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Concentrations of monoaromatic hydrocarbons in the air of the underground car park and individual garages attached to residential buildings

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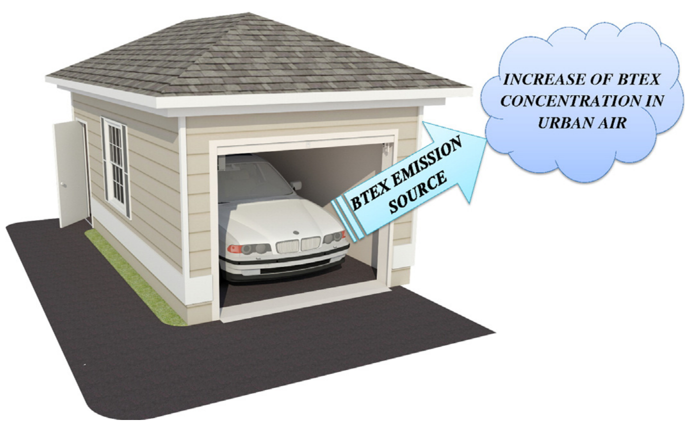
HIGHLIGHTS

- Liquid fuel combustion is the main source of emission of BTEX into the two-level underground car park air;
- The underground car park might be considered as the so-called "hot spot", a specific emission source of BTEX to urban air;
- There was a meaningful relationship between the number of parked cars and the concentration of BTEX in the car park air;
- The type of fuel for running the car considerably affects the concentration of BTEX in the residential garages air;
- The garage used as a workshop and storage area had approx. 10-fold higher BTEX concentration in air than the other garages.

GRAPHICAL ABSTRACT



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ABSTRACT

The paper describes the characteristics of a two-level underground car park and three individual garages attached to residential buildings, differing by the resident utilization habits, located in North Poland (Tri-City agglomeration area). The strategy of collecting the analyte samples from air in mentioned enclosed areas, concerning the determination of benzene, toluene, ethylbenzene, o-xylene and p,m-xylenes (BTEX) concentrations was performed using passive sampling technique – Radiello® diffusive passive samplers with graphitised charcoal cartridge as a sorption medium. The stage of liberation and final determination of collected analytes was conducted with the use of thermal desorption-gas chromatography-flame ionisation detector (TD-GC-FID) system. As a result of the performed measurements in two-level underground car park, it was observed that the time-weighted average concentrations of BTEX in air were as follows: Level-1 – benzene – 5.2 ± 1.1 μg/m^3, toluene – 12.3 ± 2.4 μg/m^3, ethylbenzene 2.85 ± 0.80 μg/m^3, o-xylene – 4.6 ± 1.4 μg/m^3, p, m-xylenes – 8.8 ± 2,4 μg/m^3; Level-2 – benzene - 5.2 ± 1.1 μg/m^3, toluene – 12.9 ± 3.6 μg/m^3, ethylbenzene – 2.73 ± 0.79 μg/m^3, o-xylene – 4.2 ± 1.1 μg/m^3, p, m-xylenes – 8.5 ± 2.3 μg/m^3. As for residential garages, the time-weighted average concentrations of BTEX in air were in the following ranges: from 5.9 to 53 μg/m^3 (benzene), from 7.1 to 195 μg/m^3 (toluene), from 3.0 to 39 μg/m^3 (ethylbenzene), from 5.6 to 44 μg/m^3 (o-xylene) and from 6.3 to 99 μg/m^3 (p,m-xylenes). Also, BTEX concentration ratios such as: tol/benz ratio and (m, p)-xyl/et.benz coefficient,

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were calculated based on the obtained results to assess the “freshness” of air mass and the influence exerted by vehicle movement on the concentration of BTEX in air in studied enclosed areas.

1. Introduction

Garage enclosures and large-sized underground and aboveground car parks must be analysed as a specific type of microenvironment (Papakonstantinou et al., 2003). Such compartments are usually designed and built as an integral household element, or residential building (individual garages), or as separate, large-sized areas to store many cars in the same place, in a convenient fashion for employees of a company or enterprise, customers of large-sized stores, or residents of large housing estates (Demir, 2015). For freestanding car parks occupying large areas, it is very frequent to design and built them as underground compartments, instead of having them constructed in open area. Also, such a constructional solution requires process-related solutions to allow proper air circulation and air exchange inside the underground car park (Batterman et al., 2006a).

The specificity of microenvironment in residential vehicle garages or underground car parks occupying large areas results from the fact that the air in this type of buildings contains chemical compounds that can occur at very high concentration levels. In addition, for garages attached to the households or residential buildings, pollutants may be transported from the garages to other rooms intended for occupants, e.g. kitchen, living room and bedroom (Batterman et al., 2006b, Dodson et al., 2008; Nirvan et al., 2012). Despite that the common user stays in such places for a relatively short time per day (access to the parking space, getting out of the car, approaching the exit of the underground car park), a very high accumulation of harmful compounds in the air is the reason for which the air in car parks can be classified as an additional element/factor of human exposure to xenobiotics, and consequently human health may be affected (Glorennec et al., 2008). Moreover, underground car parks can be recognized as the so-called “hot spots”, i.e. places posing a high impact on ambient air quality, significantly rising the concentrations of selected pollutants - organic compounds (mainly those in the group of VOCs), inorganic compounds (CO and NO_x) and suspended particulate matter (PM_{10} and $PM_{2.5}$) (Kim et al., 2007; Vuković et al., 2014).

Therefore, for almost 15 years, many research centres have been making an attempt to obtain analytic information on the type, and the quantity of hazardous chemical compounds in the air in different types of large-sized car parks and various types of vehicle garages attached to the residential buildings or households. Fuel combustion is a main source of emissions - vehicle exhaust emissions are the dominant source of aromatic hydrocarbons which largely affects the quality of air in different types of car parks. Consequently, analysing the literature data on air quality in different types of car park areas, it can be noticed that the mostly following compounds or groups of chemical compounds have been determined: MTBE, benzene, toluene, ethylbenzene, xylenes (Hun et al., 2011), 1,3-butadiene, formaldehyde, CO, CO_2, NO_x, and total hydrocarbons (THCs) (Jo and Song 2001; Graham et al., 2004; Zielińska et al., 2012, Li and Xiang, 2013).

Concentrations of chemical compounds determined in the air in car park areas depend on many factors, which can be generally classified as factors depending on: the characteristics of the motor vehicle, characteristics of the car park area (usable area, frequency of use, number of parked cars etc.) and meteorological conditions present in the open area. In case of large-sized car parks, one must pay attention to the fact that air circulation and air exchange inside the car park area is provided using a suitably designed ventilation system (Batterman et al., 2006a). Therefore, there is a risk that emitted pollutants can be transported by the ventilation system, directly into the ambient air.

Additionally, based on the information presented in the scientific literature, BTEX compounds (benzene, toluene, ethylbenzene, o-xylene, m, and p-xylenes) are referred to as indicators of the extent to which man is exposed to harmful chemicals from volatile organic compounds (VOCs) (Ly-Verdú et al., 2010).

This paper presents research results to estimate concentrations of BTEX compounds in the air of a two-level underground car park in the close vicinity of a public utility building and used only by the employees of that institution. The study was conducted for 30 days, including week days (20 days) and weekends (10 days).

Also, for comparison, the results of the research on the air quality (given as the concentration of BTEX compounds) in three individual garages attached to residential buildings are presented. The garages differed in cubature, their typical use (not only to park the vehicles) and the type of fuel used to drive the vehicle.

The evaluation of indoor air quality in different types of garages (large-scale underground car park and individual garages) allows to assess the problem of BTEX emission to ambient air from sources that are not considered significant from the point of view of emission rates and their impact on the quality of the ambient air. This applies in particular to the individual garage spaces, where the air inside is not subject of regular monitoring or controlling systems, and which may be recognized as uncontrolled emission sources of BTEX compounds into the ambient air and deteriorating local ambient air quality.

Also, in presented studies concerning a specific types of microenvironments (large-scale underground car park and individual garages), the BTEX concentration ratios such as: tol/benz ratio and (m, p)-xyl/et.benz coefficient, were calculated based on the obtained results to assess the “freshness” of air mass and the vehicle movement intensity influence on the concentration of BTEX in air in studied enclosed areas. This is a specific approach in a case of mentioned microenvironment air quality research, due to the fact that BTEX concentration ratios are commonly applied in the field of urban air quality research.

Radiello® diffusive passive samplers were used to collect samples of BTEX compounds from the gaseous phase. The application of passive sampling technique (in this type of research an alternative and more convenient solution than application of dynamic/active sampling devices) made it possible to conduct air quality measurements, both in the large-scale underground car park and individual garages without any interference with its normal functioning and use.

2. Materials and methods

2.1. Description of the BTEX sampling area

The two-level underground park, upon which the air quality was studied for the concentration of BTEX compounds, is located in the city centre of Gdansk, Poland. This car park is not publically accessible as it is intended only for cars owned by employees of the public utility institution. The car park has two levels: Level 1 has 38 parking spaces (total parking area of 1571 m^2; Level 2 has 45 parking spaces (total parking area of 1638 m^2). There is only one entrance for the cars to access the underground car park (both to Level 1 and Level 2). In order to access level 2, one must travel along the access route is arranged within the entire area of Level 1. A detailed plan of the two-level underground car park in which the air quality was studied is presented in Fig. 1. Both car park levels are equipped with mechanical ventilation, which is activated periodically. The average temperature in the area on Level 1 and Level 2 was 13 ± 1 °C and 14 ± 2 °C, respectively.