The analysis on air pollution characteristics at the bus stops in Jinan City

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Abstract: The concentration of pollutants is higher near the bus stops because of the frequent start-stop emissions of bus vehicles, which brings great risks to the travel crowd. At the stop of University of Jinan, in Jinan City, PM2.5 concentration and PM10 concentration generally showed an upward trend, and the maximum concentration was mainly concentrated at 20:00-22:00, during the observation period; the concentration of PM2.5 concentration had two peak value, around 11:00 and after 20:00, respectively, during the non-smog weather; the concentration of PM2.5 concentration and PM10 concentration has been rising gradually from 6:00 to 22:00, and the peak value around 11:00 is not very obvious, during the smog weather, but the late peak of PM2.5 concentration and PM10 concentration around 17:00 is especially obvious. The peak of PM2.5 concentration and PM10 concentration of bus stop appeared due to the frequent start and stop of the bus. The content of heavy metals in atmospheric particulates is obviously higher, especially the concentrations of Cd, Cr, Pb and Hg are 59.56, 4.31, 8.68 and 4.19 times of soil background values, respectively, which are obviously enriched. The heavy metal concentrations in faulldust are very close to the heavy metal concentrations of atmosphere particulate matter, the result indicated that the heavy metal emitted by automobile exhaust gas has no obvious influence on atmospheric heavy metal content in a short time, the disturbance of ground dustfall has a great influence on the concentrations of heavy metals in the atmosphere. The exposure level of PM2.5 and PM10 during haze weather conditions is far greater than exposure level of PM2.5 and PM10 during non-haze weather conditions.

1. Introduction

With the continuous growth of vehicle ownership, vehicle emissions are the main source of urban air pollution in China. Although the emission of particulate matter and its inorganic and organic components in vehicle exhaust is relatively small, it has an important impact on human health due to the presence of many harmful substances. Studies have shown that particulate matter concentrations in traffic micro-environments such as bus stations, intersections and motor vehicles are much higher than the average level of urban areas. Jeannine F. Gent et.al[1] found that children with asthma living in an area of noncompliance with PM2.5 standards, increased risk of daily symptoms and medication use was associated with daily traffic-related fine particle sources.

Hao Jiming et.al[2] analyzed the pollutant emissions related to energy utilization in urban areas of Beijing. The results show that traffic dust has the highest contribution rate to PM10 emissions and concentrations, which are 23% and 32%, respectively, while the emission and concentration contribution rates of motor vehicle exhaust pairs are 8% and 14%, respectively. Zhao Bin et.al [3] estimated the anthropogenic emissions of air pollution in Tianjin, and the total contribution of motor
vehicles and road dust was 18%. Li Xiaoping\cite{4} analyzed the sources of pollutants in the central urban area and industrial areas of Shanghai and found that among the identifiable sources, the central urban area is dominated by atmospheric particulate matter emitted by motor vehicles. Harrison et al.\cite{5} analyzed on the sources of PM10 and PM2.5 in the atmosphere of Birmingham, UK, the result shown that secondary particulate matter is the main sources of PM10 in the region, such as motor vehicle emissions and ammonium salts and dust. In winter, the pollution of motor vehicles is dominant, and its emissions contribute to PM2.5 concentration is 41%. M. P. Fraser\cite{6} analyzed the source of PM2.5 in Houston and found that diesel vehicles have the highest contribution, followed by road dust and gasoline vehicle emissions. Erik Velasco et al.\cite{7} found that stops are hotspots of personal exposure, especially to ultrafine particles, in Singapore, and Commuters breathe on average 3.5 more particles than at ambient level. Du Xuan\cite{8}, Chang Jingjing\cite{9}, Wu Shange\cite{10} and other researcher found that the exposure level of pollutants at bus stations is higher than that of all traffic micro-environments. Jinan City is one of the most polluted cities in China. The number of motor vehicles is large, the bus system is relatively perfect, but there is no urban rail traffic and traffic congestion is serious, so a huge non-motorized travel force has emerged. Air pollution poses a huge health risk to residents' health near the traffic network, especially bus stops.

2. Sampling site and methods

2.1 Sampling site

The sampling site is University of Jinan Bus Stop (UIB Stop) which located in the important traffic artery of Jinan City. The traffic volume is large, and the seven bus lines are stopped here. There are no major pollution sources around. The road is two-way and six lanes. There are 40,000 teachers and students in University of Jinan. It is the largest concentration of floating population in Jinan, around the university. A large number of residents in the vicinity use public transportation during commuting peak hours, so traffic congestion is serious. Average traffic volume is about 28 vehicles per minute from 6:00 to 22:00, and average passenger flow of 30 passengers per minute during peak hours, and a 57-second stop time for each bus.

2.2 Method

From December 12th to 18th, in 2016, the research team used the particle counter for continuous sampling (both working days and weekends), and used the atmospheric particulate sampler to obtain 9-days samples for PM2.5 and PM10. The collection of particulate matter samples during 6:00-22:00. 5 groups of particle samples with particle size of 0.4um, 0.7um, 1.1um, 2.1um, 3.3um, 4.7um, 5.8um, 9.0um, and 10um were collected, with the JMT-3 Aerosol Particle Size Fractionation Sampler; The ZR-3930 Air Particle Sampler was used to sample the PM2.5 and PM10 samples in the same time period, and 5 groups samples were obtained; and 5 groups of road dust samples were collected. Samples were dried in oven at 70°C for 48 h. 0.5g samples were placed in Teflon digestion vessels with 4 ml of ultrapure nitric acid and 2ml ultrapure H2O2 and 1ml ultrapure Hydrofluoric acid, then put Teflon digestion vessel in steel pressure vessel, heating in constant temperature furnace with 170°C for 3h; after digestion, the final extracts were filtered into a 50ml sample, and analyzed for element concentrations by a GFAAF (SHIMADZU AA-7000).

3. Result and discussions

3.1 Weather condition

According to the data analysis of China’s air quality monitoring platform, the air quality index(AQI) was 101-150, air quality is mild pollution, on December 12, 2016; AQI is greater than 300 during December 16th to 18th, which is a serious haze weather process. The formation of this haze weather is obviously related to the weak activity of the cold air in the northern region, and wind speed is small, and inverse atmosphere; When the atmosphere is in a static state, the air level and vertical diffusion
conditions are weak, which tends to cause pollutants to accumulate near the ground, severe haze weather was forming. The pollution processes continued to December 20th, and then gradually weaken.

3.2 Particle concentration analysis
During the observation period, the minimum concentration of PM2.5 is 28.8μg/m³, Dec 13, 2016, and maximum concentration of PM2.5 is 334.7μg/m³, 4 days concentration of PM2.5 less than 115μg/m³, near the bus stop; 3 days PM10 concentration more than 350μg/m³, the maximum concentration of PM10 is 309μg/m³ on Dec 17, 2016, and the minimum concentration of PM10 is 57μg/m³, on Dec 13, 2016. Both PM2.5 concentration and PM10 concentration near UJB Stop are far above the average concentration of PM2.5 and PM10 during the same period in Jinan. The concentration of particulate matter at the bus stops is particularly prominent under smog weather conditions; it has great health risks to the human body.

PM2.5 concentration and PM10 concentration generally showed an upward trend, and the maximum concentration was mainly concentrated at 20:00-22:00, during the observation period (Fig1). During the non-smog weather, the concentration of PM2.5 concentration and PM10 concentration gradually increased gradually at 6:00, and the concentration increased rapidly, when the peak of people flow appeared around 8:00. With the gradual increase of social vehicles, there is a peak at around 11:00. Until around 17:00, the arrival of the late peak caused an increase in the concentration of PM2.5 and PM10, and another peak of PM2.5 concentration and PM10 concentration appeared. During the smog weather, the concentration of PM2.5 concentration and PM10 concentration has been gradually rising gradually from 6:00 to 22:00, and the peak value around 11:00 is not very obvious. The late peak of PM2.5 concentration and PM10 concentration around 17:00 is especially obvious. The gradual accumulation of pollutants throughout the day causes the concentration of pollutants to peak. It is easy to found that comparing the observation data of the bus stop with the average air quality data of the study area, it is found that the PM2.5 concentration and PM10 concentration near the bus stop has a significant peak, and the PM2.5 concentration and PM10 concentration of bus stop due to the frequent start and stop of the bus. In other regions, the PM2.5 concentration and PM10 concentration of bus stop same as other regions during non-public transportation peak period.

Fig.1 The concentration of PM2.5 and PM10 during 6:00-22:00 of Dec.12th-18th,2016
(a is Average concentration of PM2.5 in Jinan City, c is Average concentration of PM10 in Jinan City; b is Average concentration of PM2.5 at UJB Stop, d is Average concentration of PM10 at UJB Stop)
3.3 Heavy metal of atmospheric particulates

The content of heavy metals in the samples was measured by GFAAF (SHIMADZU AA-7000), such as Cr, Mn, Co, Ni, Cu, Zn, Pb, Cd, and Hg (Tab.1).

After samples analyzed, it is found that the content of heavy metals in atmospheric particulates is obviously higher, especially the concentrations of Cd, Cr, Pb and Hg are 59.56, 4.31, 8.68 and 4.19 times of soil background values, respectively, which are obviously enriched. Heavy metals are also enriched, and the concentrations of Mn, Zn and Cu are 1.80, 2.65 and 2.06 times of the soil background value, respectively.

After the analysis of atmospheric dustfall, it is found that the heavy metal concentrations in atmospheric dust is very close to the heavy metal concentrations of atmosphere particulate matter, the result indicated that the heavy metal emitted by automobile exhaust gas has no obvious influence on atmospheric heavy metal content in a short time, but it is the car and pedestrians. The disturbance of ground dustfall has a great influence on the concentrations of heavy metals in the atmosphere.

| Element | Cr (ppm) | Mn (ppm) | Co (ppm) | Ni (ppm) | Cu (ppm) | Zn (ppm) | Pb (ppm) | Cd (ppm) | Hg (ppm) |
|---------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| Average concentration | 227.10 | 876.89 | 11.76 | 31.42 | 37.95 | 151.44 | 197.21 | 2.68 | 0.067 |
| Dustfall (ppm) | 264.70 | 879.00 | 11.56 | 36.21 | 39.89 | 145.34 | 212.78 | 3.16 | 0.035 |
| Background values (ppm) | 52.75 | 486.38 | 11.75 | 26.79 | 18.45 | 57.11 | 22.71 | 0.05 | 0.016 |
| Times a/c | 4.31 | 1.80 | 1.00 | 1.17 | 2.06 | 2.65 | 8.68 | 59.56 | 4.19 |
| Times b/c | 5.02 | 1.81 | 0.98 | 1.35 | 2.16 | 2.54 | 9.37 | 70.22 | 2.19 |

3.4 Risk analysis of human exposure during commutation in haze weather

The health hazard caused by air pollution is the cumulative effect caused by repeated exposures over a long period of time. The degree of hazard not only depends on the concentration of pollutants such as P2.5 and PM10, but also on the exposure time of the population.

Studies have shown that estimates of population exposure and measured values have a good correlation with human exposure (Correlation coefficient is 0.659). Therefore, by estimating the population waiting time stop and the concentration of pollutants at the bus stop to estimate the pollution exposure level of the crowd during the bus exchange, it has practical reference value in evaluating the health effects of the population.

Exposure level calculation formula as follows.

\[ E_i = \frac{\sum C_i \times T_y}{\sum T_y} \]  

\( E_i \) is the time-weighted concentration of the pollutant (unit: \( \mu g/m^3 \))

\( C_i \) is the average concentration of pollutants during the time period (unit: \( \mu g/m^3 \))

\( T_y \) is the value of this period

\( \sum T_y \) is the sum of time

Select the average data of PM2.5 and PM10 concentration monitored during the morning peak period of UJB Stop from 8:00-9:00, assuming that the exposure time of the population is 5 min, calculated by the formula (1).

Exposure level of PM2.5 during haze weather conditions (\( E_h \)), \( E_h = 261.8 \mu g/m^3 \) Exposure level of PM2.5 during non-haze weather conditions (\( E_{non-h} \)). \( E_{non-h} = 78 \mu g/m^3 \)

Exposure level of PM10 during haze weather conditions (\( E_h \)), \( E_h = 329.7 \mu g/m^3 \)

Exposure level of PM10 during non-haze weather conditions (\( E_{non-h} \)), \( E_{non-h} = 88 \mu g/m^3 \)

So exposure level of PM2.5 and PM10 during haze weather conditions (\( E_h \)) are far greater than
exposure level of PM2.5 and PM10 during non-haze weather conditions ($E_{\text{non-h}}$).

The individual exposure level is related to the concentration of pollutants and the exposure time; the individual exposure during the haze weather exchange is higher, which is potentially harmful to the human body. Bus vehicles start and stop frequently, idle speed, the vehicle exhaust emissions are much higher than the time during the speed is stable. The crowds wait and inevitably inhale a large amount of particulate matter at the bus stop.

4. Conclusions

The air pollution cannot be ignored at the bus stops. The concentrations of pollutants are higher near the bus stops because of the frequent start-stop emissions of bus, which brings great risks to the travel crowd. After the analysis concentrations of PM2.5 and PM10 near the UJB Stop found that, PM2.5 concentration and PM10 concentration generally showed an upward trend, and the maximum concentration was mainly concentrated at 20:00-22:00, during the observation period; the concentration of PM2.5 concentration had two peak value, around 11:00 and after 20:00, during the non-smog weather; the concentration of PM2.5 concentration and PM10 concentration has been gradually rising gradually from 6:00 to 22:00, during the smog weather, and the peak value around 11:00 is not very obvious, the late peak of PM2.5 concentration and PM10 concentration around 17:00 is especially obvious. The gradual accumulation of pollutants all day causes the concentration of pollutants to peak value. The PM2.5 concentration and PM10 concentration of bus stop are due to the frequent start and stop of the bus.

The content of heavy metals in atmospheric particulates is obviously higher, especially the concentrations of Cd, Cr, Pb and Hg are 59.56, 4.31, 8.68 and 4.19 times of soil background values, respectively, which are obviously enriched. Heavy metals are also enriched, and the concentrations of Mn, Zn and Cu are 1.80, 2.65 and 2.06 times of the soil background value, respectively. The heavy metal concentrations in falldust is very close to the heavy metal concentrations of atmosphere particulate matter, the result indicated that the heavy metal emitted by automobile exhaust gas has no obvious influence on atmospheric heavy metal content in a short time, the disturbance of ground dustfall has a great influence on the concentrations of heavy metals in the atmosphere.

The exposure level of PM2.5 and PM10 during haze weather conditions is far greater than exposure level of PM2.5 and PM10 during non-haze weather conditions.

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