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Effects of ambient air pollution from municipal solid waste landfill on children's non-specific immunity and respiratory health☆

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ABSTRACT

This cross-sectional study investigated the association between air pollutant (AP) and respiratory health of 951 children residing near a municipal solid waste (MSW) landfill in Northern China. Results showed that students in non-exposure areas had significantly higher levels of lysozyme, secretory immunoglobulin A (SIgA), and better lung capacity than students in exposure areas ($p < .05$). Multiple regression model analysis indicated that lysozyme levels exhibited a consistent negative association with methane (CH_4: $\beta = -76.3$, 95% CI −105 to −47.7) and sulfuretted hydrogen (H_2S: $\beta = -11.7$, 95% CI −20.2 to −3.19). In addition, SIgA levels were negatively associated with H_2S ($\beta = -68.9$, 95% CI −97.9 to −39.9) and ammonia (NH_3: $\beta = -30.3$, 95% CI −51.7 to −8.96). Among all AP, H_2S and sulfur dioxide (SO_2) were the most robustly related with reduced lung function. H_2S exposure was negatively associated with six lung function indices, 1-s forced expiratory volume (FEV1%), mean forced expiratory flow between 25% and 75% (MMF), maximum voluntary ventilation (MVV), and forced expiratory flow at 25%, 50%, and 75% of the pulmonary volume (FEF25, FEF50, FEF75); and SO_2 was negatively associated with FEV1%, MVV, FEF25, FEF50 and FEF75. Our results suggested that AP exposure was negatively associated with more lung function parameters in boys than in girls. In conclusion, our findings suggested that children living adjacent to landfill sites were more likely to have deficient non-specific immunity and impaired lung function.

1. Introduction

The disposal of municipal solid waste (MSW) is a priority issue in the organization of modern societies (WHO, 2007). In spite of the increasing recycling activities, landfill sites are still widely used to manage the final phase of waste disposal due to process simplicity, low investment and operating cost, and large handling capacity (Li et al., 2017; Tian et al., 2013). According to the U.S. Environmental Protection Agency (EPA), MSW landfills are identified as a hazardous air pollutant source under the Urban Air Toxic Strategy (Hafeez et al., 2016). Typically, anaerobic decomposition of MSW in landfills generates 45%–60% CH_4 and 40%–60% CO_2 together with minor nitrogen, oxygen, ammonia, sulfides, hydrogen, carbon monoxide, and nonmethane organic compounds (NMOCs) (ATSDR, 2001; Tian et al., 2013; USEPA, 1999). There is extensive evidence that air pollutants (i.e. particulate matter, ozone, nitrogen oxides) are linked to respiratory diseases in children (Gilbreath and Kass, 2006; Palmiotto et al., 2014; WHO, 2007; Zeng et al., 2016). However, the concentration of most landfill gases (LFG, i.e. hydrogen sulfide and ammonia) that are likely to reach surrounding communities are maintained below known harmful levels (ATSDR, 2001). Currently, most studies that examine the effects of chemical exposure to health consider much higher chemical exposure levels than those

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associated with landfills (Laborde et al., 2015; Schembari et al., 2015; Wang et al., 2017). The evidence on the association of adverse health effects stemming from low-level and multi-pollutants exposure with living near landfills is often “inconclusive” or “contradictory” (Forastiere et al., 2011; Russi et al., 2008; WHO, 2007).

Until recently, MSW collection and disposal in China has largely involved in landfills. In 2015, the overall MSW production in China was approximately 185.64 million tons, which increased by 10.4% compared to that in 2014 (CENEWS-MEP, 2015, 2016). Of the total amount, 63.7% was disposed in landfill, 34.3% was processed with incinerate, and 2.0% was recovered by differentiated collection and recycled (NBSC, 2016). The Standard for Pollution Control on the Landfill Site of Municipal Solid Waste (GB 16,889–2008) in China was brought into effect on April 2, 2008 (MEPPR, 2008). However, it is not appropriately followed and some old landfills are still poorly operated. Consequently, an enormous amount of LFG is and will continue to be generated, leading to problems with LFG management.

Children represent the largest population subgroup particularly susceptible to air pollution (Bertoldi et al., 2012; Clark et al., 2010; Villeneuve et al., 2007). Children’ lungs and immune system are still developing, and children have narrower airways, and breathe more air per unit of body weight than adults, and thus receive proportionately higher doses of pollutants (Altug et al., 2014; Brand et al., 2016; Clougherty, 2010). Epidemiological studies have shown that exposure to air pollution may increase hospital admissions or emergency room visits for children with asthma (Ahmed et al., 2017; Brand et al., 2016; Clark et al., 2010) and respiratory diseases (Labelle et al., 2015). A time-stratified case-crossover study based on 57,912 emergency department asthma visits in Canada, showed that children asthma visits were markedly associated with increased NO_2 or CO levels. (Villeneuve et al., 2007). Thus, exposure to air pollution has a significant impact on children's health and well-being.

Lysozyme and secretory immunoglobulin A (SIgA) are typically considered as the first line of defense from air pollutants, and are critical for mucosal immunity (Chairatana and Nolan, 2017; Ide et al., 2016). The amount of salivary lysozyme is generally lower in individuals who live in heavily polluted areas than in those who live in relatively unpolluted areas (WHO, 1995). SIgA is abundant in mucosal secretions and SIgA levels in oral fluids are key for the first line of defense against antigens that cause upper respiratory infection, periodontal disease, and caries (Sun et al., 2016). Moreover, lung function, as an objective indicator of respiratory health, is generally considered as the primary target of air pollutants. In recent years, lung function, lysozyme and SIgA are physiological measurements that have been used clinically to evaluate respiratory and nonspecific immune health (Ahmed et al., 2017; Altug et al., 2014; Liu et al., 2009; Pal et al., 2013). Possible cause-effect relationships between critical pollutants (i.e. PM_{10}, NO_2, O_3, SO_2) and respiratory status have been established (Altug et al., 2014; USEPA, 2009, 2013). However, literature on the association of lysozyme and SIgA with low levels LFG exposure is still limited.

The landfill under investigation is located in Northern China. It comprised an area of approximately 46.53 ha. It has been used since 1999 with a final capacity of 12, 450, 000 m^3. In recent years, growing concerns and complaints lodged against the landfill thus increasing the need for evaluation of the landfill. Therefore, children living adjacent to the MSW landfill were investigated, with the aim to estimate the potential impacts of LFG exposure on children's lung function and non-specific immunity.

2. Materials and methods

2.1. Study design and population

The study was conducted at an MSW landfill in Northern China. The landfill has been operational since 1999, with a total area of about 46.53 ha. Approximately 2500 tons of MSW are deposited in this landfill on a daily base. In this study, a circular area with a radius (of 5 km) surrounding the landfill was defined as the exposure area, which was based on the recommendation by the World Health Organization report (WHO, 2007). Four primary schools within the exposure area were selected to participate the baseline survey. School #1 is located 1.4 km distant from the MSW landfill, School #2 0.8 km, School #3 3.4 km, and School #4 2.1 km. School #5 is located 5.8 km away from the landfill, which was defined as the non-exposure area (Fig. 1).

From the five selected schools, students who had lived in the area for at least five years and had their homes within a distance of less than 1 km from the monitored schools were invited to participate in the cross-sectional epidemiological survey. Upon enrollment, a standardized questionnaire was administered to obtain socio-demographic information of the participants (e.g., age, weight, and height), and current or past health status. Additional variables, such as parental education, occupation, home type, heating type, home coal use, house pet, and distance of home from a main road were also included.

2.2. Ambient air pollution (AP) monitoring

Ambient air monitoring data for methane (CH_4), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ammonia (NH_3), carbon monoxide (CO), sulfuretted hydrogen (H_2S), odor, and particulate matter with aerodynamic diameter <10 μm (PM_{10}) were detected using a standardized method described in previous studies (Song et al., 2017; Zeng et al., 2016; Zhou et al., 2015). Air pollutants were sampled continuously and the concentrations were reported on an hourly base. Pollutants were detected via gas chromatography for CH_4 and H_2S, nitrogen oxides-*N*-(1-naphthyl)ethylene/diamine dihydrochloride spectrophotometry for NO_2, formaldehyde absorbing-pararosaniline spectrophotometry for SO_2, sodium hypochlorite-salicylic acid spectrometry for NH_3, non-dispersive infrared spectrometry for CO, triangle odor bag method for odor, and gravimetric method for PM10. Pollutant concentrations were averaged over a 24-hr period.

2.3. Health outcomes

2.3.1. Nonspecific immune function measurement

Saliva samples were collected between 8:00 a.m. and 10:00 a.m.. Participants were seated with their head tilted forward and saliva production was stimulated by the chewing of sterilized cotton. The samples were immediately frozen at −80 °C until analysis. Salivary SIgA concentration was determined with enzyme linked immunosorbent assay (ELISA) method using a commercial SIgA ELISA kit (Atomic hi-tech co., LTD, China) and salivary lysozyme was analyzed with a classical turbidimetric method using a commercial lysozyme kit (Nanjing Jiancheng Bioengineering Institute, China), as detailed in a previous study (Guo et al., 2009).

2.3.2. Lung function measurement

Pulmonary function tests were conducted for each student by the respiratory clinical staff. Vital capacity (VC), forced vital ca-