Science of the Total Environment 490 (2014) 545–554

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Chronic exposure to odorous chemicals in residential areas and effects on human psychosocial health: Dose–response relationships

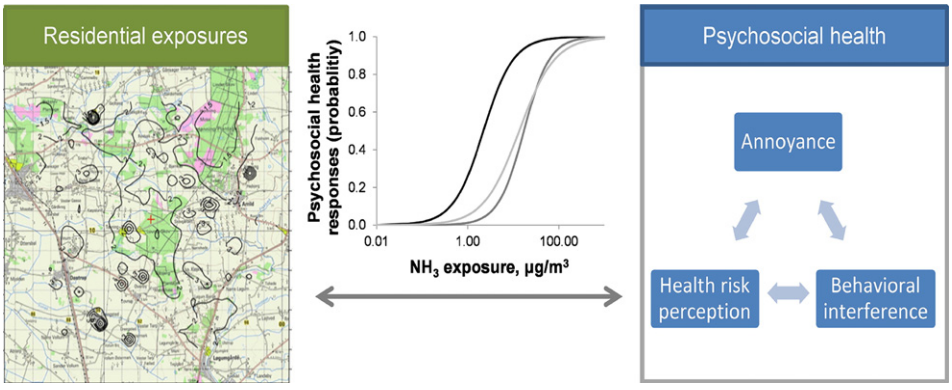
Victoria Blanes-Vidal [a,*], Jesper Bælum [b], Esmaeil S. Nadimi [c], Per Løfstrøm [d], Lars P. Christensen [a]

[a] Department of Chemical Engineering, Biotechnology and Environmental Technology, Faculty of Engineering, University of Southern Denmark, Niels Bohrs Alle, 1, DK-5230, Odense M, Denmark
[b] Institute of Public Health, Research Unit of General Practice, University of Southern Denmark, J.B. Winsløws Vej 9A, DK-5000 Odense C, Denmark
[c] Maersk Mc-Kinney Moller Institute, Faculty of Engineering, University of Southern Denmark, Campusvej 55, DK-5230 Odense M, Denmark
[d] Department of Environmental Science, Aarhus University, Frederiksborgvej 399, DK-4000 Roskilde, Denmark

HIGHLIGHTS

- Odor exposure is a stressor that can affect human health and well-being.
- We examined relationships between residential NH_3 exposure and psychosocial effects.
- Psychosocial effects were annoyance, risk perception and behavioral interference.
- We quantified these associations and obtained dose–response models.
- We provided insights into the underlying mechanisms that result in these responses.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 13 January 2014
Received in revised form 28 March 2014
Accepted 13 May 2014
Available online xxxx

Editor: Lidia Morawska

Keywords:
Air pollution exposure
Health
Dose–response
Nuisance
Waste
Slurry

ABSTRACT

Perceived air pollution, including environmental odor pollution, is known to be an environmental stressor that affects individuals' psychosocial health and well-being. However, very few studies have been able to quantify exposure–response associations based on individual-specific residential exposures to a proxy gas and to examine the mechanisms underlying these associations. In this study, individual-specific exposures in non-urban residential environments during 2005–2010 on a gas released from animal biodegradable wastes (ammonia, NH_3) were calculated by the Danish Eulerian long-range transport model and the local-scale transport deposition model. We used binomial and multinomial logistic regression and mediation analyses to examine the associations between average exposures and questionnaire-based data on psychosocial responses, after controlling for person-specific covariates. About 45% of the respondents were annoyed by residential odor pollution. Exposures were associated with annoyance (adjusted odds ratio [OR_{adj}] = 3.54, 95% confidence interval [CI] = 2.33–5.39), health risk perception (OR_{adj} = 4.94; 95% CI = 1.95–12.5) and behavioral interference (OR_{adj} = 3.28; 95% CI = 1.77–6.11), for each unit increase in $\log_e(NH_3$ exposure). Annoyance was a strong mediator in exposure–behavior interference and exposure–health risk perception relationships (81% and 44% mediation, respectively). Health risk perception did not play a mediating role in exposure–annoyance or exposure–behavioral interference relationships. This is the first study to provide a quantitative estimation of the dose–response associations between ambient NH_3

* Corresponding author. Tel.: +45 27781937; fax: +45 65507374.
E-mail address: vbv@kbm.sdu.dk (V. Blanes-Vidal).

http://dx.doi.org/10.1016/j.scitotenv.2014.05.041

exposures and psychosocial effects caused by odor pollution in non-urban residential outdoor environments. It further shows that these effects are both direct and mediated by other psychosocial responses. The results support the use of NH_3 as a proxy gas of air pollution from animal biodegradable wastes in epidemiologic studies.

1. Introduction

Perceived air pollution, including environmental odor pollution, has been associated with a series of adverse physical and psychosocial health impacts in humans. Common physical health symptoms among people exposed to odorous chemicals at their residences from e.g. industries or agricultural activities, include eye, nose, and throat irritation, headache, nausea, diarrhea, hoarseness, sore throat, cough, chest tightness, nasal congestion, palpitations, shortness of breath and drowsiness (Schiffman and Williams, 2005). In many cases, conventional toxicological paradigms are not able to explain the association between exposure and symptoms, because reporting of physical effects occurs even when exposures are far below toxicity thresholds. Previous authors have suggested that psychosocial (stress-mediated) responses, such as perceived odor annoyance, may play an important role in physical symptom reporting (Sucker et al., 2009). Environmental odor pollution is indeed an important ambient stressor, since exposure is physically perceptible, negatively valued, unpredictable, uncontrollable, and requires moderate adjustments (Campbell, 1983). Psychosocial effects can be defined as the complex of distress, dysfunction and disability manifested in a wide range of social, psychological and behavioral outcomes, as a consequence of actual or 'perceived' environmental contamination (Elliott et al., 1993). Psychosocial effects not only may exacerbate chemical intolerance and symptoms, but also they are considered 'negative health effects' per se, in accordance with the World Health Organization's (WHO) definition of health (WHO, 1987).

Previous studies have reported annoyance, health risk perception and behavioral interference as important psychosocial responses to environmental odors. 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). Annoyance is considered a form of psychological stress, and it may coincide with other negative emotions, e.g., anger, disappointment, dissatisfaction, helplessness, anxiety, and agitation (Schiffman and Williams, 2005).

Risk perception is a subjective judgment by which a person assesses a particular threat or hazard, based on life experiences, information, beliefs, and ideas, that are individual-specific or shared by his/her social group. Odor-related health risk perception can be defined as a concern about the potential consequences that exposure to odorous chemicals in the environment may have on the health. Finally, behavioral interference refers to any disruption of the lifestyle, interference with intended activities and unwanted changes in social behavior. Behavioral interference caused by outdoor odor pollution may lead to significant social impacts, especially in communities where lives are rooted in enjoying the outdoors (Thu, 2002).

The relations between odor exposure and psychosocial responses are complex. According to the Transaction Model of Stress and Coping (Lazarus and Folkman, 1984; Cavalini et al., 1991), people's responses to stressors are influenced by individual differences in sensory perception (e.g. olfactory sensitivity), stressor appraisal and coping strategies. Stressor appraisal is people's evaluation of any potential harm or benefit derived from the stressor. When an odor is appraised as harmful or objectionable (primary appraisal), coping strategies are developed, which can be "problem-oriented", i.e. aimed at minimizing or managing the source of stress; for instance, by closing windows to prevent malodorous air from entering inside the dwelling or not going outside; or "emotion-oriented", i.e. aimed at reducing or managing the emotional distress caused by the stressor; for instance, by comforting cognition about health effects. When the person has little control over the source and perceives that the only way of managing his/her exposure to the stressor is by altering intended plans to avoid exposure (behavioral interference), this situation may be a secondary source of annoyance. Therefore, problem-oriented coping itself may result in annoyance, even when it successfully resolves the exposure problem. Based on these coping strategies, people re-appraise their situation (secondary appraisal). To sum up, a person will experience annoyance when he/she appraises the odor as objectionable or harmful (primary appraisal), and, considering their options to cope with the situation (secondary appraisal), find that his/her coping resources are insufficient or detrimental.

Therefore, chemical exposures explain part, but not all, of the variation in people's reactions to odors. Individual variations arise partly from differences in how individuals react to the same odor environments, which also depend on the context where exposures occur (Dalton, 1996). Consequently, observational epidemiological studies (as opposed to laboratory trials) provide in principle more realistic quantifications of exposure–response relationships. Given that odor concentrations over regions show high spatial variability (NRC, 2003), one big challenge in resolving the air quality/well-being relationships in observational studies is the assessment of household-specific residential exposures to odorous chemicals. Quantifications of exposure–psychosocial response associations from field studies based on individual exposure assessments are very scarce, since most previous observational studies have been semi-ecological studies, in which responses and important covariates are measured on the individual level, while exposure is assigned on a group level (Oglesby et al., 2000; Claeson et al., 2013). Besides, while some studies have discussed what factors influence the psychosocial responses to odor exposure, it is yet to be determined how these factors exert their combined effects.

The objective of our study was to investigate the associations between exposure to a proxy indicator of odor pollution in non-urban residential environments and psychosocial effects (i.e. odor annoyance, health risk perception and behavioral interference) and the mechanisms through which these associations occur; based on individual-specific exposures estimations.

In our study, three hypotheses were formulated and tested:

1. The *exposure hypothesis* was that higher chemical exposures will result in increased likelihood of odor annoyance, health risk perception and behavioral interference. Besides, higher exposures will result in higher level of annoyance.
2. The *appraisal hypothesis* was that health risk perception is a mediator in exposure–annoyance and exposure–behavioral interference relationships. That is, that appraisal of exposure as harmful (with possible health effects) should account for at least part of the annoyance and behavioral interference experienced by the exposed residents.
3. The *coping hypothesis* was that annoyance is a mediator in the exposure–behavioral interference relationship. That is, that exposure may result in annoyance perception, which in turn may initiate an active coping strategy involving modifications of individuals' behaviors. The reverse mediation was also considered, that is: given that modifying behavior due to the exposure may result in secondary annoyance, exposure–annoyance responses could be partly mediated by behavioral interference.

2. Materials and methods

2.1. Population data collection

A cross-sectional, population-based study was conducted in six 12 km × 12 km non-urban Danish regions. The six regions guaranteed