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Air quality perception of pedestrians in an urban outdoor Mediterranean environment: A field survey approach

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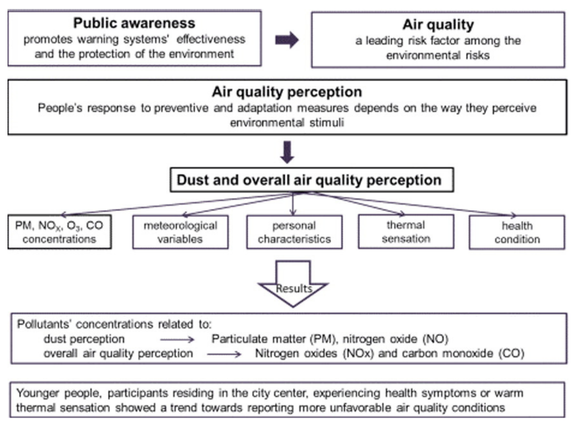
HIGHLIGHTS

- Understanding air quality perception, promotes warning systems' effectiveness
- Air quality perception was studied against PM, NO_X, O_3, and CO concentrations
- People reported their perception with respect to dust and overall air quality
- Air quality perception depends on pollution, age and area of residence
- Health symptoms and warm thermal sensation induce dusty or poor perception

GRAPHICAL ABSTRACT



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ABSTRACT

Perception plays a significant role on people's response to preventive measures. In the view of public awareness, the aim of this study was to explore factors that affect air quality perception and to reveal its potential patterns. Air quality perception of individuals, in terms of dust and overall air quality, was examined in relation to air pollutants concentrations, meteorological variables, personal characteristics as well as their thermal sensation and health condition. The data used were obtained from environmental measurements, in situ and from stations, and questionnaire surveys conducted in an outdoor urban Mediterranean area, Athens, Greece. The participants were asked to report their air quality perception and thermal sensation based on predefined scales. A thermal index, Physiological Equivalent Temperature (PET), was estimated to obtain an objective measure of thermal sensation. Particulate matter (PM_{10}) and nitrogen oxide (NO) were associated with dust perception. Nitrogen oxides (NO_x) and carbon monoxide (CO) were associated to air quality perception. Age, area of residence, health symptoms and thermal sensation also affected the perception of air quality. Dusty or poor air quality conditions were more likely to be reported when pollutants' concentrations were increased. Younger people, participants residing in the city center, experiencing health symptoms or warm thermal sensation showed a trend towards reporting more unfavorable air quality conditions.

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1. Introduction

Environmental quality plays a major role in the quality of life, affecting humans' health and welfare. It is a general concept that includes thermal environment, air, water and soil quality and pollution, ultraviolet radiation and climate change. Poor environmental conditions are related to health damages or even premature death, especially of individuals who are already at greater risk such as children and elderly (WHO, 2016). A World Health Organization (WHO) report on how much and in what ways improving the environment can promote health and well-being (Pruss-Ustun et al., 2016), confirms that 23% of global deaths and 26% of deaths among children under five years old could have been prevented if environmental risks, reasonably amenable to management or change, were removed. A key result of this report was also that environmental risks account for a large fraction of the global burden of disease.

Air quality is a leading risk factor among the environmental risks. Household and ambient air pollution, airborne particles or dust, toxic organic and inorganic substances and even odors are linked with diseases such as respiratory infections, asthma, chronic obstructive pulmonary disease, cardiovascular diseases, cancers, tuberculosis, neonatal conditions, as well as mental, behavioral and neurological disorders. The contribution of those diseases to the environmental burden of disease in 2012 exceeded 46% worldwide (Pruss-Ustun et al., 2016).

Numerous epidemiological studies' reviews or meta-analyses point out the adverse effects of air quality on human health (Shah et al., 2015; Zheng et al., 2015). More specifically for Southern European areas, the findings suggest among others, increased risk association for respiratory and cerebrovascular diseases, lung cancer and particulate matter (PM) (Beelen et al., 2014; Faustini et al., 2013; Harlan et al., 2006; Middleton et al., 2008; Moustris et al., 2015; Raaschou-Nielsen et al., 2013), for ischemic heart and cerebrovascular diseases and nitrogen oxides (NO_x) (Ballester et al., 2001; Katsoulis et al., 2014), for cardiovascular hospitalizations and carbon monoxide (CO) (Samoli et al., 2016) and for mortality and ozone (O_3), particularly during heat waves episodes (Analitis et al., 2014), implying a possible joint effect of air pollution with heat.

Several strategies and preventive public health measures have been applied aiming to reduce human health risks (Pruss-Ustun et al., 2016). People's behavior and response to preventive measures depends on the way they perceive environmental stimuli, therefore to protect public health through adaptation measures it is important to consider people's perception and behavioral changes (Berry et al., 2011; Elliott et al., 1999). Accordingly, the sense of air quality, as a factor of environmental quality, involves subjective perceptions and attitudes which vary among groups and individuals (Van Kamp et al., 2003).

Studies on indoor and outdoor air quality perception, have mainly shown non statistical significant association of perceived air quality to the measured pollutants concentrations (Brody et al., 2004; Dorizas et al., 2015; Semenza et al., 2008). Instead, air quality perception seems to be influenced by visual and olfactory experience, experience of psychological and physical effects or impacts on health (symptoms), nuisance or annoyance, publicity, interpersonal interaction and conversation, local knowledge, lifestyle factors (for instance, time spent outdoors can influence perceptions) (Brody et al., 2004; Nikolopoulou et al., 2011; Oltra and Sala, 2014) as well as temperature variations and thermal sensation (Dorizas et al., 2015; Zhang et al., 2011).

This study is the first that attempts to explore outdoor air quality perception in an urban Mediterranean environment, Athens, Greece. The aim is to bridge the gap between the perception of risk by experts and the public, identify factors that affect air quality perception and reveal its patterns. The potential to predict air quality perception is also investigated. This could benefit authorities and policy makers to improve the effectiveness of warning systems in reducing personal risk and people's contribution to the adverse conditions.

2. Methods

2.1. Field surveys

The surveys involved environmental conditions monitoring and structured interviews during summer and autumn 2010 and winter 2011 at three sites of the Athens metropolitan area: (a) Syntagma square, a central urban square, hub of public transportation, surrounded by avenues and streets, (b) Ermou street, a central pedestrian and commercial street, and (c) Flisvos coast, an urban coastal region with paved roads and small parks. The surveys were performed for 2 days per season and site, one day during morning and midday hours and one during afternoon and night hours except for Flisvos coast where measurements were not performed during winter and afternoon or night hours in the autumn due to low attendance. An additional survey day was performed in Syntagma during winter to obtain a number of questionnaires closer to the other seasons. Therefore, the surveys were conducted for 6 days between 15th and 21st of July 2010 and 5 days for each of the periods from 16th to 24th October 2010 and 9th to 27th February 2011, for a total of 16 days. Spring was excluded as a transient season with similar environmental conditions to autumn.

Environmental conditions were monitored at the height of 1.1 m above the ground by a fully automated mobile station. The instrumentation involved in this study includes (i) a Rotronic S3CO3 thermo-hygrometer with a non-ventilated aluminum radiation shield, (ii) a Second Wind C3 anemometer, (iii) a Kipp & Zonen CM3 pyranometer, and (iv) a grey globe thermometer (PVC 40 mm diameter sphere painted grey, 0.3 emissivity). The data were recorded on a CR10X Campbell Scientific Ltd. data-logger. The environmental variables measured were air temperature (T_{air}, °C), relative humidity (RH, %), average wind speed (WS, $m\cdot^{-1}$), globe temperature (T_{globe}, °C), and total solar radiation on a horizontal plane ($SR_{\downarrow}$, $W\cdot m^{-2}$), all in 1 min interval.

The participants in the surveys were people passing by or visiting the monitored sites, asked to report some personal characteristics and evaluate the environmental quality that they were experiencing at the moment of the interview. The personal characteristics considered here include factual and subjective variables. Factual personal variables were: gender (male/female), age (<18, 18–34, 35–54, >55 years old), weight (kg), height (m), clothing description, main activity during the last half hour (sleeping, sitting, standing, walking, doing sports), exposure time (visit duration at the interview site : <5 min, 5 to 30 min, 30 min to 1 h, >1 h), recent experience (places where the respondents were before their visit to the interview site: indoors, outdoors, means of transportation, work), exposure history (whether the subjects were or were not in an air-conditioned environment before their visit to the interview site), place of residence (center and suburbs of Athens city, province or abroad), smoking status (smokers, non-smokers), and medical history (having or not a medical history of asthma, respiratory or cardiovascular diseases, allergy). Subjective personal variables were participants' health condition with respect to whether they were experiencing or not symptoms such as headache, dizziness, breathing difficulties, and exhaustion (health symptoms), and irritated nose, throat or eyes (irritation symptoms). Overall comfort and thermal perception were also considered.

The environmental quality pertained to participants' perception of air quality concerning dust and overall pollutant air quality, overall comfort and thermal sensation. The participants were asked to report their environmental perception based on a 5-point scale except for thermal sensation that was based on a 7-point scale. The number of discrete categories to describe perception was selected based on previous studies (Nikolopoulou et al., 2011) and ISO 10551 (1995). The numerical expression of the scales was chosen to be symmetrical around zero ranging from −2 to +2 for 5-point scales and from −3 to +3 for thermal sensation scale. Negative values represent dusty, poor, uncomfortable and cool votes and positive values clean, good, comfortable and warm votes (Table 1).