Personal noise exposure in different microenvironments

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Abstract. Noise pollution is a major environmental issue, especially in urban areas where noise levels tend to be higher because of intensive traffic and industry activities. Epidemiological studies have demonstrated that noise exposure can cause a number of adverse physiological and psychological responses and diseases to human health. Accurate assessment of exposure is essential for health risk assessment. The aim of this study was to assess personal noise exposure in different microenvironments (MEs) according to time-activity patterns of individuals. Data were collected from 31 volunteers using questionnaires and smartphones. Participants were 20-26 years old and were carrying smartphones for 5 working days. The analysis of time-activity patterns and GPS data was performed using ArcGIS software. GPS data were classified into six location categories (home, work/study, other indoor, other outdoor static, outdoor walking and in-vehicle travel) to determine time spent in each location.

The results showed that there was a significant difference between noise levels in six location categories. The highest average noise level was determined in-vehicle travel location 62.8 dB. The difference between in-vehicle travel location and other locations were 12.2, 11.0, 6.4, 14.8 and 6.6 dB, respectively in home, work/study, other indoor, other outdoor static, outdoor walking locations.

Keywords: Noise pollution, exposure, GPS, microenvironment

1. Introduction

Noise is a major environmental issue in the modern world, originating from various sources and more attention needs to be paid to it (Lee *et al*., 2014). According to the World Health Organization (WHO), traffic noise is a main source of noise pollution and the second worst environmental stressor, affecting human health in Europe (Hjortebjerg *et al*., 2016). Noise from road transport contributes for about 80 % to the total noise pollution in urban areas (Clark *et al*., 2006). It is estimated that more than 125 million people could actually be exposed to road traffic noise above 55 dB L_{den}, and more than 37 million exposed to noise levels above 65 dB L_{den} in Europe (EEA, 2014).

The increase of urbanization, modern technologies and transportation leads to higher noise levels. Epidemiological studies showed that noise exposure can have an impact on a number of adverse health effects in adults and children, including annoyance, stress, sleep disturbance, physiological, psychological and social effects (Babisch *et al*., 2013; Halperin, 2014; Münzel *et al*., 2014). A number of research results reported the associations between the long-term environmental noise exposure and mental disorders, the prevalence of hypertension, the incidence of coronary heart disease and stroke (Sorensen *et al*., 2012; van Kamp *et al*., 2008).

The assessment of exposure to environmental pollution is essential part in order to determine an exposure–response relation. Nowadays, new technologies are used in epidemiological and environmental studies for better understanding of pollution sources and relationship between pollutant concentration, exposure, and dose (Nieuwenhuijsen *et al*., 2015). The assessment of personal exposure based on individual time-activity patterns increases the accuracy and validity of the study results (Steinle *et al*., 2013). It is vital to know where people spent their time in order to assess integrated personal exposure as the sum of concentration and time spent in each microenvironment (ME), which is defined as a location or activity where the exposure occurs. It is important to evaluate spatial and temporal distribution of pollutant concentrations in each microenvironment to assess personal exposure.

The aim of this study was to determine noise exposure in different microenvironments based on time-activity patterns.

2. Methods

2.1. Description of the study area

The study area is located in the central part of Lithuania, in Kaunas city (Figure 1). It is the second-largest city in Lithuania with the area of 157 km^2 and the population of 292,677 inhabitants. Kaunas has an international airport located 14 km northeast of the city centre and it is served by a number of major highways. There is one of the most important railway stations in the country.

2.2. Study participants

The study population included 31 participants. They were students 20-26 years of age, who agreed to participate in the research. The study was carried out in

2015. Participants were asked to answer the questionnaire to collect demographic, socio-economic, health and other factors.

Figure 1. The study location

2.3. Exposure assessment

The study participants were asked to wear a smartphone with a built-in GPS receiver and to fill travel dairy for five working days in order to track their location and to determine time-activity patterns. The data analysis was performed using ArcGIS software (Esri, Redlands USA). We distinguished six different locations - home, work/study, other indoor, other outdoor static, outdoor walking and in-vehicle travel to determine the duration of time spent in each of these microenvironments and to investigate contribution of specific ME to personal noise exposure. To identify specific ME and to assess time spent in each location for every individual, we used geographic information system (GIS). ArcGIS software was used to combine modelled noise pollution map of Kaunas city with microenvironment data. The noise level was determined in each ME and total exposure was calculated by summing noise exposure in all MEs.

2.4. Statistical analysis

To assess personal noise exposure and differences between MEs, we performed statistical analysis using IBM SPSS software package. The demographic, socio-economic, health and other factors were taken into account when calculating differences in personal noise exposure between subjects. Daily noise levels were calculated for each sampling day for each participant using six location categories. A paired samples t-test was conducted to compare mean differences between noise level in home and other MEs.

3. Results

The data analysis was performed in order to identify time-activity patterns and to assess time spent in each of 6 location categories. Two figures are presented below, which show hours per day spent in indoor MEs (Figure 2) and outdoor or travel MEs (Figure 3). Most of the time participant spent indoors. The analysis revealed that 69.9 % of time participant spent at home. They spent 12.4 and 9 % of time in work/study location and in other indoor places. The duration of time spent in outdoor and travel locations was much lower compared with indoor locations. The smallest amount of time participants spent in other outdoor locations. 3 % of time they spent walking and in-vehicle travel.

The noise level in different microenvironments is presented in Figure 4. The highest noise level was determined in in-vehicle ME and it was 62.8 dB. These results are expected as traffic is one of the main sources of noise in urban areas as well as in Kaunas city.

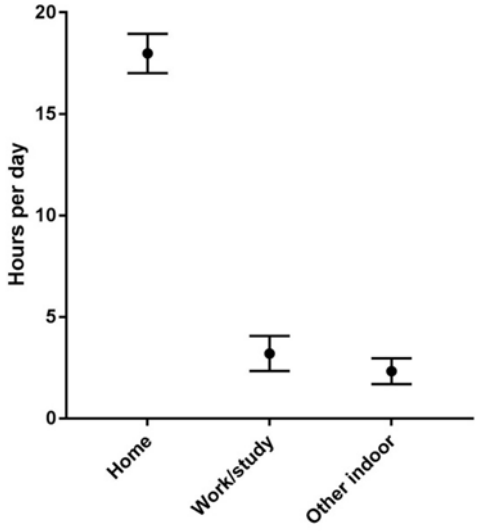

Figure 2. Hours per day spent in indoor MEs

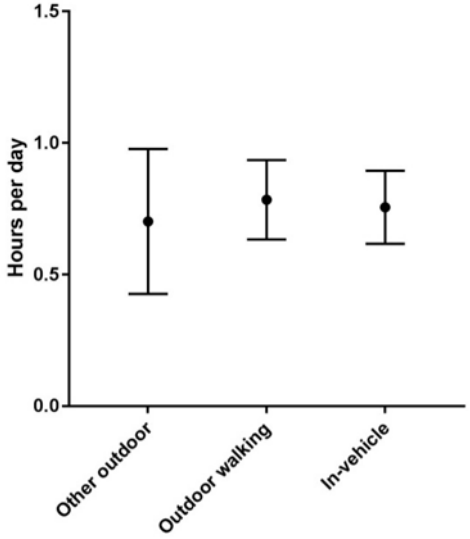

Figure 3. Hours per day spent in outdoor and travel MEs

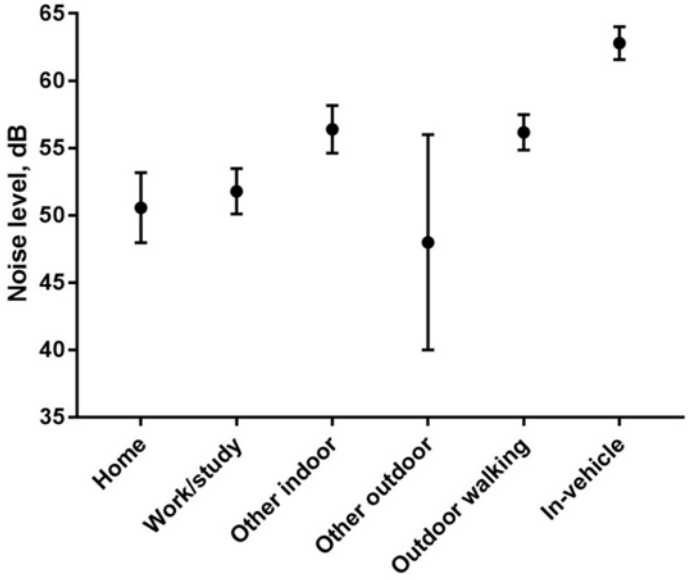

Figure 4. Noise level in different microenvironments

The lowest noise level was assessed in other outdoor ME (48.0 dB). The results showed that in this ME was observed the largest variance of noise level and this could be explained by the fact that people tend to spend their time outdoor in very different places – out of the city, in parks, in the city centre, and because of that the noise level varied from 30.4 to 67.9 dB. The mean bias between home, work/study and other indoor MEs was 12.2, 11.0 and 6.4 dB compared with in-vehicle ME. The differences in other outdoor and outdoor walking MEs were 14.8 and 6.6 dB compared with in-vehicle ME. The analysis showed that participants most of the time spent at home and in the further analysis we compared if the mean noise level differed statistically significant between home and other MEs. The results of paired sample t-test showed that there was a significant difference between noise level in home ME and other indoor ME ($t(30)= -4.06$, $p<0.0001$), also between noise level in home ME and outdoor walking ME ($t(30)= -4.27$, $p<0.0001$) and in-vehicle ME ($t(30)= -8.24$, $p<0.0001$).

4. Conclusions

The study was conducted to determine noise level in different microenvironments and to compare differences between these MEs using smartphones with in-built GPS receiver in order to track participants' locations and time spent in each of it. The study results showed that most of the time people spent indoors (home, work/study, other

indoor MEs) and less time outdoors, these results are similar with other studies (Matz *et al*., 2014; Odeh *et al*., 2016).

The highest noise levels were determined in in-vehicle and outdoor walking MEs as traffic is the major source of noise in cities and it is hard to avoid it while walking.

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