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Air pollution from biodegradable wastes and non-specific health symptoms among residents: Direct or annoyance-mediated associations?

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HIGHLIGHTS

- Non-specific symptoms among residents exposed to emissions from wastes were studied.
- Unlike previous studies, individual-specific chemical exposures were used.
- Exposures play an important role in the genesis of non-specific symptoms.
- The effects of low-to-moderate exposures seem to be mediated by odor annoyance.

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ABSTRACT

Adverse health effects of exposure to high levels of air pollutants from biodegradable wastes have been well-studied. However, few investigations have examined the potential effects of chronic exposure to low-to-moderate levels on non-specific health symptoms among residents. Besides, most studies have relied on distances to waste sites to assign exposure status, and have not investigated whether the exposure–symptoms associations are direct or mediated by odor annoyance. In this study, individual-level exposures to a proxy indicator of biodegradable waste pollution (ammonia, NH_3) in non-urban residences ($n = 454$) during 2005–2010 were characterized by data from emission–dispersion validated models. Logistic regression and mediating analyses were used to examine associations between exposures and questionnaire-based data on annoyance and non-specific symptoms, after adjusting by person-specific covariates. Strong dose-response associations were found between exposures and annoyance, and between annoyance and symptoms. Associations between exposures and symptoms (nausea, headache, dizziness, difficulty concentrating and unnatural fatigue) were indirect (annoyance-mediated). This study indicates that environmental exposures play an important role in the genesis of non-specific symptoms among residents exposed to low-to-moderate air pollution from biodegradable wastes, although the effects seem to be indirect, relayed through stress-related mechanisms.

1. Introduction

Public awareness about the health impacts of air pollution has grown in the last decades. Along with it, there is a rising concern about the potential adverse effects that air contaminants released from biodegradable wastes sites may have on the health of local residents. A large number of potentially hazardous pollutants are emitted during handling, storage, treatment and disposal of agricultural, animal and municipal biodegradable wastes, including ammonia, hydrogen sulfide, phenols, indoles, volatile fatty acids, carbon dioxide, methane, particulate matter and endotoxins (Blanes-Vidal et al., 2009). Previous studies have shown that residents living close to waste sites report a series of negative effects on the health (Schiffman and Williams, 2005). Typical physical health symptoms include non-specific health symptoms, such as dizziness, difficulty concentrating, headache, unnatural fatigue and nausea (Wing and Wolf, 2000).

Despite the potential adverse effects of these exposures, the majority of epidemiological studies investigating these

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associations have been ecologic studies, in which communities of individuals have been classified as exposed or unexposed based on residence in an specific geographic area or using some measure of distance from a waste site (Thu et al., 1997; Wing and Wolf, 2000; Aatamila et al., 2011). Given the high spatial variability of concentrations over regions, these procedures are not sufficient to adequately characterize the individuals in terms of exposure (WHO Europe, 2007). Besides, knowledge of actual exposures is needed to establish dose-response relationships and to determine levels of exposure that should not be exceeded.

Another notable shortcoming of current studies is their limitation to provide insights into the mechanisms in which air pollution from wastes may exert adverse health effects on the residents. Given that air pollutants from wastes are frequently detected in the open-land at concentrations far below toxicity thresholds (Steinheider et al., 1998; Sucker et al., 2009), direct toxicity effects from chemical exposures are unlikely. Some authors have argued that the mechanism underlying health symptoms is predominantly psychological, as it has been postulated for subjects with idiopathic environmental intolerance (Das-Munshi et al., 2006). Air pollutants emitted from biodegradable wastes include odorous compounds which result in a disagreeable odor that causes unpleasant sensations to the average person upon exposure (Blanes-Vidal et al., 2009). Therefore, people exposed to air pollutants from wastes at their residences, usually perceive unpleasant odors along with the chemical exposures. Odor is an environmental stressor that can trigger psychosocial responses (such as, annoyance), which can lead healthy subjects to experience non-specific health symptoms (Williams and Lees-Haley, 1997; Shusterman, 2001; Schiffman and Williams, 2005). Annoyance can be defined as a feeling of displeasure associated with any agent or condition, known or believed by an individual or group to adversely affect them (Lindvall and Radford, 1973). In addition to eliciting symptoms, odor annoyance is a negative health effect per se, in accordance with the World Health Organization's (WHO) definition of health (WHO, 1987).

While previous epidemiological studies have supported the importance of odor annoyance mechanisms for explaining the increased occurrence of non-specific symptoms among residents living close to waste, these studies have suffered from different methodological limitations. In addition to the already mentioned lack of individual-specific exposure assessments, formal mediation analyses were not carried out in these studies to statistically test whether and to which extent the association between exposure and non-specific symptoms is mediated by odor annoyance (Neutra et al., 1991; Steinheider et al., 1998; Sucker et al., 2009; Aatamila et al., 2011).

The present study investigates the direct and indirect associations between individual-specific residential exposures to a proxy gas from biodegradable wastes (ammonia, NH_3), odor annoyance and five non-specific health symptoms, based on formal mediation analyses, among residents exposed to low-to-moderate air pollution levels. More specifically, the study focuses on answering the following questions:

1. Is there a dose-response association between exposure to air pollution from biodegradables wastes (in terms of individual-specific NH_3 exposure) and odor annoyance, after adjusting for person-specific variables?
2. Is exposure to air pollution from wastes associated with non-specific symptoms in residents (self-reported)?
3. Are residents annoyed by odors more likely to experience non-specific symptoms (self-reported)?
4. Is the association between exposure and symptoms direct or is it mediated by odor annoyance?

2. Methods

2.1. Data collection on demographics, odor annoyance and symptoms

A cross-sectional data collection was carried out in six regions distributed throughout Denmark (Supplementary material, Blanes-Vidal et al., 2014a,b). A total of 1120 households within the six study areas were randomly selected and a structured questionnaire was mailed from October 2011 to February 2012. The questionnaire was based on a standard questionnaire on indoor climate (Brauer et al., 2000), which includes items concerning symptoms, perceived environment and personal characteristics. Some supplementary questions were included. Adults (>18 years old) living at the household (1 adult/household) were requested to fill and return the anonymous questionnaire. Research was conducted in accordance with principles of the Declaration of Helsinki and approved by the Danish Data Protection Agency (Datatilsynet).

The structured questionnaire started with general socio-demographic and lifestyle data (e.g. gender, age, job) and an open-ended question on the main advantages and disadvantages of living in the countryside. The second part included questions regarding the outdoor environment, such as: degree of perceived odor annoyance (i.e. Not annoying = 0, Slightly annoying = 1, Moderately annoying = 2, Very annoying = 3, and Extremely annoying = 4) and origin (i.e. traffic, industry, farm, livestock waste spreading, unknown, or others). The third part of the questionnaire referred to physical symptoms and health. Five non-specific health symptoms were considered in this study: dizziness, difficulty concentrating, headache, unnatural fatigue and nausea (Schiffman et al., 2000; Shusterman, 2002; Schiffman and Williams, 2005). Residents were asked to estimate the frequency of symptoms within the last two years in a 0–4 scale: 0 = Never/Very rarely; 1 = Several times per year; 2 = Several times per month; 3 = Several times per week; 4 = Daily. Self-reported information on physician-diagnosed medical conditions was categorized into: (1) acute respiratory conditions (including acute infections of the respiratory tract, acute bronchitis, flu or pneumonia in the last 2 years), (2) chronic respiratory conditions (including asthma, allergic rhinitis, chronic bronchitis, lung disease or other diseases of the airways) and (3) other chronic diseases.

2.2. Exposure assessment

Objective air pollution estimations at each household was performed based on emission-based atmospheric dispersion modeling data. Ammonia (NH_3) concentration was chosen as a proxy of exposure to airborne pollutants in the study regions. The selection of NH_3 as marker of air pollution in the study regions was based on the following considerations (Blanes-Vidal et al., 2012a). First, handling, storage, treatment and disposal of farming, animal and agricultural wastes is the main source of air pollution in the study areas and NH_3 is a typical pollutant released from these activities (Geels et al., 2012). Between 80% and 90% of total NH_3 emissions in Western Europe and US originate from farming, animal and agricultural wastes. Second, the processes of wastewater mixing, agitation and application which causes an acute increase of emissions of odors and other gases, also results in a sharp increase in NH_3 emissions. Third, NH_3 is an odorous and irritating gas, which has shown correlation with farming odor as assessed by trained panelists in previous studies. Finally, NH_3 is associated with increased occurrence of psychosocial health effects, and respiratory and sensory irritation symptoms in non-urban populations (Blanes-Vidal et al., 2014a,b). It is important to emphasize that in this study NH_3 is solely used as "proxy" (a marker) for air pollution exposure. It is therefore not assumed that NH_3 is the only pollutant present