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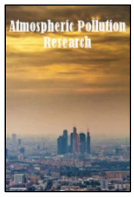

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Urban ambient air quality investigation and health risk assessment during haze and non–haze periods in Shanghai, China

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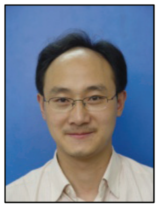
ABSTRACT

Haze pollution has attracted much interest during the past decade for its significant effects on visibility, public health, and even global climate. The main objective of this study is to investigate ambient air quality during haze and non–haze periods and related health hazard for the local residents in Shanghai, China. Different levels, seasonal patterns, and health–risks of air pollutants (PM_{10}, NO_2, and SO_2) in haze and non–haze periods were observed. The results showed that the average PM_{10}, NO_2, and SO_2 concentrations were 110.9 µg/m^3, 67.7 µg/m^3, and 48.8 µg/m^3 in haze periods and 63.6 µg/m^3, 45.3 µg/m^3, and 27.5 µg/m^3 in non–haze periods, respectively. Due to a combination of increased emissions from heating sources coupled with meteorological conditions, PM_{10}, NO_2, and SO_2 levels were highest in winter and lowest in autumn. For the potential health risk analysis, the residents have been divided into four age categories namely, infants, children (1 year), children (8–10 years) and adults. The analysis took into account age–specific breathing rates, body weights for different age categories. Health risks for all age groups in haze periods were higher than those in non–haze periods, and the local residents suffered from the highest health risks due to NO_2 in haze periods.

Keywords: *Haze, ambient air quality, health risk, dose–response*



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1. Introduction

Haze is defined as the weather phenomenon which leads to atmospheric visibility less than 10 km due to the suspended solid or liquid particles, smoke, and vapors in the atmosphere, which seriously affect human health (Yadav et al., 2003; Tan et al., 2009; Duan et al., 2012). Haze pollution has attracted much interest during the past decade for its impact on visibility, public health, and even global climate (Sun et al., 2006; Kim et al., 2008; Tan et al., 2009). Local and regional haze occur frequently in many Chinese cities, mainly caused by emissions from vehicle exhausts, coal combustion, biomass burning, and resuspended dust (Wang et al., 2009; Chen et al., 2012; Duan et al., 2012).

Numerous studies worldwide have confirmed that both long– and short–term exposure to air pollutants are associated with increases in mortality and morbidity (Venners et al., 2003; Kan et al., 2008; Dockery, 2009). According to a World Health Organization (WHO) assessment of the burden of disease due to air pollution, more than two million premature deaths each year can be attributed to the effects of urban outdoor air pollution and indoor air pollution (WHO, 2005), and outdoor air pollution was associated with approximately 300 000 premature deaths per year in China (Cohen et al., 2005). As the largest developing country in the world, China has achieved rapid economic development. However, this success comes at the cost of deterioration of the environment. Air pollution has become one of the top environmental concerns in China.

During the past decade, Shanghai, which is one of the largest cities in China, has undergone the most rapid economic development and urbanization in its history and particulate matter (PM), sulfur dioxide (SO_2), and nitrogen oxides (NO_x) have become the major air pollutants. On January 19, 2007, daily concentration of PM_{10} reached 512 µg/m^3, while the hourly concentrations of $PM_{2.5}$ and PM_{10} reached peak values of 466 µg/m^3 and 744 µg/m^3, respectively (Fu et al., 2008). Epidemiological studies have found outdoor air pollution was associated with increased risk of total and cardiovascular hospital admission in Shanghai (Chen et al., 2010).

High concentrations of $PM_{2.5}$ were observed in haze episodes. Major ionic species (NO_3^-, SO_4^{2-}, and NH_4^+) and organic materials were the two dominant contributors to $PM_{2.5}$ (Kang et al., 2004) and the sulfates were linked to heterogeneous uptake of SO_2 followed by the subsequent catalytic oxidation by oxygen together with iron and manganese (Wang et al., 2012). The high contribution of sulfate and nitrate in haze episodes could be related to the high oxidation rates of SO_2 and NO_x in haze episodes (Sun et al., 2006). Moreover, the concentration level of gaseous pollutants such as SO_2 and NO_2 on the haze pollution day consistently exceeded those before and after the haze air pollution occurrence (Xie et al., 2005). The characteristics of atmospheric carbonyls during haze days in Beijing were studied (Duan et al., 2012). Carbonyl compounds in ambient air were measured in haze and clear days of Guangzhou, the provincial capital of Guangdong province (Lu et al., 2009). A sampling campaign of aerosols over

Urumqi, the capital city of Xinjiang Uygur Autonomous Region, was carried out to investigate the severe air pollution and the chemistry of heavy haze (Li et al., 2008). The vertical distributions of optical and micro–physical properties of ambient aerosols during haze periods in Shanghai have been revealed recently (Chen et al., 2012). Moreover, population exposures and the corresponding health risks of particulate matter in the ambient air of Yangtze River Delta Region (YRDR) were reported recently (Zhou et al., 2010; Zhao et al., 2011). As inhalable particulate pollutant, PM_{10} is of primary concern and the potential health risks associated with exposure to PM_{10} have been evaluated in recent studies (Castro et al., 2011; Xie et al., 2011).

Nevertheless, to our best knowledge, there is still poor understanding of health risks in haze periods and non–haze periods due to air pollutants exposure in China. Thus, in the present work, the levels and health–risks of pollutants (PM_{10}, NO_2, and SO_2) in haze and non–haze periods in Shanghai has been investigated through risk–based approach and the new information about the relationship between health risks and air pollution in Shanghai, which may have implications for local environmental and social policies.

2. Materials and Methods

2.1. Data

This study was initiated on January 1, 2009 and continued until December 31, 2009. PM_{10}, NO_2, and SO_2 concentrations were continuously measured at six fixed–site stations (Hongkou, Jin'an, Luwan, Putuo, Xuhui, and Yangpu) under China National Quality Control for Air Monitoring located in different areas of Shanghai. The monitoring system in Shanghai, which includes the choice of the monitor locations, has been certified by the China State Environmental Protection Agency (Chen et al., 2010), and the specific location of the monitor locations have been made public by Shanghai Environmental Protection Bureau (SEPB, 2013). The methods based on Tapered Element Oscillating Microbalance (TEOM), ultraviolet fluorescence, and chemiluminescence were used for the measurement of PM_{10}, NO_2, and SO_2, respectively (Cao et al., 2009). The 1 095 daily records of the concentrations of PM_{10}, NO_2, and SO_2 were obtained from the data base of SEPB.

Haze formation is closely related to meteorological conditions and air pollution. Urban haze generally results from high levels of air particles emitted by anthropogenic sources and gas–to–particle conversion (Tan et al., 2009). Haze is defined as the weather phenomenon which leads to atmospheric visibility less than 10 km due to the suspended solid or liquid particles, smoke, and vapors in the atmosphere. Haze events are characterized by low visibility, low wind speed, high relative humidity, and high levels of SO_2 and NO_x (Tan et al., 2009). The exact dates on which haze weather happened were obtained from Shanghai Environmental Monitoring Center (SEMC).

The health outcomes due to ambient air pollution include mortality, chronic morbidity, hospital admissions and outpatients, and decline in lung function. Compared with adults, children are more vulnerable to particulates and gaseous pollutants in the air because of their immature immune systems. Moreover, children have differential abilities to metabolize and detoxify environmental agents and have an airway epithelium that is more permeable to inhaled air pollutants (Schwartz, 2004). Daily hospital admission counts of children with respiratory diseases from the pediatric department of Shanghai Sixth People's Hospital and Children's Hospital of Fudan University were collected. The causes of hospital admission were coded according to International Classification of Diseases, Revision 10 (ICD–10).

2.2. Health risk assessment

The assessment of health risks of the population associated with inhalation exposure of PM_{10}, NO_2 and SO_2 was based on the estimated dose rates and the lowest observed adverse effect levels (LOAELs).

The Health risks assessment is age–specific. The population is divided into four age–specific categories namely, new born, children (1 year), children (8–10 years) and adults (Cerna et al., 1998). The dose rate for each pollutant has been estimated through the following expression (Pandey et al., 2005; Kalaiarasan et al., 2009):

$$Dose\ rate(D) = (BR/BW)\int_0^{24} C(t)OF(t)\,dt \qquad (1)$$

where, *D* is the age–specific dose rate (μg/kg); *BR* is age–specific breathing rate (L/min); *BW* is age–specific body weight (kg); *C*(*t*) is the concentration of each pollutant (μg/m^3); *OF*(*t*) is occupancy factor (percentage of population likely to be in the building at a given interval of time). For each pollutant, we assume that the indoor and outdoor concentrations to be equal. Thus, *OF*(*t*) equals to 1. The uncertainties due to this assumption will be discussed hereinafter. Since there are no data in China on age–specific breathing rates, age–specific body weights, the values reported by Cerna et al. (1998) are used as shown in Table 1.

Table 1. *Breathing rates, body weights, and LOAEL values for morbidity*

Age category	Inhalation volume (m^3/day)	Body weight (kg)	LOAEL (μg/kg)
New born	20	70	15.7
Children(1 year)	10	30	27.5
Children(8–10 years)	3.8	10	20.9
Adult	0.8	3	14.7

LOAELs are defined as the lowest tested doses of pollutants that have been reported to cause harmful (adverse) health effects on people or animal. LOAELs for PM_{10} and SO_2 were taken from Cerna et al. (1998) as average of morbidity values (Table 1). While for estimating the LOAEL value for NO_2, the following dose–response model was constructed on the basis of data available in Neuberger et al. (2002):

$$Y = 103.6X^{-0.1003} \qquad (2)$$

where *Y* is the response (in terms of % end–expiratory flow rates), *X* is dose rates (μg/kg) for children estimated from the corresponding values given for NO_2 in Neuberger et al. (2002). The dose value at which end–exspiratory flow rate becomes lower than 100% was taken as the LOAEL value for NO_2 (Pandey et al., 2005).

Thus, the health risks have been defined by the following equation (Pandey et al., 2005; Kalaiarasan et al., 2009; Castro et al., 2011; Zhao et al., 2011):

$$Health\ Risk\,(HR) = [(dose\,rate)/(pollutant - specific\ LOAEL)] \qquad (3)$$

If the dose rate exceeds LOAEL, there may be concern for potential health risk of residents associated with inhalation exposure of air pollutants. HR is dimensionless and useful for making relative comparisons.

3. Results and Discussions

3.1. Comparison of annual average Concentrations of PM_{10}, NO_2, SO_2 during haze and non–haze periods

There were 134 haze days in Shanghai in 2009, during which the average PM_{10}, NO_2, and SO_2 concentrations were

110.9±49.5 μg/m^3, 67.7±20.4 μg/m^3, and 48.8±24.4 μg/m^3, respectively. The other 231 days were non–haze days, during which the average PM_{10}, NO_2 and SO_2 concentrations were 63.6±36.8 μg/m^3, 45.2±14.5 μg/m^3, and 27.5±13.2 μg/m^3 respectively (Table 2). The values were analyzed statistically using the Student's t–test and the result showed that there was significant difference between them (P<0.01). The average PM_{10}, NO_2, and SO_2 concentrations during haze periods were 1.74, 1.50, and 1.78 times the values of those during non–haze periods, indicating that pollution of PM_{10}, NO_2, and SO_2 in haze periods was more serious than that in non–haze periods. The average PM_{10} and SO_2 concentrations during the haze period and PM_{10} concentration during the non–haze period exceeded the national ambient air quality standard Grade I (50 μg/m^3 for PM_{10} and SO_2; GB3095–1996) and the average SO_2 concentration in non–haze period and NO_2 concentration during haze and non–haze periods were within the limit of the national ambient air quality standard Grade I (80 μg/m^3 for NO_2; GB3095–1996). According to "WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide" (WHO, 2006), annual average concentration limit of PM_{10} and NO_2 are 20 μg/m^3 and 40 μg/m^3 respectively. All the annual average concentrations of PM_{10} and NO_2 were over the concentration limits of "WHO Air quality guidelines". The PM_{10} concentrations were similar to those reported for other densely populated regions of China, such as Beijing (142.0 μg/m^3, Chan and Yao, 2008) and Guangzhou (134.0 μg/m^3, Wan et al., 2011), but were substantially higher than those reported for big cities in Europe and East Asia, such as Dublin, Ireland (18.0 μg/m^3, EPA Ireland, 2007) and Tokyo, Japan (29.0 μg/m^3, Tokyo Metropolitan Government Bureau of General Affairs, 2007). The mean values of PM were comparable to values reported earlier for Dayalbagh and St. John's in India (Kumar et al., 2007a). NO_2 concentrations were also higher than those reported for big cities in Europe, such as Antwerp, Belgium (38.9 μg/m^3, Stranger et al., 2009). A recent report showed that the average outdoor level for NO_2 in Stockholm, Sweden was only 12.4 μg/m^3 (Wichmann et al., 2010). The average SO_2 concentrations in Shanghai were also very high, compared to the big cities in Europe and North America, such as Antwerp, Belgium (4.8 μg/m^3, Stranger et al., 2009) and Boston, USA (32.3 μg/m^3 in winter, 10.3 μg/m^3 in summer, Brown et al., 2009).

3.2. Seasonal variation of PM_{10}, NO_2, and SO_2

Comparison of monthly average concentrations of PM_{10}, NO_2, and SO_2 during haze and non–haze periods is shown in Figure 1. The highest PM_{10} levels during haze and non–haze periods were 150.3 μg/m^3 in October and 99.2 μg/m^3 in December, respectively. The highest NO_2 and SO_2 levels during haze periods were both found in December, which turned out to be 80.7 μg/m^3 and 79.6 μg/m^3, respectively. The respective highest levels during non–haze periods were 56.1 μg/m^3 in March and 41.6 μg/m^3 in December.

PM_{10}, NO_2, and SO_2 levels were highest in winter, followed by spring and summer, with lowest concentrations in autumn (Table 2). Furthermore, there were more haze days in winter (18 days for December) than summer (9 days for July). The high PM_{10}, NO_2, and SO_2 levels and higher frequency of occurrence of haze events in winter were most likely due to a combination of increased emissions from heating sources coupled with meteorological conditions. It's reported that air parcels arriving in Shanghai in the summer were mainly from the East China Sea and carried clean air. On the other hand, air parcels arriving in Shanghai in the winter were from the Northeast (Yellow Sea) to Northwest (inland) directions and carried polluted air from Jiangsu province (Feng et al., 2006). The variations were consistent with the studies on other Chinese cities, such as Beijing (He et al., 2001), Guangzhou, Hong Kong (Cao et al., 2003a; Cao et al., 2003b), and Nanjing (Wang et al., 2003).

The children were presumed to be more vulnerable and at greater risk for air pollution–related effects (Gouveia and Fletcher, 2000; Schwartz, 2004). In 2009, a total of 271 580 hospital admissions were recorded for pediatric department of Shanghai Sixth People's Hospital and Children's Hospital of Fudan University. Average daily admissions of pediatric department during the winter (November, December, and January) were 455.2 and 405.6 for the two hospitals respectively, while the average admissions for the year of 2009 were 356.4 and 262.6 respectively (Table 2). The greater number of pediatric outpatients in winter could be due to many reasons, such as influenza season, haze pollution exposure, etc.

Table 2. *Hospital admissions and average concentrations of PM_{10}, NO_2, and SO_2*

	Average daily admissions (Mean±SD)		Pollutant concentrations (μg/m^3)		
	Hospital A[a]	Hospital B[b]	PM_{10}	NO_2	SO_2
January	294.4±76.0	231.5±83.7	83.0±64.7	60.8±18.3	50.8±24.6
February	258.7±30.4	245.9±43.5	75.0±43.6	53.6±13.4	34.0±16.2
March	334.5±32.4	308.5±53.5	83.3±45.7	61.2±19.9	35.8±16.0
April	330.4±26.4	321.2±30.9	86.1±43.7	56.2±23.0	32.9±16.1
May	359.8±34.9	339.1±35.5	79.6±29.5	55.4±15.2	36.0±13.7
June	363.3±32.3	340.1±32.4	88.1±48.9	49.4±18.7	32.2±14.5
July	355.8±34.2	338.5±37.5	58.8±22.3	42.1±14.0	26.3±7.0
August	447.1±90.8	368.8±54.4	60.3±31.0	34.4±13.1	22.6±6.1
September	458.3±39.7	424.7±37.5	53.6±15.6	40.6±11.0	18.8±7.4
October	406.2±97.3	383.2±96.7	96.6±46.2	57.5±18.8	29.0±11.6
November	604.1±138.9	541.8±88.9	84.4±46.1	61.9±21.8	40.5±24.0
December	471.7±74.4	447.8±65.3	121.8±69.8	69.1±21.6	63.6±31.4
Winter	455.2±161.5	405.6±152.6	96.5±63.2	63.9±20.7	51.8±28.2
haze	373.6±108.4	338.9±99.5	110.9±49.5	67.7±20.4	48.8±24.4
non–haze	401.6±110.9	370.8±96.7	63.6±36.8	45.2±14.5	27.5±13.2
Year of 2009	356.4±98.5	262.6±70.6	81.0±47.7	53.5±20.1	35.3±20.8

[a] *Hospital A: Shanghai Sixth People's Hospital*
[b] *Hospital B: Children's Hospital of Fudan University*

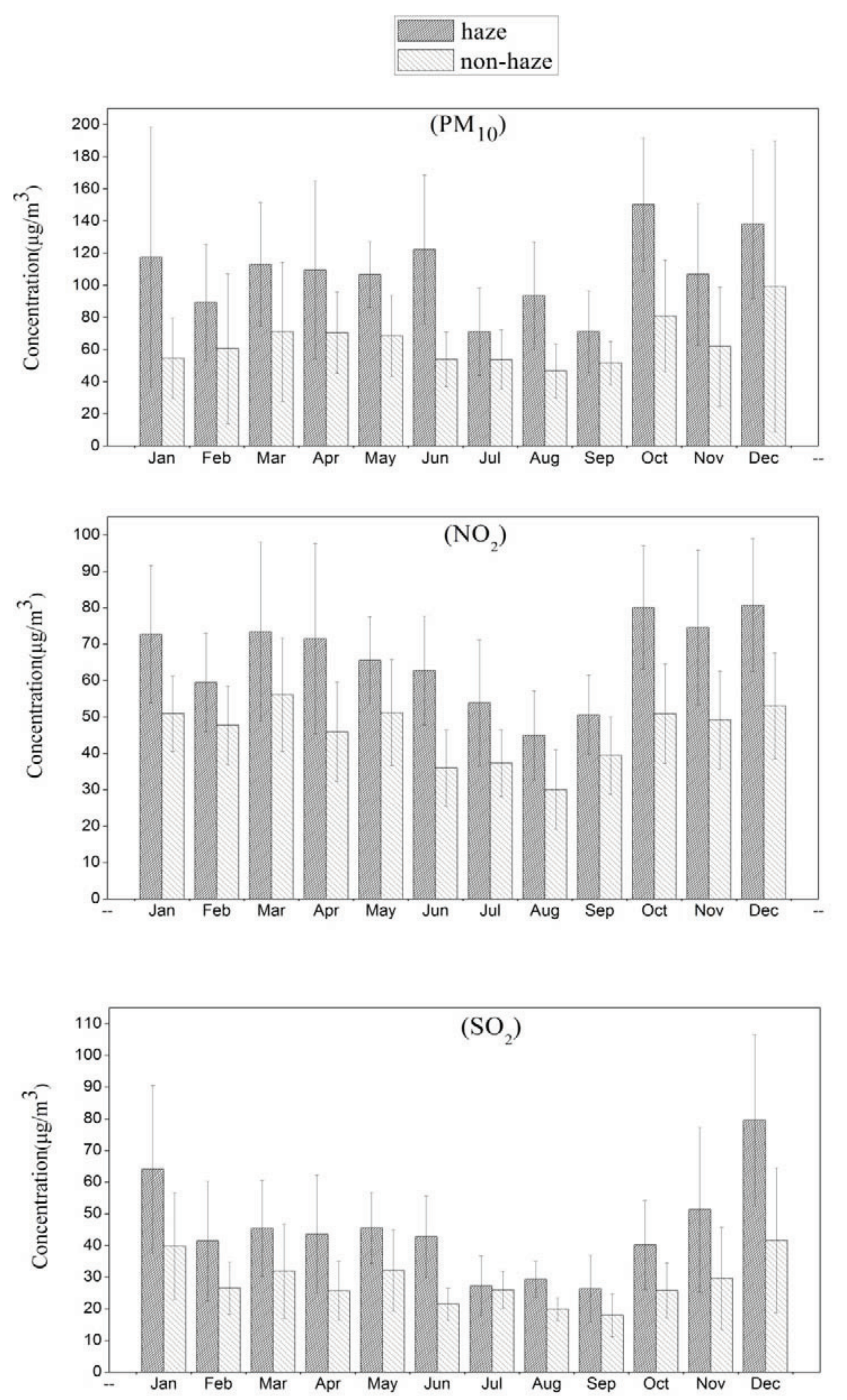

Figure 1. *Monthly average concentrations of PM_{10}, NO_2, and SO_2 during haze and non–haze periods.*

3.3. Health risk assessment

Dose rates, obtained for four age groups and for different pollutants under different weather conditions (haze periods and non–haze periods) are shown in Table 3. It's observed that dose rates for all age groups in haze periods were higher than those in non–haze periods, which indicated that the health risks for all age groups in haze periods are higher than those in non–haze periods. At the same time, dose rates for children (1 year) were always higher than those for the other age groups, which indicated that the young children could have higher health risks. However, health risk was estimated as a function which was proportional to the dose rates and inversely to the LOAEL values. The lower the value of pollutant–specific LOAEL, the higher is the health risk. Similarly, the higher is the dose rate, higher is the health risk. Comparison of HR values, which are shown in Table 3, indicated that health risks for all age groups in haze periods were also always higher than those in non–haze periods. However, average daily hospital admissions of pediatric department of Shanghai Sixth People's Hospital and Children's Hospital of Fudan University during the non–haze period were higher than haze periods (Table 2). The finding of the lag structure is consistent with our prior study on the correlation analysis of the concentrations of $PM_{2.5}$ and PM_{10} and the number of outpatient visits in Shanghai (Yin et al., 2011) and several other air pollution health studies in Shanghai (Cao et al., 2009), Taiwan (Bell et al., 2008), and USA (Dominici et al., 2006). Statistically significant associations were observed for some lag structures of pollutants' concentrations in Shanghai, and outpatient visit was statistically significantly associated with 3–day lagged pollution for NO_2 and SO_2 (Cao et al., 2009). The correlation analysis between the concentrations of $PM_{2.5}$ and PM_{10} in the haze periods and the number of outpatients of the breathing sections and the breathing sections of pediatrics of 6 major hospitals in Shanghai had been studied previously and the results showed that PM_{10} and $PM_{2.5}$ could have cumulative effects and the number of outpatient visits reached its maximum level 6 days after the haze pollution occurred (Yin et al., 2011).

The local residents suffered from the highest health risks due to NO_2 in haze periods (Table 3). The lowest health risk was due to PM_{10} for Children (8–10 years) in the non–haze periods (0.77). The health risks due to NO_2 were about 8.02 times more risky than PM_{10} and about 6.58 times more risky than SO_2. NO_2, which is an indicator of traffic–related air pollutants, turns out to be the most risky pollutant in Shanghai (Table 3). Ambient air NO_2 level has been increasing due to the increased number of motor vehicles. Coal has been and is still the major source of energy in China. However, ambient air pollution in large cities, such as Beijing and Shanghai, has changed from the conventional coal combustion type to a mixture of coal–combustion and motor–vehicle emissions type (Chen, et al., 2004). NO_2 has long–term effects on respiratory systems and it results in decreasing lung function in children (Neuberger et al., 2002; Neuberger et al., 2004; Meng et al., 2012). However, an earlier study revealed that PM_{10}, NO_2, and SO_2 were relatively highly correlated with each other (Pearson correlation coefficients ranged from 0.64 to 0.73), which limited the ability to separate the independent effect for each pollutant (Kan et al., 2008). It's also found that gaseous pollutants (SO_2 and NO_2) had stronger health effects than particulate matter in Shanghai (Chen et al., 2004). Outdoor air pollution (SO_2 and NO_2) was associated with increased risk of hospital outpatient and emergency room visits in Shanghai. A 10 $\mu g/m^3$ increase in concentrations of PM_{10}, NO_2, and SO_2 corresponded to 0.11%, 0.34%, and 0.55% increase of outpatient visits; and 0.01%, 0.17%, and 0.08% increase of emergency room visits respectively (Cao et al., 2009).

3.4. Limitations, uncertainties and assumptions

Levels, seasonal variations, and health risks of PM_{10}, NO_2, and SO_2 in haze and non–haze periods and the related health risks for the residents of Shanghai in 2009 have been studied quantitatively. Our analysis had strengths and limitations. The estimation of exposure and health risks in this study was based on the outdoor air pollution. However, people spend approximately 90% of their time indoors (Sexton et al., 2004). Theoretically the indoor level depends on the outdoor level, the air exchange rate, the penetration factor, the decay rate, the emission due to indoor sources and indoor volume. Thus, the estimation of indoor PM_{10}, NO_2, and SO_2 levels was with great difficulty. In the past decade a number of studies investigated the indoor–outdoor (I/O) ratio of PM_{10}, NO_2, and SO_2 levels (Kumar et al., 2007b; Klinmalee et al., 2009; Stranger et al., 2009; Pekey et al., 2010; Wichmann et al., 2010; Chithra and Nagendra, 2012; Pegas et al., 2012). The indoor PM_{10}, NO_2, and SO_2 levels could be higher or lower than outdoor levels. The difference between these outdoor values and the true exposures was an inherent and unavoidable type of measurement error. However, PM_{10}, NO_2, and SO_2 indoor levels had strong associations with outdoor levels. Thus, the indoor and outdoor concentrations of PM_{10}, NO_2, and SO_2 were assumed to be equal in our study and *OF(t)* equals to 1. For risk analysis, the current estimation is age–specific. Gender–specific data and specific data for elderly people were not available, thus limiting our ability to identify the risks of subgroups susceptible to air pollution exposure. Moreover, there is a lack of some parameters used in the HR model, and the investigation of the lag structure of between hospital admission and exposure to haze pollution still remains to be further investigated.

For quantifying the impact of air pollution on human health, normally three types of approaches are used: meteorological approach, risk–based (exposure, dose rates) approach and epidemiological approach (Pandey et al., 2005; Zhao et al., 2011). Most of air pollution health studies were carried out through the epidemiological approach, which studied the health outcomes such as hospital admissions, disease rates, mortality, and potential mechanisms of biological effects. The objectives of this study are to investigate the exposure and health risks of the air pollutants through a risk–based approach, and to attempt to provide new information about the relationship between health risks and air pollution in Shanghai, which may have implications for environmental and social policies.

4. Conclusion

This study provides the levels, seasonal variations, and the health risks assessment of pollutants (PM_{10}, NO_2, and SO_2) in the ambient air of haze and non–haze periods in Shanghai. The average PM_{10}, NO_2, and SO_2 concentrations during haze periods were 1.74, 1.50, and 1.78 times the values of those during non–haze periods, respectively. Due to a combination of increased emissions from heating sources coupled with meteorological conditions, PM_{10}, NO_2, and SO_2 levels were highest in winter and lowest in autumn. Health risks for all age groups in haze periods were higher than those in non–haze periods. The local residents suffered from the highest health risks due to NO_2 in haze periods.

Table 3. *Dose rates and health risk values for different age categories due to PM_{10}, NO_2, and SO_2 in haze and non–haze periods*

	Dose rate (μg/kg)				HR (dimensionless)			
	New born	Children (1 year)	Children (8–10 years)	Adult	New born	Children (1 year)	Children (8–10 years)	Adult
PM_{10} (haze)	31.56±14.13	55.55±24.75	28.01±12.54	29.69±13.23	2.01±0.90	2.02±0.90	1.34±0.60	2.02±0.90
PM_{10} (non–haze)	18.06±10.52	31.90±18.43	16.09±9.41	17.05±9.85	1.15±0.67	1.16±0.67	0.77±0.45	1.16±0.67
NO_2 (haze)	253.40±76.30	444.68±134.20	225.30±67.93	237.99±71.74	16.14±4.86	16.17±4.88	10.78±3.25	16.19±4.88
NO_2 (non–haze)	169.40±40.51	297.28±135.58	150.69±63.54	159.05±29.11	10.79±2.58	10.81±4.93	7.21±3.04	10.82±1.98
SO_2 (haze)	38.47±19.31	67.93±33.83	34.28±17.14	35.87±17.93	2.45±1.23	2.47±1.23	1.64±0.82	2.44±1.22
SO_2 (non–haze)	21.67±10.36	38.23±18.43	19.23±9.20	20.29±9.70	1.38±0.66	1.39±0.67	0.92±0.44	1.38±0.66

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