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Pulmonary toxicity study in rats with PM_{10} and $PM_{2.5}$: Differential responses related to scale and composition

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ABSTRACT

Objection: To study the pollution of atmospheric particles at winter in Beijing and compare the lung toxicity which induced by particle samples from different sampling sites.
Method: We collected samples from two sampling points during the winter for toxicity testing and chemical analysis. Wistar rats were administered with particles by intratracheal instillation. After exposure, biochemically index, esimmunity indexes, histopathology and DNA damage were detected in rat pulmonary cells.
Result: The elements with enrichment factors (EF) larger than 10 were As, Cd, Cu, Zn, S and Pb in the four experiment groups. The priority control of the total concentration of polycyclic aromatic hydrocarbons (PAHs) in PM_{10} and $PM_{2.5}$ of Near-traffic source was much higher than that of Far-traffic source, it demonstrated that near the traffic source of PAHs pollution was heavier than that of Far-traffic source, as it was close to main roads Beiyuan Road, motor vehicle emissions were much higher. The pathology of lung showed that the degree of inflammation was increased with the particle diameter minished, it was the same as the detection of biochemical parameters such as lactate dehydrogenase (LDH), Total anti-oxidant status(T-AOC) and total protein (TP) in BALF and inflammation cytokine(interleukin-1, interleukin-6 and tumor necrosis factor-alpha) in lung homogenate. The indexes of DNA damage including the content of DNA and Olive empennage of $PM_{2.5}$ were significant higher than that of PM_{10} at the same surveillance point ($P < 0.05$), near-traffic particles were higher than the far-traffic particles at the same diameter, ($P < 0.05$).
Conclusion: Near-traffic area particles had certain pollution at winter in Beijing. Meanwhile, atmospheric particulate matters on lung toxicity were related to the particles size and distance related sites which were exposed: smaller size, more toxicity; nearer from traffic, more toxicity.

1. Introduction

Epidemiological studies have highlighted that, the major pollution factors of urban atmosphere are airborne particulates PM_{10} (particulate matter with aerodynamic diameter less than 10 μm), $PM_{2.5}$ and TSP (total suspended particulate matter), and followed by SO_2 and NO_x (Greenwell et al., 2002; Wei and Chapman, 2001). Long-term exposure to high concentrations of PM increases the risk of lung cancer, respiratory diseases and arteriosclerosis, whereas short-term exposure peaks can cause exacerbation of several forms of respiratory diseases, including bronchitis and asthma, as well as changes in heart rate variability (Chiaverini, 2002; Samet et al., 2000; Sorensen et al., 2003).

More and more studies (Chapman et al., 1997; Donaldson et al. 1998) about physicochemical characterizations and health effects of ambient particles have been reported recently. Because of their small size they can penetrate bronchiole, pulmonary alveoli and into blood circulation in the end, and then produce serious biological toxicity. Furthermore, it is generally acknowledged that specific chemicals present in PM, such as metals or polycyclic aromatic hydrocarbons (PAHs) and their derivatives, determine to a large extent the toxic potency of PM (EPA, 1999, 1997; Churg and Brauer, 1997). Organs such as the lung and heart (Mill et al., 2007), cells (McNeilly et al., 2004) and DNA (Greenwell et al., 2002; Shao et al., 2006, 2007) can be damaged by these particles and then

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produce serious sickness such as irritability asthma, leukemia, lung cancer, and so on(Laden et al., 2000; Baek et al., 1991; Churg and Brauer, 1997; Martin et al., 1997; Oberdorster, 2001; Shield, 1993). Many countries consistent with the WHO air quality guidelines recommend to use the mass concentration of $PM_{2.5}$ or PM_{10} as the indicator of health risk.

Particulate air pollution originates from both anthropogenic sources and natural sources. It contains biological material, organic compounds, hydrocarbons, acid aerosols and metals attached to a carbonaceous core. Traffic intensity is one of the most important determinants of ambient anthropogenic PM concentrations, and its contribution varies between different PM size fractions (Pope et al., 2002; Driseoll et al., 1997; Brew et al., 2000). Traffic intensity can also influence the physicochemical characteristics of ambient PM, particularly with regard to concentrations of PAH, metals and radical generating capacity (Parsons and Salter, 2003; Bocca et al., 2003; Vera Castellano et al., 2003; Hartwig, 2002). All motorized vehicles operating on fossil fuel combustion emit PM, but only little is known on the chemical composition and toxicity of gasoline emissions.

2. Materials and methods

2.1. Reagents and instruments

All the chemicals used in the experiments were purchased from the following suppliers: normal and low melting point agarose, RPMI-1640medium (Promega); PI, Tris-base, DMSO, $EDTANa_2$, Triton X-100 (Sigma); Heavy metal detected: Cr, Cd, Pb– Z-8000 atomic absorption spectrum instrument (Hitachi Japan); Hg, As–AFS230 atomic fluorescence spectrophotometer instrument (Haiguang China); Cu, Zn, Fe, Ni, S–PII inductive couple-plasma atomic emission spectrophotometer (PE America); PAHs detected: GC–MS (Finnigan DSQ).

2.2. Sampling collection

$PM_{2.5}$ and PM_{10} samples were collected from a traffic dense area (near-traffic area) and a relatively clear area (far-traffic area). Two sampling sites were located in Beiyuan highway and orchard of Beijing 5th ring road, respectively (Fig. 1). The flux of vehicle in Beiyuan highway was about 2639 ± 1491.9/ h. The distance between the two sampling sites was about 200 m. At the sampling sites, the samplers were installed on the 1.5 m platform, and were used synchronously to collect samples for 24 h in one day for total one month. The particulate samples were collected onto glass fiber membranes, and the flow rate of sampler was 77.7 L min^{-1}.

The filters were pre-heated before sampling at 600 °C for 2 h to eliminate any adsorbed.

Organic compounds. A balance with accuracy of 0.1 mg was used to weigh the filter paper which was conditioned in an electronic desiccator before and after sample collection for 24 h. After collection, loaded filters were stored in a refrigerator at about 4 °C before chemical analysis to limit the evaporation of volatile components.

2.3. PAHs analysis

For PAHs analysis, the samples were extracted ultrasonically with dichloromethane (DCM), concentrated using a rotary evaporator, purified with a silica gel cleanup technique, reconcentrated by rotary evaporation, and finally condensed to extract 1 ml under a gentle nitrogen stream in 60 °C water bath. All the samples were analyzed using gas chromatography coupled to mass spectrometer

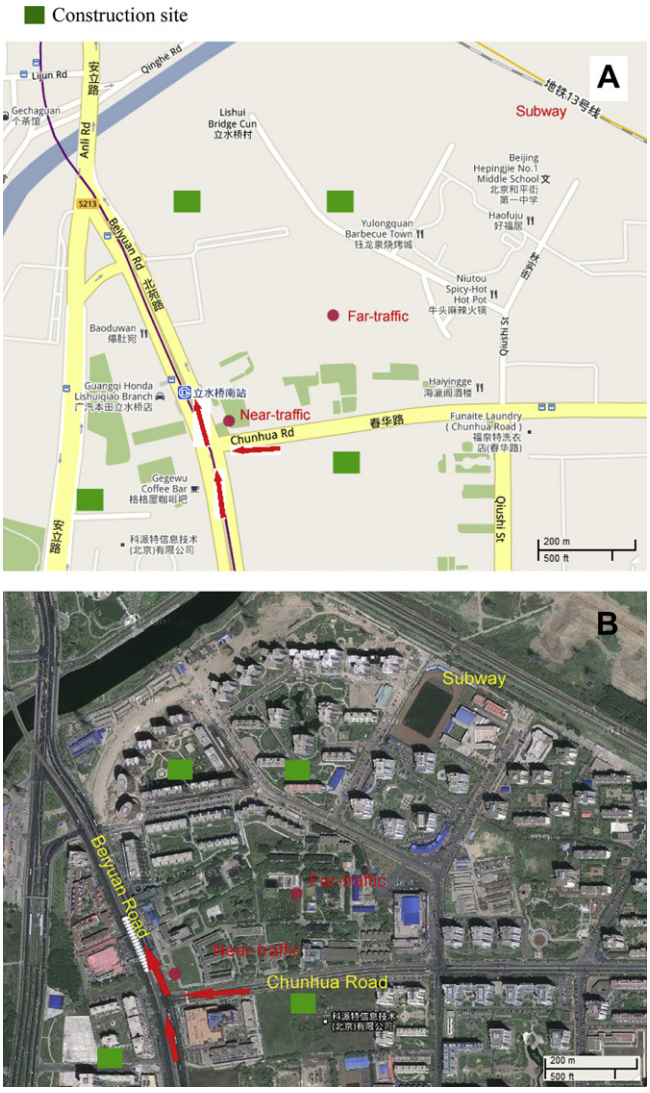

Fig. 1. Map of sampling sites in Beijing 5th ring road (Beiyuan road and orchard): A: electronic map; B: satellite map ■ Construction site.

(GC–MS, made by Thermo Finnigan DSQ company, USA), with an HP-5MS capillary column (30 m × 0.25 mm × 0.25 μm) operated in the electron-impact mode (70 eV). The chromatographic conditions were as follows: temperature program: 65 °C (kept for 5 min), 65–290 °C at 3 °C min^{-1}, 290 °C (kept for 20 min).

2.4. Element analysis

The sample filters were digested with 3 ml concentrated HNO_3, 1 ml concentrated HCl, and 1 ml concentrated HF. Then the solutions were dried, and diluted to 10 ml with deionized water. Major elements were determined by inductively coupled plasma atomic emission spectroscopy (ICP, made by GE Company, USA). Blank membrane was for the blank, we tested the content of elements in it and deducted it.

The enrichment factors (EF) was calculated by:

$$EF = (C_X/C_{Fe})_{PM}/(C_X/C_{Fe})_{crust}$$

Where C_X is the concentration of the element in PM (pm) and C_{Fe} is the abundance of Fe in crust(r). In this study, Fe is selected as a reference material.