atmospheric boundary layer is not considered. According to the meteorological condition forecasted by the Meteorological Bureau, the weather on January 21, 2018 specifically is: it is cloudy, the minimum temperature is -5°C and the maximum temperature is 10°C. The monitoring results of the portable anemometer show that the wind speed and wind direction are stable in this area. The three monitoring sites are relatively close and the flight is at intervals of 10 minutes. The data collected from 3 monitoring sites can be regarded as the same time. To sum up, this study only took the impact of different urban land types on the vertical distribution of PM2.5 concentration near the ground into consideration.

3. Results and discussion

3.1 The vertical distribution of PM2.5 in three monitoring sites at the same period

According to the PM2.5 data obtained by the instrument that was used in the flight experiment based on the complete data the UAV monitoring platform has obtained. The average PM2.5 data of each monitoring height is obtained after processing the data, and the data are classified according to the different monitoring sites at the same time period, as shown in Tabs.1,2,3 and 4.

Table 1: PM2.5 data of each monitoring site at 8:00 am

Attitude (m)	Waters (μg/m³)	Green Space (μg/m³)	Roads (μg/m³)
0	427	435	425
10	435	434	408
20	430	430	394
30	435	429	363
40	431	417	355
50	414	413	276
60	392	384	251
70	388	340	239
80	382	257	198
90	364	237	201
100	295	223	189

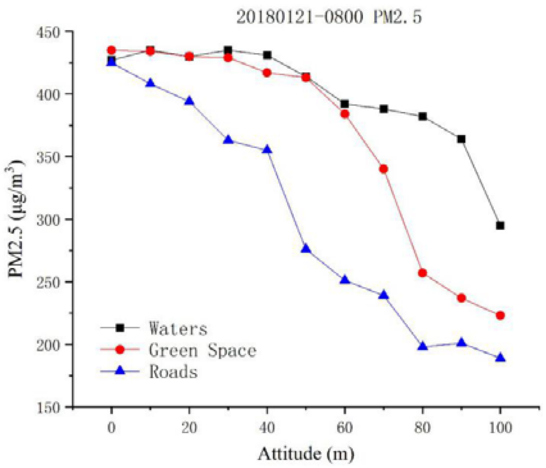

Figure 3: The change of PM2.5 data of each monitoring site at 8:00 am

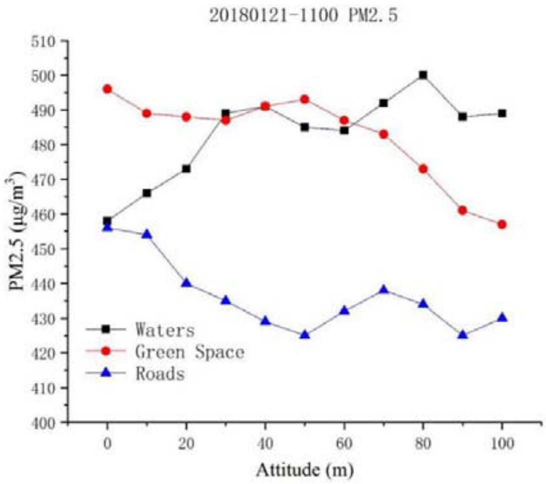

Figure 4: The change of PM2.5 data of each monitoring site at 11:00 am

Table 2: PM2.5 data of each monitoring site at 11:00 am

Attitude (m)	Waters (µg/m³)	Green Space (µg/m³)	Roads (µg/m³)
0	Chapter 2 458	Chapter 3 496	Chapter 4 456
10	Chapter 5 466	Chapter 6 489	Chapter 7 454
20	Chapter 8 473	Chapter 9 488	Chapter 10 440
30	Chapter 11 489	Chapter 12 487	Chapter 13 435
40	Chapter 14 491	Chapter 15 491	Chapter 16 429
50	Chapter 17 485	Chapter 18 493	Chapter 19 425
60	Chapter 20 484	Chapter 21 487	Chapter 22 432
70	Chapter 23 492	Chapter 24 483	Chapter 25 438
80	Chapter 26 500	Chapter 27 473	Chapter 28 434
90	Chapter 29 488	Chapter 30 461	Chapter 31 425
100	Chapter 32 489	Chapter 33 457	Chapter 34 430

Table 3: The PM2.5 data of each monitoring site at 14:00 pm

Attitude (m)	Waters (µg/m³)	Green Space(µg/m³)	Roads(µg/m³)
0	Chapter 35 370	Chapter 36 369	Chapter 37 365
10	Chapter 38 371	Chapter 39 366	Chapter 40 357
20	Chapter 41 368	Chapter 42 370	Chapter 43 361
30	Chapter 44 374	Chapter 45 365	Chapter 46 360
40	Chapter 47 375	Chapter 48 367	Chapter 49 360
50	Chapter 50 374	Chapter 51 369	Chapter 52 354
60	Chapter 53 358	Chapter 54 364	Chapter 55 362
70	Chapter 56 360	Chapter 57 366	Chapter 58 363
80	Chapter 59 357	Chapter 60 369	Chapter 61 362
90	Chapter 62 355	Chapter 63 368	Chapter 64 360
100	Chapter 65 351	Chapter 66 365	Chapter 67 353

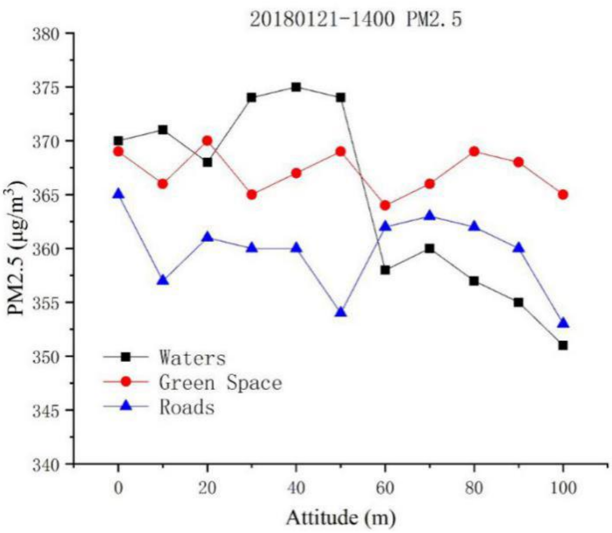

Figure 5: Changes of PM2.5 data of each monitoring site at 14:00 pm

By analyzing these figures that at 8:00 am, we can come to the conclusion, the underlying ground PM2.5 of three land types sharply decrease with the increase of height and the decreasing latitude is waters (30%)<green space(46%)<road(45%); at 11:00 am, the PM2.5 concentration of green space near the ground tends to increase delicately and the increasing latitude is 6% while the waters and road decrease a little bit and the decreasing latitude is waters(6%)<road(8%); at 14:00 pm, the PM2.5 concentration of three land types are all in a decreasing tendency with the height increase, and in addition to a few exceptional heights, the decreasing latitude is waters(5%)> road(3%) >green space(1%); at 17 pm, the interfacing height of three land types aren't beyond 3%, in a stable trend (as shown in Figs.3, 4, 5 and 6). To sum up, the vertical distribution of PM2.5 concentration in three urban land types near the ground is different, which is the most obvious at 8 am, that is PM2.5 concentration sharply decreases with the height increase and the other periods are in a tiny decreasing tendency. The PM2.5 concentration of such three land types as the waters, green space and road is different in vertical distribution.

Table 4: The PM2.5 data of each monitoring site at 17:00 pm

Attitude (m)	Waters (μg/m³)	Green Space (μg/m³)	Roads (μg/m³)
0	Chapter 68 306	Chapter 69 309	Chapter 70 312
10	Chapter 71 309	Chapter 72 312	Chapter 73 321
20	Chapter 74 309	Chapter 75 315	Chapter 76 320
30	Chapter 77 314	Chapter 78 314	Chapter 79 326
40	Chapter 80 311	Chapter 81 313	Chapter 82 327
50	Chapter 83 312	Chapter 84 315	Chapter 85 323
60	Chapter 86 305	Chapter 87 309	Chapter 88 326
70	Chapter 89 307	Chapter 90 304	Chapter 91 316
80	Chapter 92 306	Chapter 93 313	Chapter 94 318
90	Chapter 95 304	Chapter 96 300	Chapter 97 310
100	Chapter 98 301	Chapter 99 301	Chapter 100 310

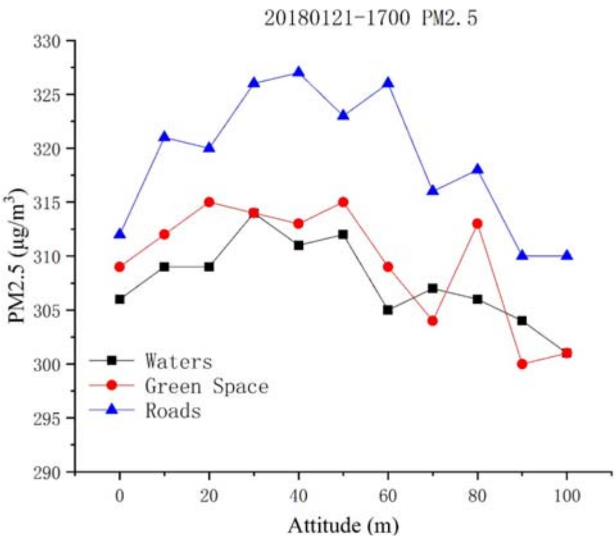

Figure 6: The change of PM2.5 data of each monitoring site at 17:00 pm

4 Conclusions

The heavy pollution period of Xi'an was selected in this experiment, and the UAV detection platform was used to monitor PM2.5 concentration data from three urban land types near the ground in the water area, green space and roads. The different types of land use and the vertical distribution of PM2.5 concentration are explored. After obtaining the experimental data, we analyze the same monitoring point in different monitoring points. At the same time period, there were differences between PM2.5 concentration data at different heights of monitoring points, and there was also a significant difference in increasing latitude and decreasing latitude with the changes of height. Vertical distribution of PM2.5 concentration near the ground is different due to different land types. In order to reduce the impact of PM2.5 on buildings and people, we can reasonably distribute different types of urban land in urban planning.

The experiment has achieved the expected effect, but it still needs further improvement. Later experiments need to monitor more periods, choose different water to complete the contrast test, and further optimize the selection of different land types. To further analyze the reasons for the differences in the vertical distribution of PM2.5 near the ground of different land use types by increasing wind speed, temperature and humidity data.

Acknowledgements

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