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Study on the Sensitivity Indicators by Sandstorm PM_{10} Exposure

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Abstract

Objective: PM_{10} is one of the typical pollutants involved with sandstorm. More and more attentions on the sensitive bio-marks by PM_{10} exposure are attracted. This study is to probe the sensitivities indicators' levels by sandstorm PM_{10} exposure.
Methods: A cross-sectional study involving administration on a survey 150 residents in Erlianhaote was performed. PM_{10} concentrations collected on a daily basis from the local monitor stations from March to June, 2016 were employed as the daily environmental exposure levels (DEEL). Indicators of IGM, CRP, CC16, IL16, IGA, LGG, IGE and IL8 were assayed, as well as questionnaire for individual disease histories were done.
Results: Results indicated that PM_{10} exposure level was positively related to IGG, IGM, IGA, LGG and CRP, age was positively related to CRP and LGG, and history of cardiovascular disease was related to CRP by multi-factor line regression analysis. Further analysis revealed that levels of IGG ($p < 0.01$) and IGM ($p < 0.05$) increased in the group with PM_{10} DEEL exceeded 200 $\mu g/m^3$, compared to the group with the average exposure levels less than 200 $\mu g/m^3$; while levels of IGM ($p < 0.05$), IGA ($p < 0.05$), LGG ($p < 0.05$) and CRP ($p < 0.01$) were found higher in the group with PM_{10} DEEL exceed 300 $\mu g/m^3$, compare to the group with the levels less than 300 $\mu g/m^3$.
Conclusion: Our findings suggest that sandstorm PM_{10} exposure might contribute to the changes of some immune and inflammation index. These findings provide clinical indicators for the sandstorm PM_{10} exposure and help to understand the risk of sandstorm pollution.

Keywords: Particle matter (PM_{10}), Sandstorms, Sensitivity indicators

Introduction

Asian dust storm plays a major role on the air quality of the densely populated areas of China, Korea and Japan, and is also important to the global dust cycle. In extreme cases, it may cause human lives loss and disruptions of social and economic activities. Particle matter 10 (Particle matter 10, PM_{10}) is one of the typical air pollutants of dust storms. Prolonged exposure to high concentration PM_{10} may bring certain health risk. There is a close, quantitative relationship between PM_{10} exposure and increased morbidity[1]. A study of air pollution on health in European reported that if PM_{10} concentration increased by per 50 $\mu g/m^3$, total mortality in West European cities would rise by 2.1%[2]. Another study reported that a 0.65% risk of hospitalization for MI would rise with per 10 $\mu g/m^3$ outdoor PM_{10} concentration increase[3]. Besides that, chronic exposure to PM_{10} contributes to the risk of developing cardiovascular and respiratory diseases, as well as lung cancer[4].

Until now, many researchers have paid more and more attentions on the sensitivity indicators by PM_{10} exposure. It is crucial to identify the risk by sandstorm PM_{10} exposure on clinic, and helps to quantity the hazard of sandstorm PM.

Animal models reported an indicator BALF (Bronchoalveolar lavage fluid, BALF) increased when exposed to mixture atmosphere pollutants with PM_{10},

SO_2, NO_2 and CO, and some prion inflammatory factors were also found changed, which included IL-1 (interleukin-1, IL-1), IL-6 (interleukin-6), IL-10 (interleukin-10, IL-10), IL-13 (interleukin-13, IL-13), IFN-γ (Interferon-γ, IFN-γ), CC16 (16 kDa Clara cell protein, CC16), TNF-α (tumor necrosis factor 2 alpha) and Cytokines. These indicators were recommended to be bio-marks for acute inflammation[5,6]. Another research revealed that IL-1β (interleukin-1, IL-1β), ICAM-1 (intercellular cell adhesion molecule-1, ICAM-1), COX-2 (Cyclooxygenase, COX-2) and iNOS (inducible nitric oxide synthase, iNOS) were found altered by air PM exposure in rat models, and the counterpart histological change associated with the genes expression were verified, thus they were thought as sensitivity indicators. Additionally[7]. PM_{10} exposure induced the expression of messenger RNA and cytokine production[8], altering the immune function and influencing the serum immunoglobulin E (IGE) level, even the effects were associated to PM constitutes[9]. In summary, high PM_{10} exposure has been proved to damage the immune system and induce the disorder of equilibrium pressure balance in cell. The average level of IL-6 in people exposed to PM_{10} (446.5 ± 59.8, ng/L) was reported higher than that of the control groups (56.3 ± 9.1, ng/L) ($p < 0.05$), and similar trends were found in other indicators of IL-8 and TNF ($p < 0.05$). Additionally, not all of the indicators appeared the elevated trend. the level of IFN-γ (Interferon-γ) in exposed people (18.6 ± 1.8, ng/L) were found lower than the control group (20.3 ± 0.8, ng/L) ($p < 0.05$)[10], further analysis the change of this indicator revealed that PM exposure may induce oxidative stress disorder in the asthma and the COPD (chronic obstructive pulmonary disease, COPD), and free radical activities were associated with the inflammation and epithelial factors of lung injury[11].

Although there are some conclusions on PM_{10} exposure and effects, the current available information is unclear on describing the relationships between sandstorm PM_{10} dose and the sensitive indicators. Therefore, this study aims to establish the relationship between sandstorm PM_{10} exposure and the serum sensitive biomarkers.

Results

The Daily environmental exposure levels (DEEL) were summarized (Figure 1). It pictured out PM_{10} profiles (Figure 1), suggesting some several sandstorms

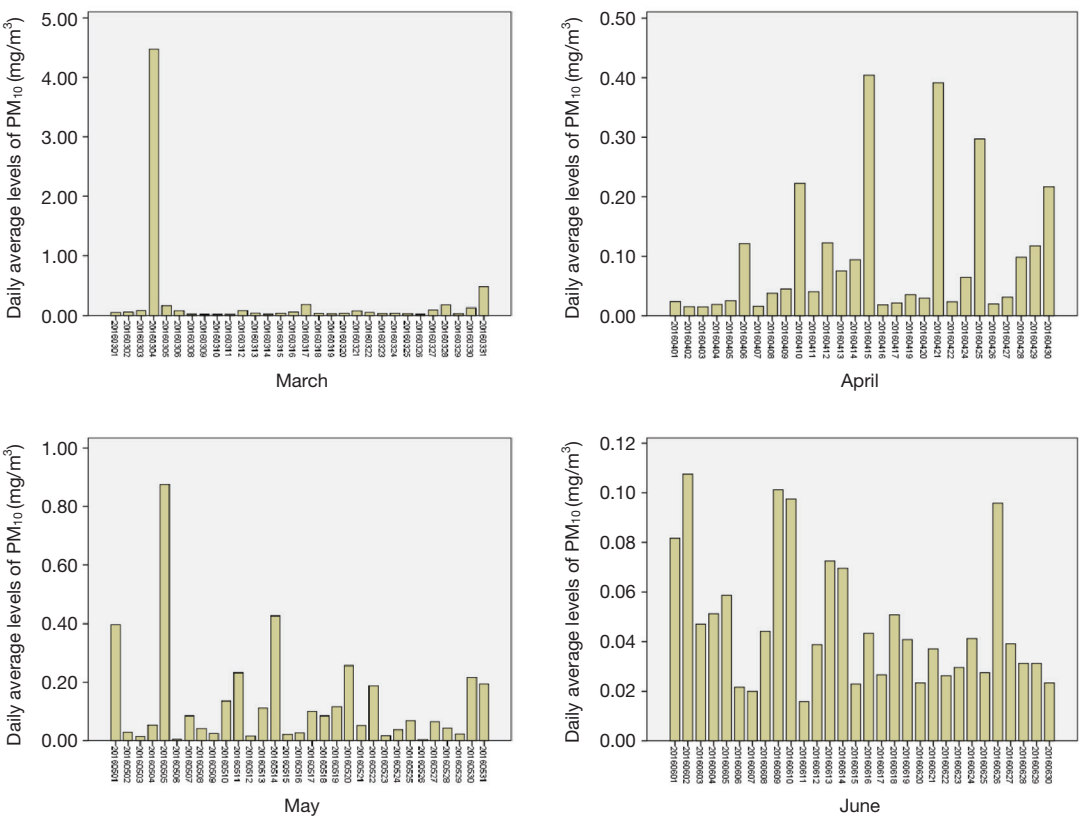

Figure 1. Daily average PM_{10} environmental concertration (mg/m^3).

Table 1. Summary of the paticipation.

	Ages scope	Percentage	The number of the paticipation
Ages	21-30	21.94	150
	31-40	23.74	
	41-50	32.73	
	51-60	21.58	
Gender	Male	55.4	
	Female	44.6	
Occupation	Herdsman	34.5	
	Officeman	65.5	
Exposure patterns on the transportation mode	Wearing mask during the sandstorm	25.3	
	No any pretection during the sandstorm	74.7	
Education degree	> Undergraduate	52.4	
	High school-Undergraduate	23	
	< High school	24.6	
Ethnic	Chinese	83.0	
	Mongolian	17.0	

Table 2. Relationship between PM_{10} and the indicators.

	PM_{10}	IGM	CRP	CC16	IL16	IGA	LGG	IGE	IL8
PM_{10}	1	0.296**	0.316**	0.199*	0.178	0.273**	0.338**	0.303**	0.112
IGM	0.296**	1	0.745**	0.562**	0.617**	0.701**	0.582**	0.693**	0.430**
CRP	0.316**	0.745**	1	0.501**	0.570**	0.558**	0.497**	0.687**	0.439**
CC16	0.199*	0.562**	0.501**	1	0.436**	0.583**	0.531**	0.639**	0.359**
IL16	0.178	0.617**	0.570**	0.436**	1	0.431**	0.463**	0.570**	0.339**

**Correlation is significant at the 0.01 level (two-tailed).
*Correlation is significant at the 0.05 level (two-tailed).

took place from March to June, 2016. A strong sandstorm happened, with the daily average PM_{10} level once reached 4.47 mg/m^3 in the March 4.

We performed questionnaire to all the participants, which include gender, ages and the exposure patterns on their transportation modes (Table 1). Only one correlation were found the significance, which was exposure patterns and IGE ($p < 0.05$) (not shown here). The exposure patterns was classified into two types, that was whether people would take the protective way during the sandstorm subjectively, such as wearing mask or not. No correlations were verified between factors of education, types of the occupation, ethnic and indicators but ages. Through multi-factors line regression analysis, age was positively related to CRP and LGG ($p < 0.05$) (not shown here).

Indicators of IGM ($p < 0.01$), CRP ($p < 0.01$), CC16 ($p < 0.05$), IGA ($p < 0.01$), LGG ($p < 0.01$) and IGE ($p < 0.01$) were shown to have correlations with PM_{10} concentration (Table 2), and several indicators were cross-correlated (Table 2). For instance, IGM had the tightly correlations with CRP (0.745, $p < 0.01$), CC16 (0.562, $p < 0.01$), IL16 (0.617, $p < 0.01$), IGA (0.701, $p < 0.01$), LGG (0.582, $p < 0.01$), IGE (0.693, $p < 0.01$) and IL8 (0.430, $p < 0.01$), respectively (Table 2). Similar results were found in other indicators. Findings suggested that some indicators may be altered by ambient PM_{10}, meanwhile, indicator itself may be changed by each other.

The daily average PM_{10} levels were then calculated based on hourly data from local monitor stations, including the day people registered and the lagged two days. The average exposure level was weighed for the following estimation of dose-effects. DEEL PM_{10} was ranked with different exposure levels. Firstly, participations were divided into two groups by DEEL ranked by 200 μg/m^3. All people's DEEL below 200 μg/m^3 were designated as group I, while the left were named as group II. Some immune system indicators of IGM (Immunoglobulin M, IGM) and IGG (immunoglobulin G, IGG) were related to the DEEL of 200 μg/m^3 ($p <$ 0.05) (Table 3). IGG was rather sensitive to the expo-

Table 3. Daily average exposure level grouped by 200 μg/m^3.

	Indicators (Mean ± SD)							
	IGM (ng/mL)	CRP (pg/mL)	CC16 (pg/mL)	IL16 (ng/L)	IGA (ng/mL)	IGG (μg/mL)	IGE (μg/mL)	IL8 (pg/mL)
Group I (average exposure levels < 200 μg/m^3)	59.6 ± 40.6	0.6 ± 0.4	3.7 ± 2.1	100.1 ± 38.1	205.6 ± 151.0	27.7 ± 13.6	0.5 ± 0.3	272.8 ± 449.0
Group II (average exposure levels ≥ 200 μg/m^3)	81.3 ± 53.0	0.7 ± 0.8	4.4 ± 2.4	109.2 ± 69.4	263.5 ± 174.2	44.4 ± 21.0	0.6 ± 0.4	335.9 ± 391.1
P-value[a]	*	ns	ns	ns	ns	**	ns	ns

P-value[a]. Mean levels testing for significant differences between the two study groups.
ns, not significant. **mean difference of groups (group I with the average exposure levels < 200 μg/m^3 vs group II with the average exposure levels ≥ 200 μg/m^3). $p < 0.01$; *mean difference of groups (group I with the average exposure levels < 200 μg/m^3 vs group II with the average exposure levels ≥ 200 μg/m^3). $p < 0.05$.

Table 4. Daily average exposure level grouped by 300 μg/m^3.

	Indicators (Mean ± SD)							
	IGM (ng/mL)	CRP (pg/mL)	CC16 (pg/mL)	IL16 (ng/L)	IGA (ng/mL)	IGG (μg/mL)	IGE (μg/mL)	IL8 (pg/mL)
Group I# (average exposure levels < 300 μg/m^3)	63.3 ± 34.7	0.6 ± 0.3	3.9 ± 2.0	101.6 ± 47.7	213.4 ± 146.2	31.6 ± 25.4	0.5 ± 0.4	272.8 ± 449.0
Group II# (average exposure levels ≥ 300 μg/m^3)	92.5 ± 44.9	1.0 ± 0.3	4.4 ± 2.6	114.7 ± 72.5	303.4 ± 219.8	47.8 ± 35.6	0.7 ± 0.5	335.9 ± 391.1
P-value[a]	*	**	ns	ns	*	*	ns	ns

P-value[a]. Mean levels testing for significant differences between the two study groups.
ns, not significant. **mean difference of groups (group I with the average exposure levels < 300 μg/m^3 vs group II with the average exposure levels ≥ 300 μg/m^3). $p < 0.01$. *mean difference of groups (group I with the average exposure levels < 300 μg/m^3 vs group II with the average exposure levels ≥ 300 μg/m^3). $p < 0.05$.

sure concentration. IGG levels in group with the PM_{10} exposure level higher that 200 μg/m^3 had the elevated levels (44.4 ± 21.0, μg/mL) than the group with less level than 200 μg/m^3 ($p < 0.01$). Considering both IGM and IGG correlated to PM_{10} level (Table 2), we speculated that several immune system enzymes may be impacted by PM_{10} exposure, on condition that DEEL of PM_{10} exceed 200 μg/m^3.

On the other hand, participants were divided into another two groups by ranking DEEL PM_{10} as 300 μg/m^3 (group I#: the average ambient PM_{10} level was less than 300 μg/m^3; group II#: the average ambient PM_{10} level was higher than 300 μg/m^3). Some immune system indicators, IGM and LGG, illustrated the increased level with ranked PM_{10} level of 300 μg/m^3 (Table 4). IGA, were found more elevated trend in the ranked 300 μg/m^3 group to the ranked 200 μg/m^3 group. Additionally, indicator CRP, relating to the onset of inflammation, showed the tightly correlation with the ambient PM_{10} levels ($p < 0.01$) (Table 4). Furthermore, IGM, IGA, LGG in group II# had higher values than that of Group I# ($p < 0.05$). It had presented that ambient PM_{10} exposure level also positively related to IGG, IGM, IGE, IGA, CC16 and CRP ($p < 0.05$) (Table 1). A comparison analysis revealed that IGG level increased sharply when PM_{10} level exceeded 200 μg/m^3, while more indicators IGM, IGA, LGG and CRP increased when PM_{10} level were higher than 300 μg/m^3. Among of them, CRP level showed more tightly relationship with the PM_{10} concentration.

Discussion

PM_{10} is thought to be typical contaminant involving sandstorm, which level could indicate the intensity of sandstorm[12]. In our study, most of the places in Inner Mongolia experience sandstorm frequently in spring,

and Erlianhaote is a typical place (Figure 1). PM_{10} levels in the strong sandstorm area may be five to ten times to the weak area. For instance, in our study, the average outdoor PM_{10} concentration in Erlianhaote was found to be 4.47 mg/m^3 in March fourth (Figure 1), it could be deduced that a big sandstorm happened at that time.

The sensitivities bio-marks relating to sandstorm PM_{10} is one concern. Numerous epidemiological studies indicated that both long and short-term exposure to atmospheric PM_{10} contributed to mortality and morbidity increase[13,14]. In recent years, researchers paid more attention to early sensitive bio-marks of PM exposure, since it became increasingly important to identify the risk. Young children, the elderly, individuals with predisposed diseases, such as cardiovascular and pulmonary diseases and workers were reported to be at high risk of PM_{10} exposure, due to their increased biological sensitivities[15,16]. Animal experiments revealed that in winter, PM_{10} induced significant inflammatory response in rat lung, and interfered the level of mRNA up-regulation of all inflammation factors, such as IL-1β (Interleukin-1β, IL-1β), ICAM-1 (intercellular cell adhesion molecule-1, ICAM-1), COX-2 (Cyclooxygenase, COX-2) and iNOS (inducible nitric oxide synthase)[17]. A study displayed that the serum CRP (C-reaction protein, CRP) of traffic policemen with high PM exposure higher than that of the common population ($p < 0.05$), addressing that PM exposure might decrease the lung function and alter the serum immunological function[15]. This enzyme was confirmed to have the correlation with ambient PM exposure[18]. Besides environmental factors, other confounding factors had also been confirmed to affect the CRP level, such as age[19]. In our study, we have summarized all the participation information (Table 1), no correlations were found among indicators and factors of education, types of the occupation, ethnic except ages. Results indicated that ages was positively correlated to CRP and LGG ($p < 0.05$) (not shown here), which had the consistency with the previous view. In our design, rather low percentage old people (whose years old > 60) were involved (Table 1). Our findings illustrated some relationships between ambient PM_{10} exposure and IGM ($p < 0.01$), CRP ($p < 0.01$), IGA ($p < 0.01$), IGG ($p < 0.01$), IGE ($p < 0.01$) and CC16 ($p < 0.05$) (Table 2), which expressed that PM_{10} exposure might alter some enzyme's levels.

Exposure pattern such as wearing the mask during the sandstorm would reduce total amount of PM_{10} exposure. Our analysis revealed that there were no correlations between those factors with the indicator tested, but the exposure patterns and IGE ($p < 0.05$). Further analysis showed that high level of CRP (1.0 ± 0.3 pg/mL) in the people exposed to the average exposure levels higher than 300 μg/m^3, which was far higher than the people who were exposed to average PM_{10} below 300 μg/m^3 (0.6 ± 0.3, pg/mL) (Table 4) ($p < 0.01$). It meant CRP may be served as one of the sensitivity indicators to PM_{10} exposure.

Difference of indicators had some certain correlations with each other. For instance, IGM had tightly correlations with CRP, CC16, IL16, IGA, lgG, IGE and IL8 ($p < 0.01$), respectively (Table 2), it suggested that enzyme indicator itself can be affected by other enzymes. Interestingly, our findings exhibited the indicators of IGM, IGG and IGA of Group I and II (Table 3), were affected by DEEL ranked with 200 μg/m^3 on condition that controlling the mixture factors by multivariate statistical analysis, which meant their sensitivities to the PM_{10} levels could be identified as DEEL of 200 μg/m^3. Among them, IGG was found to be the most sensitive, its levels increased from the lower average value (27.7 ± 13.6, μg/mL, group I) to the higher value (44.4 ± 21.0, μg/mL, group II) ($p < 0.01$). The relationship between exposure dose ranked by 300 μg/m^3 and effects were further discussed. Changes of more enzyme levels reflecting immune system were explored ($p < 0.05$) on condition that the daily environmental concentration increased to 300 μg/m^3. Indicators of IGM, IGA, LGG in group I# were higher than group II# ($p < 0.05$) (Table 4), which implied more enzymes relating to the immune system may be altered by the high PM_{10} exposure. CRP, the indicator relating to the onset of inflammation, showed its change under high PM_{10} exposure ($p < 0.01$). CRP is an annular (ring-shaped), pentameric protein found in blood plasma, the level of which is often in response to inflammation[20]. Our findings suggested that high PM_{10} exposure (daily environmental concentration ≥ 300 μg/m^3) might induce the inflammation, the damage mechanism need to be further studied.

Conclusion

Explore the sensitivities bio-marks reflecting PM_{10} exposure in epidemiologic had been a key focus on disease prediction. Our results indicated that IGG may act as the sensitive indicators reflecting the PM exposure level less than 200 μg/m^3, while indicators of IGM, IGA, LGG, CRP may be served as the sensitive indicators to PM_{10} exposure higher than 300 μg/m^3.

Materials and Methods

Study Design

In recent years, systematic research on Asian dust

storms[21], show that Inner Mongolia is one of the main areas experiencing sandstorm frequently. In this study, PM_{10} concentrations were analyzed from March to June in Erlianhaote, a city located in Inner Mongolia, affected by sandstorm frequently.

A cross-sectional study involving administration of a survey and some clinical indicators was undertaken. A self-administered survey was performed by 150 local residents in Erlianhaote. All healthy volunteer had been examined for their physical condition, and they were proved to have no fever or other infection. The day they registered the serum indicators were measured. The average exposure levels were calculated from the registered days and the two lag days.

Ethical Considerations

Ethical approvals were obtained from the Erlianhaote CDC agency with the number 201601.

PM_{10} Concentration

Portable particulate monitor PDR-1500 instruments (USA, Thermo), and other Thermo 1405 F series instruments were used to sample PM_{10} in twenty-four hours continuously. Equipment had been regularly inspected, and maintained in a timely manner to ensure its quality assurance. The average levels of PM_{10}, lagged two days after sandstorm started, were calculated for the following estimation of dose-effects.

Indicator Assay

All serum indicators were measured in Erlianhaote affiliated hospital by ELISA kit. The ELISA, or enzyme-linked immunosorbent assay, is a widely used method for determining the presence or absence of a specific target protein. Via a series of washing and binding steps, an antibody conjugated, or linked, to an enzyme will recognize a target protein at the bottom of a 96-well plate. When substrate is added to the sample, an enzymatic reaction will occur, causing a color change that allows the identification and quantification of the target protein. The indicators measured in this study were CRP, CC16, IL16 (interleukin-16), IGA (immunoglobulin A, IGA), IGG, IGE (immunoglobulin E) and IL8 (Interleukin-8). All procedures followed protocol of the reagents, which bought from Shanghai Qayee-Bio, Technology Co., Ltd., China. Quality control was performed according to the principle from low to high. Values of indicators in each exposed group were pooled to generate an average value and to calculate the coefficient of variation (CV)%. The standard curve based on the average attenuation counts was drawn. One sample was divided into two pieces, which underwent the same measurements at different times, to ensure the reliability of our results. All the coefficients of variation were $<10\%$.

Questionnaire Survey

All questionnaires were administered on conditions that informed consents signed. Questionnaire contents were classified into ages, gender, education, occupation, lifestyle, daily life exposure information, and the subjective understanding of the risk of dust storms, etc. All questionnaires were performed by face-to-face interviews, and socio-demographic data were self-reported by participants. Questions about protection mode included whether the people wear mask during the sandstorm or not.

Statistical Analysis

Statistical analyses were performed with SPSS 18.0. Multi-factor line regression analysis was performed for age, history of disease and the indicators. The correlations between factors (ages, education, types of the occupation, ethnic, etc.) and sandstorm's concern index were described by Pearson analysis and p-values less than 0.05 or 0.01 were considered to indicate statistically significant differences.

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Conflict of Interest

The authors declare that they have no conflicts of interest with the contents of this article.

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