International Journal of Hygiene and Environmental Health 219 (2016) 770–779

Contents lists available at ScienceDirect

International Journal of Hygiene and Environmental Health

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

Characterization of exposure in epidemiological studies on air pollution from biodegradable wastes: Misclassification and comparison of exposure assessment strategies

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ARTICLE INFO

Article history:
Received 7 June 2016
Received in revised form 16 August 2016
Accepted 25 August 2016

Keywords:
Exposure misclassification
Predictive models
Air pollution
Animal waste
Rural population

ABSTRACT

The assignment of exposure is one of the main challenges faced by environmental epidemiologists. However, misclassification of exposures has not been explored in population epidemiological studies on air pollution from biodegradable wastes. The objective of this study was to investigate the use of different approaches for assessing exposure to air pollution from biodegradable wastes by analyzing (1) the misclassification of exposure that is committed by using these surrogates, (2) the existence of differential misclassification (3) the effects that misclassification may have on health effect estimates and the interpretation of epidemiological results, and (4) the ability of the exposure measures to predict health outcomes using 10-fold cross validation. Four different exposure assessment approaches were studied: ammonia concentrations at the residence (Metric I), distance to the closest source (Metric II), number of sources within certain distances from the residence (Metric IIIa,b) and location in a specific region (Metric IV). Exposure-response models based on Metric I provided the highest predictive ability (72.3%) and goodness-of-fit, followed by IV, III and II. When compared to Metric I, Metric IV yielded the best results for exposure misclassification analysis and interpretation of health effect estimates, followed by Metric IIIb, IIIa and II. The study showed that modelled NH_3 concentrations provide more accurate estimations of true exposure than distances-based surrogates, and that distance-based surrogates (especially those based on distance to the closest point source) are imprecise methods to identify exposed populations, although they may be useful for initial studies.

1. Introduction

The assignment of exposure plays a central role in observational epidemiology and is one of the main challenges faced by environmental epidemiologists. True exposure measures are often replaced by exposure surrogates, since it is often impractical to measure exposures directly for many study populations (Baxter et al., 2010). This leads to exposure measurement error (when exposure is measured in a quantitative scale, i.e. numerical variables) and exposure misclassification (when study participants are classified into different exposure levels, i.e. categorical variables) (Armstrong, 1998; Zeger et al., 2000). Misclassification may bias the exposure-health association estimates, predict incorrect health risks and misidentify affected populations (Batterman et al., 2014). According to Blair et al. (2007), misclassification of exposures can have a greater impact on study findings than confounding and should be considered in nearly every epidemiologic study.

The evaluation of misclassification in epidemiological studies of air pollution is particularly challenging due to the complexity involved in estimating personal exposure to a mixture of pollutants, differences between short and long term exposures and spatial and temporal variability of air pollutant concentrations (Thurston et al., 2009; Özkaynak et al., 2013). Several factors can affect the air pollutant concentrations such as atmospheric conditions, topography, location of the residence, contribution of local and regional sources and their characteristics (Dons et al., 2011).

Previous epidemiological studies have investigated misclassification and errors committed when using different exposure

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http://dx.doi.org/10.1016/j.ijheh.2016.08.006
1438-4639/

assessment methods in outdoor air pollution studies. These evaluations consisted in e.g. comparing different methods and/or models (Rosenlund et al., 2008; Ashworth et al., 2013; Dionisio et al., 2013), comparing effect estimates obtained by different exposure approaches both quantitatively (Baxter et al., 2010; Sajani et al., 2011; Batterman et al., 2014) and qualitatively (Daniels et al., 2001) and performing a scientific review of the commonly used assessments (Huang and Batterman, 2000; Cordioli et al., 2013; Özkaynak et al., 2013). The performance of air pollution exposure assessment methods has been investigated for a variety of sources and pollutant types, including incineration (Ashworth et al., 2013; Cordioli et al., 2013), traffic (Batterman et al., 2014; Lane et al., 2013; Baxter et al., 2010; Rosenlund et al., 2008; Ryan et al., 2007), use of pesticides (Daniels et al., 2001) and specific types of industries (Hodgson et al., 2007). However, misclassification of exposures and its consequences on health effects estimates have not been explored yet in population epidemiological studies on air pollution from biodegradable wastes.

Several noxious pollutants are emitted during collection, handling, storage and land application of agricultural and animal biodegradable wastes. The list of airborne chemicals is extensive, and includes ammonia (NH_3), hydrogen sulfide (H_2S), Volatile Organic Compounds (VOC) and particulate matter (PM), among others (Heber et al., 2006; Blanes-Vidal et al., 2009). Ammonia, in Western Europe and the US, is almost entirely originated from agricultural and animal biodegradable wastes, e.g. the Danish agricultural sector is responsible for 97.5% of total NH_3 emissions (CORINAIR, 2007; Nielsen et al., 2013); and for that reason it has been used as proxy gas in previous studies (Blanes-Vidal et al., 2012, 2014a,b; Loftus et al., 2015). Rural populations living near agricultural and animal production activities are exposed to the emitted air pollutants, and different authors have demonstrated increased occurrence of physical symptoms and conditions (e.g. cough, wheezing, nasal irritation, shortness of breath, asthma) (Radon et al., 2001; Schinasi et al., 2011; Blanes-Vidal et al., 2014b; Campagna et al., 2004; Merchant et al., 2005; Hulin et al., 2013) and psychological symptoms (Horton et al., 2009; Villeneuve et al., 2009; Blanes-Vidal et al., 2014a) among these populations.

The majority of these studies used surrogates of different complexities to estimate true exposures, such as: (a) residence in a specific geographic region (Herr et al., 2003; Claeson et al., 2013); (b) number of sources within a certain distance to the community/residence (Mirabelli et al., 2006; Radon et al., 2007; Smit et al., 2014); (c) distance to emission sources (Villeneuve et al., 2009; Aatamila et al., 2011; Smit et al., 2014); (d) self-reported information on exposure (Avery et al., 2004; Merchant et al., 2005); and (e) measures from central site monitors extrapolated to all the residents of a certain area (Campagna et al., 2004; Horton et al., 2009). Studies have often categorized exposure into two or three levels (i.e. exposed vs. not exposed, or low, medium and high exposure).

The objective of this study was to investigate the use of different approaches for assessing exposure to air pollution from biodegradable wastes, and to evaluate the misclassification of exposure that is committed by using these surrogates, the existence of differential misclassification and the effects that misclassification may have on health effect estimates and the interpretation of epidemiological results. Four different exposure assessment approaches were studied: residential exposure to a proxy gas based on emission-dispersion models (Metric I), distance to the closest air pollution source (Metric II), number of air pollution sources within certain distances from the residence (Metric IIIa,b) and location of the residence in a specific study area (Metric IV). Evaluation was performed based on a cross-sectional study on exposure-health associations in non-urban regions in Denmark.

2. Materials and methods

2.1. Study population and data collection on personal information, odor annoyance and symptoms

The study population were residents living in six non-urban regions of Denmark: Anholt (Region I), Ulborg (Region II), Keldsnor (Region III), Tange (Region IV), Lindet (Region V) and Sundeved (Region VI) (Fig. 1). The study areas were chosen because they exhibit different levels of agricultural and animal production activities and have air quality monitoring stations, which are part of the Danish National Air Quality Monitoring Programme.

Questionnaires were mailed to a random sample of adult (>18 years old) residents from October 2011 to February 2012. Each adult was asked to complete and return questionnaires by mail. In total, 1120 households within the pre-defined areas received the questionnaire. About 40.5% of the approached residents (454 individuals) completed and returned the questionnaire. The methodology was carried out in accordance with principles stablished by the Declaration of Helsinki and was approved by the Danish Data Protection Agency (Datatilsynet). More information can be found in Blanes-Vidal et al. (2014a, b) and Blanes-Vidal (2015).

The structured questionnaire had three main sections: the first part referred to socio-demographic and life-style questions (e.g. gender, age, smoking status and job), whereas the second and third part were related to the environment and health conditions, which included information on self-perceived level of odor annoyance (i.e. not annoyed, slighted annoyed, moderately annoyed and extremely annoyed) and frequency on the occurrence of health symptoms (i.e. daily, several times per week, several times per month, several times per year, rarely/never). Health symptoms were selected based on previous literature and included: “itching, dryness or irritation of eyes”, “itching, dryness or irritation of nose”, “runny nose”, “cough”, “chest wheezing or whistling”, “difficulty breathing”, “headache”, “nausea”, “unnatural fatigue”, “dizziness”, and “difficulty concentrating”. Some of these symptoms can generate impairment in patient health and quality of life, similar to some better-diagnosed diseases (Kroenke, 2001). Moreover, information about physician-diagnosed medical conditions was also requested

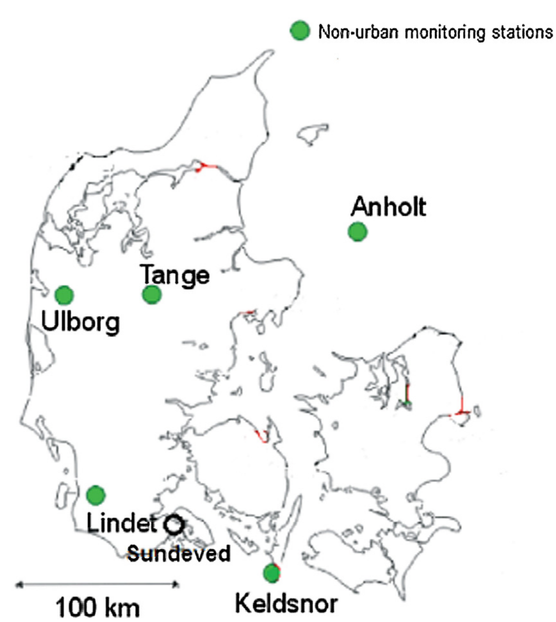

Fig. 1. Non-urban regions of Denmark analyzed in this study (Anholt, Tange, Ulborg, Lindet, Sundeved and Keldsnor).