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EXPOSURE OF THE DRIVER STAYING INSIDE THE CAR CABIN TO VOLATILE ORGANIC COMPOUNDS

EKSPOZYCJA KIEROWCY PRZEBYWAJĄCEGO WEWNĄTRZ KABINY NOWEGO POJAZDU NA LOTNE ZWIĄZKI ORGANICZNE

Abstract: Nowadays the motorization is one of the basic branch of industry. Dynamic development of the – transportation sector has very positive impact on the social and civilization benefits, but on the other side, it generates also a lot of problems, especially related to the people health and life. The road transport is one of the main air pollution source, particularly in the cities. Furthermore, the motorization development caused increased in residence time inside vehicles. In the cities the traffic intensity is significantly higher than in the rural areas. This is the reason why road congestions are created. Exhausts, including hazardous volatile organic compounds, can easily penetrate into the cabin in the road congestion situation and they are the serious danger to the drivers and passengers. In the new cars, additional sources of volatile organic compounds are elements of the cabin interior.

In this paper the results of the research on volatile organic compounds concentration inside passenger car in simulated conditions were presented. Additionally, the main sources of volatile organic compounds inside the car cabin were identify and the evaluation of driver exposure was defined.

Keywords: car vehicle interior, indoor air quality, volatile organic compounds

Introduction

Not only pedestrians or cyclists moving along the streets are exposed to the air pollution caused by exhaust emission. Obviously, in the urban conditions traffic is more

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intensive than in rural areas. The streets are crowded, the average speed of cars is low and vehicles stops frequently at the crossroads, so the fuel consumption and consequently fumes emission increase. These are the reasons of congestion, connected with the huge amount of the vehicles moving through the city at the same time (especially in the rush hours) [1–3]. The fumes get into the vehicles staying at the congestion and pose a threat to the drivers and their passengers [4]. Exhaust gases cumulates inside the car cabin. Time of residence inside the vehicle increases with the development of motorization, hence the problem with exposure of driver at the toxic fumes components becomes more intense. Especially dangerous for people health are hydrocarbons of the volatile organic compounds (VOCs) groups' as well as polycyclic aromatic hydrocarbons (PAHs) [5]. It is therefore important to engage research on the exposure of the driver to that pollutants.

Research concept

Research consisted on evaluation of the amount of the volatile organic compounds (VOCs) getting into the passenger car cabin during simulated driving condition. The VOCs emitted from elements of vehicle equipment were ignored by specifying background of VOCs already emitted in cabin. Investigation consisted of three main stages: sampling, preparation of samples to analysis and chemical analysis of VOCs concentration with gas chromatography.

In order to simulate a driving conditions two cars were used. Tested vehicle (at the back) and emitting vehicle (ahead). Engine of emitting car was idling and subsequently operating with rotation speed about 2500–3000 rpm. The windows of the car behind were closed and ventilation system was working at the first level. Distance between cars was 70 cm (Fig. 1). This is the distance that is kept by cars in the real, urban conditions in congestion.

Fig. 1. Setting the vehicles relation to each other during measurement

Materials and methods

Parameters of vehicles used for the experiment are listed in Table 1.

Table 1

Basic parameters of tested vehicles

Mark and type	Mazda 3 Exclusive+	Opel Corsa C
Category	Passenger car	
Year of production	2011	2001
Fuel type	gasoline	gasoline
Engine capacity [ccm]	1598	973
Engine power [hp]	105	58

The first step of research was sampling which was performed in a chassis dynamometer hall. It let to eliminate the atmospheric conditions, especially the wind, which would affect the dilution of the emitted exhausts. From time to time the external fan was turned on which caused that conditions of the simulation were similar to outdoor. It also protect the working engine from excessive heating. Before the measurement, the samples of VOCs background were taken. Samples were taken in two places: out of the car, near air inlet and inside the cabin, where driver has head (Fig. 2) [6]. For sampling semi-automatic exhauster ASP-2 II was used. It is 2-channels device, so it was possible to sampling at the same time inside and outside. VOCs were adsorbed inside tubes filled with active carbon. The time of sampling was the same in both cases, background and right measurement and was 3 hours and the flow was 30 dm^3/h. Samples for the measurement were taken directly after sample for background.

Fig. 2. Sampling locations

The result was set of 4 samples: outdoor background, outdoor measurement, background inside and measurement inside the cabin. The next steps were preparing the samples to chemical analysis and gas chromatography analysis. Sample preparation consisted on desorption of sediment on the active carbon VOCs with carbon disulfide used as a solvent. Chromatographic analysis was performed with aid gas chromatograph Varian 450-GC with FID detector, capillary column Varian VF-WAXms (30m × 0.25 mm ID DF: 0.25 μm) and autosampler. Analysis of the VOCs were conducted with the following parameters:

– oven temperature (column) – 110°C during 10 minutes,
– inlet temperature – 250°C,
– FID temperature – 250°C,
– split – 1:20,
– volume of injection – 1 mm^3.

Results and discussion

Chromatography analysis were qualitative and quantitative. As the result of measurements different VOCs and their concentrations were identified. The concentrations given from chromatograph analysis in ppm (parts per million) of VOCs in 2 cm^3 of solvent (carbon disulfide) had to be converted to mg/m^3 in air. Subsequently the last step was calculating how many VOCs have gotten into car cabin during the measurement by subtraction of the background VOCs concentrations from VOCs concentration adsorbed during the measurement. Identified outside and inside VOCs are presented in Table 2.

Table 2

VOCs identified outside and inside Mazda's car cabin

BO	BI	MO	MI
n-pentane	*n*-pentane	*n*-pentane	*n*-pentane
2-propanol	2-propanol	benzene	2-propanol
toluene	toluene	toluene	benzene
ethylbenzene	ethylbenzene	ethylbenzene	toluene
p-, *m*-xylene	*p*-, *m*-xylene	*p*-, *m*-xylene	ethylbenzene
cumene	cumene	cumene	*p*-, *m*-xylene
o-xylene	*p*-cymene	*o*-xylene	cumene
p-cymene		*p*-cymene	*o*-xylene
			p-cymene

BO – background outside, BI – background inside, MO – measure outside, MI – measure inside.

Percentage of identified VOCs inside car cabin in background (a) and the measurement (b) are presented in Fig. 3. The highest share in each of sample (background and the measurement) inside the car cabin had light hydrocarbons expressed as *n*-pentane. Also 2-propanol had high percentage in both samples. As can be observed, amount of light hydrocarbons in the measurement is lower than in background. It means that during the congestion simulating conditions into the cabin heavier hydrocarbons like xylene, cumene, ethylbenzene are entered.

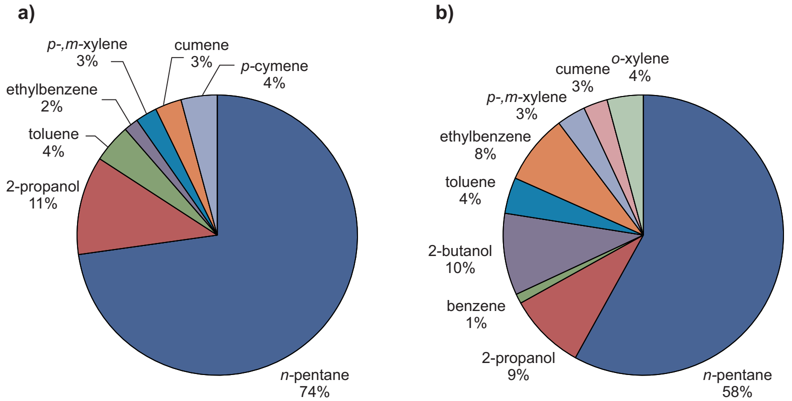

Fig. 3. Percentage of VOCs inside car cabin identified in: a) background, b) right measurement

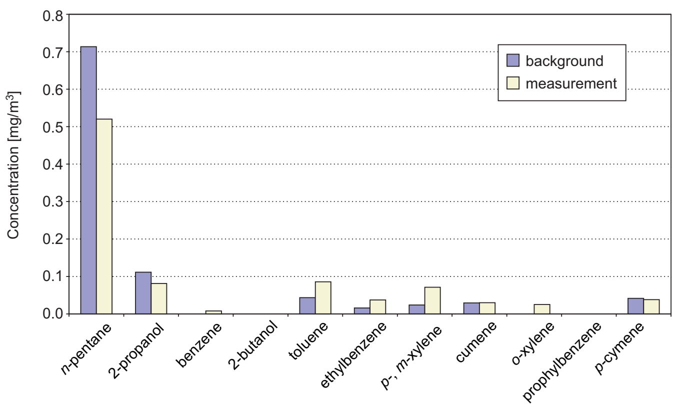

Fig. 4. Concentration of VOCs identified inside the car cabin before (background) and in the measurement

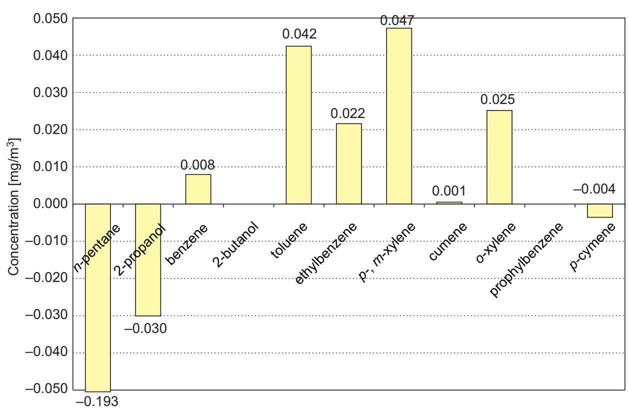

Fig. 5. Difference between VOCs concentration values identified before (background) and during measurement – the amount of VOCs getting inside cabin during simulated conditions

As it could be seen in Fig. 4, concentration of the VOCs majority is higher after measurement than in background. A few of them (*eg* benzene) appears after the simulation, so it means that during test pollutants was getting into the cabin. In Fig. 5 amount of VOCs entered into vehicle cabin during 3-hours simulation is presented.

Summary and conclusions

The research consisted on concentration of VOCs getting into the passenger car cabin determination. The tested car was new (2011), exploited car Mazda 3 and the emitting car was Opel Corsa C. In chromatography analysis 9 different VOCs were identified: *n*-pentane, 2-propanol, benzene, toluene, ethylbenzene, *para*-, *meta*- and *ortho*-xsylene, cumene and *p*-cymene.

Measured values of pollutants concentration inside the cabin wasn't very high and couldn't cause immediate reactions of the organism. None of the concentrations exceeded any exposure limit, but, what is important, long-term exposure even on the low concentration of the VOCs (especially on the benzene) could be toxic. It should be also note that the measurements were carrying out in the simulation conditions with one emitting car. In real, traffic conditions, in which participate a lot of different vehicles, amount of pollutants getting into the cabin could be much higher. VOCs identified in the background measurement, indicates that in new car could be another source of those pollutants – the materials used for made cabin equipment [7]. To avoid exposure to VOCs inside the car cabin it is beneficial to ventilate the interior by open both of doors from time to time (on opposite sides) when stationary or both of windows during driving.

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EKSPOZYCJA KIEROWCY PRZEBYWAJĄCEGO WEWNĄTRZ KABINY NOWEGO POJAZDU NA LOTNE ZWIĄZKI ORGANICZNE

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Abstrakt: W obecnych czasach motoryzacja stanowi jedną z głównych gałęzi przemysłowych. Dynamiczny rozwój motoryzacji, poza wieloma walorami społecznymi i cywilizacyjnymi, jest powodem licznych problemów, przekładających się w mniejszym lub większym stopniu na zdrowie i życie ludzi. Transport jest jednym z głównych źródeł emisji zanieczyszczeń do powietrza, szczególnie w aglomeracjach miejskich. Co więcej, rozwój motoryzacji sprawia również, że ludzie spędzają w samochodach coraz więcej czasu. W warunkach miejskich natężenie ruchu jest znacznie wyższe niż poza miastem. Często powstają zatory drogowe. Spaliny, których składnikami są również lotne związki organiczne, dostając się do wnętrza pojazdów uczestniczących w zatorze drogowym, stanowią poważne zagrożenie dla kierowców tych pojazdów oraz ich pasażerów. W nowych pojazdach dodatkowym źródłem lotnych związków organicznych mogą być elementy wyposażenia wnętrza kabiny.

W pracy przedstawiono wyniki badań stężeń lotnych związków organicznych wewnątrz kabiny nowego, eksploatowanego samochodu osobowego. Zidentyfikowano również źródła lotnych związków organicznych znajdujących się wewnątrz pojazdu oraz dokonano oceny narażenia kierowcy.

Słowa kluczowe: wnętrze kabiny pojazdu, jakość powietrza wewnętrznego, lotne związki organiczne