THE IMPACT OF CAR VEHICLE CLASS ON VOLATILE ORGANIC COMPOUNDS (VOC's) CONCENTRATION IN MICROATMOSPHERE OF CAR CABIN

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Abstract

The inner atmosphere of a car vehicle became one of the most important environments of human life. Many elements inside of a car cabin are potential sources of volatile organic compounds (VOC's) which hazardous effect on human health is proved. To estimate quality of indoor air of a car the qualitative analysis of hydrocarbons is very important considering the fact that some substances (i.e. benzene, acetone and xylene isomers) despite low concentration level characterize toxic and carcinogenic properties. A significant impact on VOC's concentration has vehicle cabin equipment and quality of applied materials. The internal sources of the pollution are elements of cabin equipment (textiles, foams, plastic materials), solvents in glues, paints, lacquers and car cosmetics. The external sources of the pollution are pollutants emitted to environment in gas phase by mobile or static sources. This paper presents the results of the research which aim was qualitative and quantitative analysis of VOC's concentration inside of various classes of car vehicle cabins. The research was done in Emission Research Laboratory of The Division of Motor Vehicles and Internal Combustion Engines. The analysis was done according to European standard (EN ISO 16017-1: 2006) on gas chromatograph (Varian 450 GC) equipped in capillary column and flame-ionization detector (FID).

Keywords: *Volatile hydrocarbons, indoor measurements, car vehicle cabin*

1. Introduction

Indoor air quality has become a public health issue of increasing concern during the last decades. Since the concentrations of air pollutants are known to be frequently higher indoors than outdoors often exceeding by up to five times the outdoor levels and because most people spend an average of 87% of their time within enclosed buildings living, working and studying. Also the inner atmosphere of a car vehicle became one of the most important environments of human life [1-4].

It has been consequently acknowledged that the inhalation of indoor air is the major determinant of human exposure to many pollutants. One of the most hazardous for human health is Volatile organic compounds (VOC's) group.

VOC's effects on human health range from odour problems to toxic or carcinogenic effects. As a consequence, more stringent legislation on VOC emission has been implemented worldwide. To comply with this legislation, the use of processes which inherently cause little or no VOC's emission is preferable [4].

Because of a fact that most of volatile organic compounds are listed as being toxic not only a problem their concentration in environment is considered necessary to be solved but also it is very important to monitor their toxic influence on human health. The second problem is very complicated and it strongly depends of the VOC's group composition in indoor air. For some substances Recommended Maximum Concentration Limit (RMCL) is settled in special directives (Tab. 1).

Tab. 1. Recommended Maximum Concentration Limit (RMCL), μg/m^3, for year period, for chosen substances from VOC's group according to Polish directive [5]

Compound	Chemical formula	RMCL, μg/m^3
Akrolein	C_3H_4O	0.9
Acetic aldehyde	C_2H_4O	2.5
MIBK (metylisobutylketone)	$C_6H_{12}O$	3.8
Formaldehyde	CH_2O	4
Benzene	C_6H_6	5
Toluene	C_7H_8	10
Xylene	C_8H_{10}	10
Butyl alcohol	$C_4H_{10}O$	26
Acetone	C_3H_6O	30
Ethylbenzene	C_8H_{10}	38
Heptane	C_7H_{16}	1000
Hexane	C_2H_{14}	1000
Octane	C_8H_{18}	1000
Nonane	C_9H_{20}	1000

A significant impact on VOC's concentration has vehicle cabin equipment and quality of applied materials. The internal sources of the pollution are elements of cabin equipment (textiles, foams, plastic materials), solvents in glues, paints, lacquers and car cosmetics [3].

In the ambient air, traffic is the dominating source for these compounds that's why the indoor air load of VOC's compounds inside of a car cabin originates in part from the outdoors. Another part is created by human activities indoors, like smoking, cleaning, fumigation and the use of varnish and solvents [3].

BTX (Benzene – Toluene - Xylene) compounds are known as markers for the exposure to volatile organic compounds [3].

2. Experiment

The aim of the research was qualitative and quantitative analysis of VOC's concentration inside of various classes car vehicle cabins. The research was done in Emission Research Laboratory of The Division of Motor Vehicles and Internal Combustion Engines.

Three types of new car vehicles were chosen for VOC's concentration analysis:

- lower class car vehicle (LCCV),
- higher class car vehicle (HCCV),
- delivery car vehicle adjusted for passenger's transportation (DCV).

The vehicles were tested in parking conditions (to traffic, outdoor pollution impact minimization). The samples were uptaken in similar, standard parameters of temperature, pressure and humidity.

VOC's samples were uptaken by tubes with active coal (SKC lot 2000). The analysis was done according to polish standard: PN – EN ISO 16017-1: 2006. The procedure of VOC's quantitative and quantitative analysis is shown on Fig. 1.

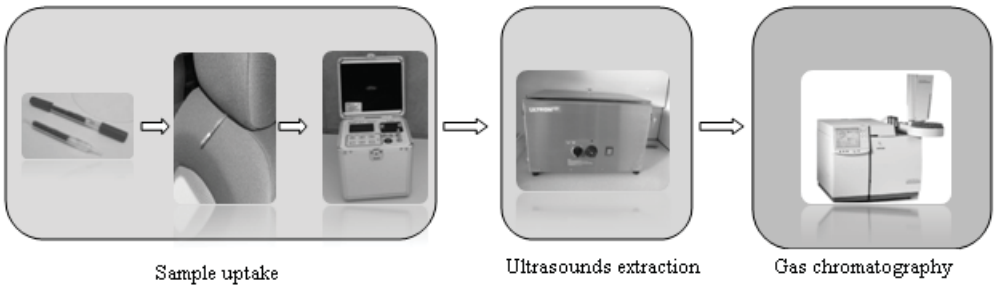

Fig. 1. The procedure of Volatile Organic Compounds marking in indoor environment of car vehicle

Carbone disulfide (CS2) was used for VOC's extraction from active coal. Gas chromatograph Varian 450 GC with FID detector and capillary column was used for quantity and quality analysis. The chromatography conditions were: column temperature (110ºC), dozers (150ºC) and detectors (250ºC).

For the detailed analysis of the exposure to VOC's pollutants, the total VOC's concentration and BTX (benzene, toluene, ortho-xylene, meta- and para-xylene) concentration were selected.

3. Results and Discussion

I the result of the research over 30 compounds was detected from VOC's group and 14 was identified:

- alcohols: 2-propanol, 1-butanol, 2-butanol,
- aromatic hydrocarbons: benzene, toluene, ethylobenzene, xylene (ortho-, meta-, para-xylene), kumene, propylobenzene, mezytylene, p-cymene,
- paraffin hydrocarbons: n-pentane.

Total VOC's concentration was the lowest for delivery car vehicle (2.2903 mg/m^3) and the highest for higher class car vehicle (3.9305 mg/m^3) (Fig. 1). The VOC's concentration in microatmosphere LCCV and DCV was comparable.

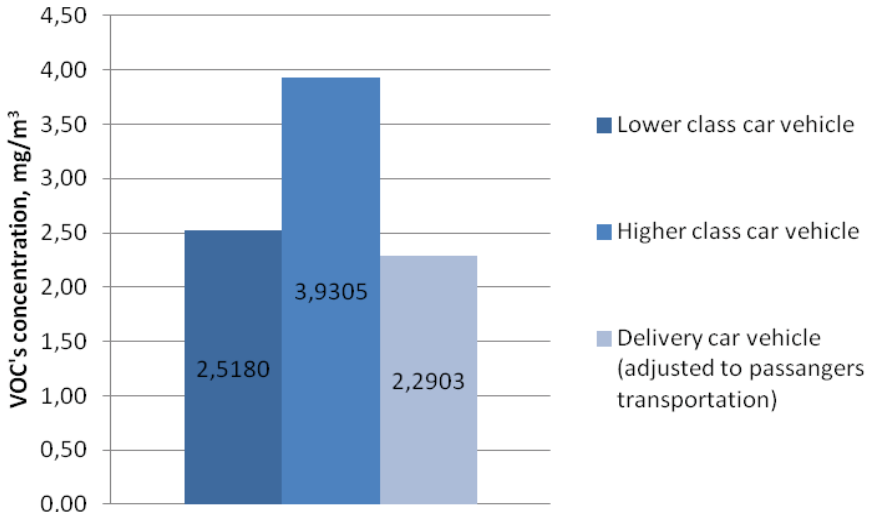

Fig. 2. Total VOC's concentration in microenvironment of car vehicle cabin

Despite over 1,5 mg per 1 m^3 higher VOC's concentration in case HCCV in comparison with DCV and LCCV, share of the most hazardous VOC's group – aromatic hydrocarbons – in identified compounds is the highest in case of delivery car (70%). VOC's composition shows that for LCCV and HCCV level of aromatic hydrocarbons share is approximately 30% (Fig. 3).

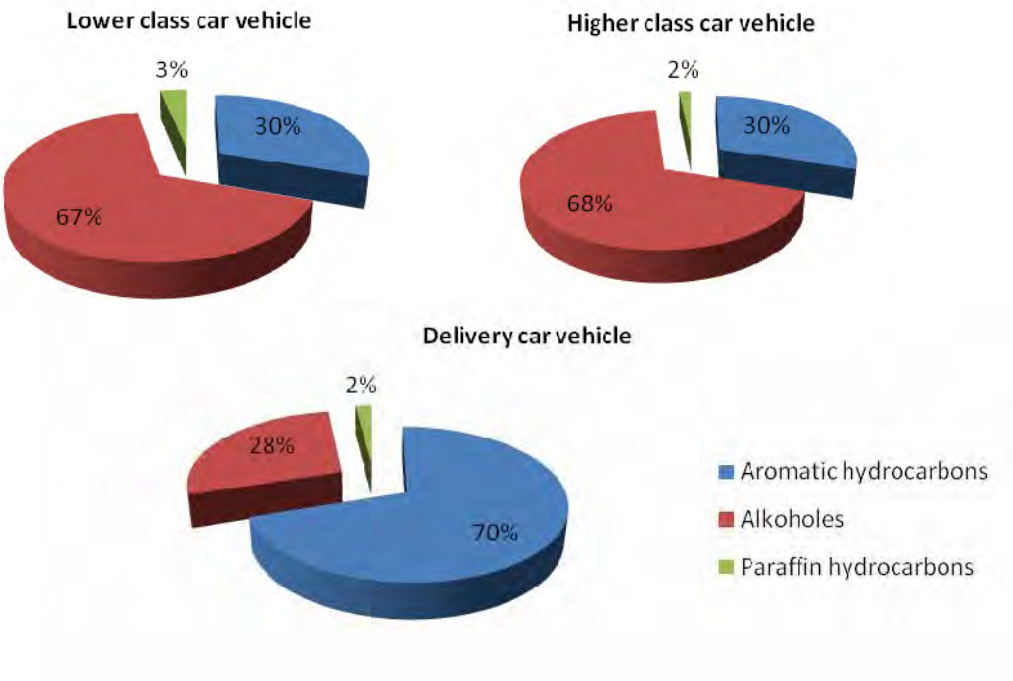

Fig. 3. VOC's group composition in microenvironment of various class car vehicles cabins

The analysis of BTX concentration indicates that the highest concentration of benzene was detected for HCCV (about 0.1 mg per m^3 higher than was detected inside LCCV and DCV) (Fig. 4).

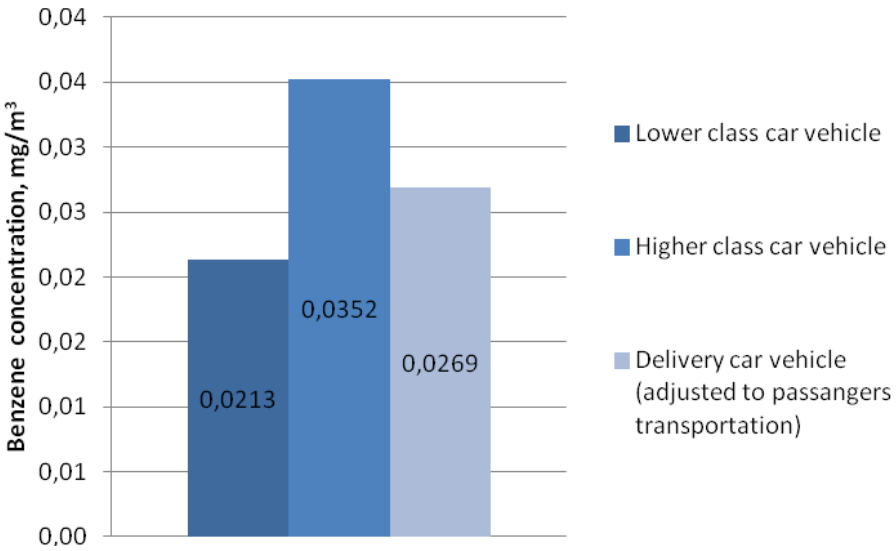

Fig. 4. Benzene concentration in microenvironment of car vehicle cabin

Benzene is one of the most toxic substances in VOC's group [3, 5]. Its mutagenic and carcinogenic properties underline the problem of its higher concentration in higher class car vehicle cabin. It is very important to investigate the source of its indoor emission especially that in high class vehicle the highest quality, tested and save for human health materials should be used (what impact on car price). Benzene is mainly used as an intermediate to make other chemicals. Its most widely-produced derivatives include styrene, which is used to make polymers and plastics, phenol for resins and adhesives (via cumene), and cyclohexane, which is used in the manufacture of Nylon. Smaller amounts of benzene are used to make some types of rubbers, lubricants, dyes, detergents [6].

Xylene isomers analysis shows that the lowest concentration was detected in microatmosphere of DCV cabin. Total xylene concentration is comparable for HCCV. Almost 5 times higher concentration was observed in case of LCCV (Fig. 5).

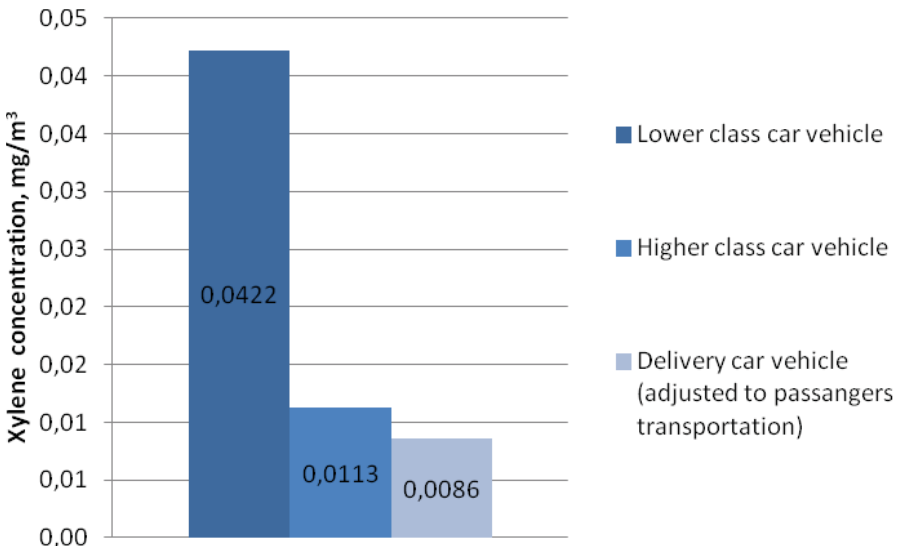

Fig. 5. Xylene concentration in microenvironment of car vehicle cabin

The results of the research indicate that in case of DCV and HCCV there is a high possibility of non-xylenium materials usage. Xylene is often used as a solvent and in the rubber, as a carrier for acrylic based concrete sealers, for polymer production, as a cleaning agent [6].

The analysis of toluene concentration in cabin atmosphere of chosen car vehicles shows similar level of pollution (average 0.25 mg/m^3) for LCCV and HCCV (lower for lower class of vehicle). The toluene concentration in the indoor air is about 5 times higher for delivery car vehicle.

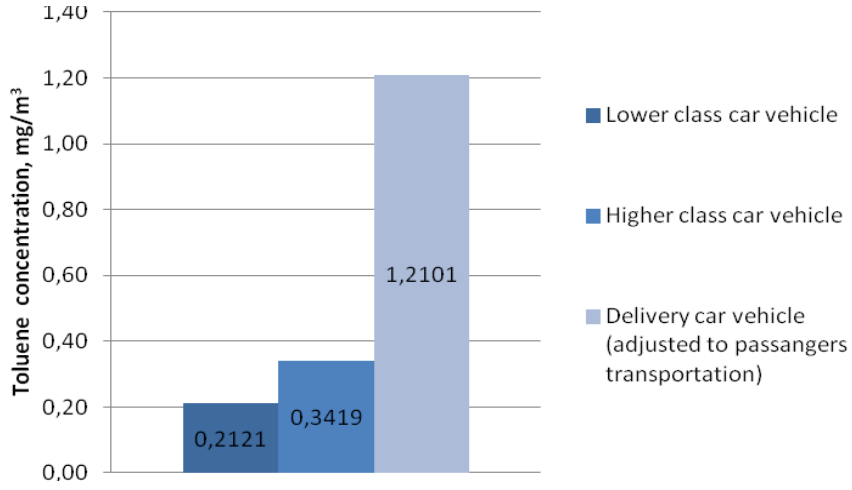

Fig. 6. Toluene concentration in microenvironment of car vehicle cabin

The toxicity and RMCL of toluene is comparable to xylene (Tab. 1) and about 2 times lower than benzene [3, 5]. The highest concentration of toluene in delivery car class vehicle indicates that in case of that vehicle the materials based on toluene as a solvent was used. Toluene is a common solvent, able to dissolve paints, paint thinners, silicone sealants, rubber, adhesives (glues), lacquers, leather tanners, and disinfectants. It can also be used as a fullerene indicator, and is a raw material for toluene diisocyanate (used in the manufacture of polyurethane foam) and TNT [6].

4. Conclusions

1. The inner atmosphere of a car vehicle became one of the most important environments of human life that is why indoor air quality (inside a car cabin) has become a public health issue.
2. The results of the researches show that high class of vehicle is not a guaranty of its safety for human health in indoor air quality aspect (high total VOC's and benzene concentration).
3. The interesting results of the investigation indicate on the need of research continuation also in material science and toxicology aspect.

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