DOI: 10.2429/proc.2014.8(1)003 2014;8(1)

Barbara FILIPEK-MAZUR[1], Monika TABAK[1] and Olga GORCZYCA[1]

CONTENT OF POLYCYCLIC AROMATIC HYDROCARBONS IN SOILS EXPOSED TO TRAFFIC POLLUTION

ZAWARTOŚĆ WIELOPIERŚCIENIOWYCH WĘGLOWODORÓW AROMATYCZNYCH W GLEBACH NARAŻONYCH NA EMISJE ZANIECZYSZCZEŃ KOMUNIKACYJNYCH

Abstract: The aim of the research was to determine the impact of traffic pollution on the content of 11 polycyclic aromatic hydrocarbons (PAHs) in soils: naphtalene, acenaphtene, acenaphtylene, fluorene, phenantrene, anthracene, fluoranthene, pyrene, benz[a]anthracene, chrysene as well as benzo[a]pyrene. The research material consisted of soil samples collected from 13 points located along regional road No. 957 passing through Zawoja (southern Poland, Malopolska region). In each point the soil samples were collected from sites located 5 and 200 m from the road edge. The PAHs content was determined using gas chromatography with mass detection, after solid phase extraction. Mean contents of individual PAHs in samples collected closer to the roadway were higher than mean contents in samples collected farther. Differences in the content of PAHs between samples collected at a distance of 5 m and 200 m from the edge of the roadway were increasing along with the increase of number of rings in the PAHs, i.e. soils located at a distance of 5 m from the edge of the roadway contained 9% more naphtalene, 37-294% more 3-ring compounds, 260-333% more 4-ring compounds, and 324% more benzo[a]pyrene.

Keywords: polycyclic aromatic hydrocarbons, soil, transportation

Introduction

Polycyclic aromatic hydrocarbons (PAHs) are organic compounds that are harmful to living organisms (they have a carcinogenic effect) [1 based on various sources]. One of the main anthropogenic sources of PAHs is road transportation. PAHs are emitted during combustion of fuels (gasoline, diesel), use of engine oils as well as during abrasion of tyres and asphalt [2-4]. As a result, these compounds are present in road dust as well as in soil in areas neighbouring with traffic routes [4, 5]. Excessive content of polycyclic aromatic hydrocarbons in soil (particularly in soil used agriculturally) constitutes a threat to living organisms because these compounds are accumulated in the links of the food chain [6].

The aim of the research was to determine the impact of traffic pollution on the content of 11 polycyclic aromatic hydrocarbons in soils.

Material and methods

The research material comprised soil samples collected from a site located in southern Poland (from the Suski district which is situated in the Malopolska region). The samples were collected from 13 grass covered points located along regional road No. 957 passing through Zawoja. In each point the soil samples were collected from places located 5 m and 200 m from the road edge, from a 0-10 cm deep layer. A characteristic of the research

[1] Department of Agricultural and Environmental Chemistry, University of Agriculture in Krakow, al. A. Mickiewicza 21, 31-120 Kraków, Poland, phone +48 12 662 43 44, fax +48 12 662 43 41, email: rrfilipe@cyf-kr.edu.pl, Monika.Tabak@ur.krakow.pl o.gorczyca@ur.krakow.pl
[*] Contribution was presented during ECOpole'13 Conference, Jarnoltowek, 23-26.10.2013

material collection sites (including information on traffic intensity) as well as data on the properties of the analyzed soils are shown in the article by Filipek-Mazur et al [7].

The content of the following 11 compounds from the PAH group was determined in the soil samples:

- 2-ring compound: naphtalene,
- 3-ring compounds: acenaphtene, acenaphtylene, fluorene, phenantrene, anthracene,
- 4-ring compounds: fluoranthene, pyrene, benz[a]anthracene, chrysene,
- 5-ring compound: benzo[a]pyrene.

The content of PAHs was determined on the Varian 4000 GC/MS system using gas chromatography with mass spectroscopy, after solid phase extraction (SPE) using Bakerbond C18 500 mg, 3 cm^3 columns. FactorFour VF-5ms capillary column was used. The determination of the PAHs content in each sample was conducted in two replications. In order to perform calibration, a method of comparison with an external reference standard was used. Restek 610 PAH Calibration Mix standard was used.

Statistical analyzes were performed using the data analysis software system STATISTICA version 10 (StatSoft, Inc.).

Results and discussion

Soils located 5 m from the edge of the roadway had a higher mean content of each of the 11 determined polycyclic aromatic hydrocarbons than the soils at a distance of 200 m (Tables 1 and 2). The studied soils, particularly the ones collected at the distance of 5 m from the edge of the roadway, had a high diversification in the content of hydrocarbons. The variability coefficient of the PAHs content was 68-230% for the soils collected closer to the roadway, and 46-138% for the soils located farther from the edge of the roadway.

Table 1

PAHs content in soils located 5 m from edge of roadway

PAH	Arithmetic mean	Minimum	Maximum	Standard deviation	Variability coefficient
	[mg · kg^{-1} d.m.]				[%]
Naphthalene	0.107	0.053	0.342	0.073	68.4
Acenaphthylene	0.012	ND *	0.036	0.010	81.8
Acenaphthene	0.059	0.006	0.318	0.087	147.2
Fluorene	0.053	0.007	0.228	0.065	122.7
Phenanthrene	0.923	0.095	4.361	1.261	136.7
Anthracene	0.197	ND	1.023	0.299	151.9
Fluoranthene	2.240	0.048	14.349	3.841	171.4
Pyrene	1.905	0.034	12.762	3.405	178.8
Benz[a]anthracene	0.789	ND	5.585	1.495	189.5
Chrysene	1.132	ND	8.337	2.227	196.7
Benzo[a]pyrene	1.251	ND	10.701	2.880	230.2
Two-ring compound	0.107	0.053	0.342	0.073	68.4
Three-ring compounds	1.244	0.114	5.654	1.684	135.4
Four-ring compounds	6.066	0.082	41.033	10.957	180.6
Five-ring compound	1.251	ND	10.701	2.880	230.2

* ND - not detected (value “0.000” was used to do the statistical calculations)

Table 2

PAHs content in soils located 200 m from edge of roadway

PAH	Arithmetic mean	Minimum	Maximum	Standard deviation	Variability coefficient
	[mg · kg^{-1} d.m.]				[%]
Naphthalene	0.098	0.068	0.231	0.045	46.3
Acenaphthylene	0.009	ND*	0.019	0.005	56.9
Acenaphthene	0.024	ND	0.070	0.022	90.7
Fluorene	0.025	ND	0.063	0.018	73.2
Phenanthrene	0.414	0.041	1.403	0.370	89.4
Anthracene	0.050	ND	0.170	0.059	118.2
Fluoranthene	0.622	0.023	2.786	0.715	115.1
Pyrene	0.500	ND	2.215	0.573	114.5
Benz[a]anthracene	0.182	ND	0.805	0.215	118.2
Chrysene	0.277	ND	1.442	0.383	138.0
Benzo[a]pyrene	0.295	ND	1.212	0.340	115.2
Two-ring compound	0.098	0.068	0.231	0.045	46.3
Three-ring compounds	0.522	0.049	1.685	0.459	87.9
Four-ring compounds	1.581	0.023	7.248	1.878	118.8
Five-ring compound	0.295	ND	1.212	0.340	115.2

* see Table 1

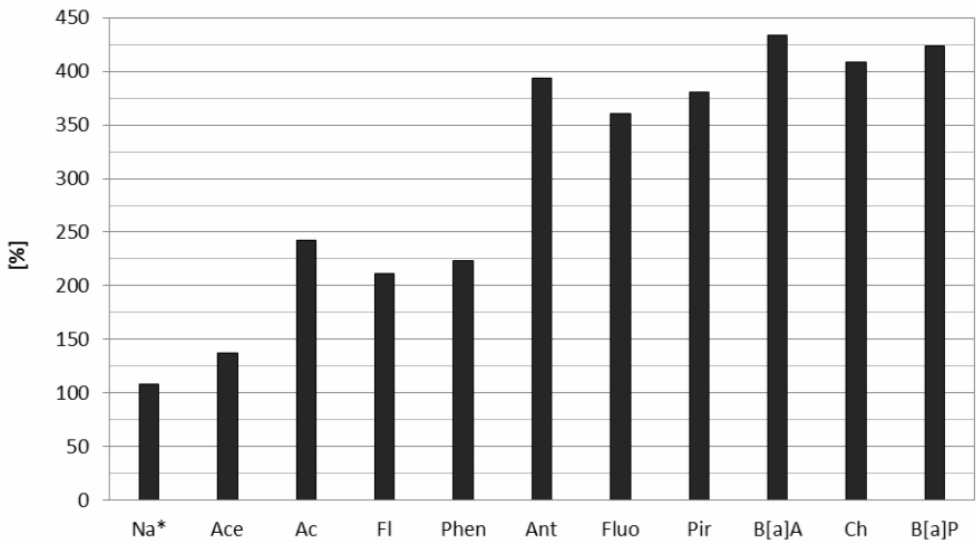

Fig. 1. Average PAHs content in soils located at a distance of 200 m from the edge of the roadway presented in relative values (with assumption that the content of individual PAHs in the soils located at a distance of 5 m is 100%); *Na - naphthalene, Ace - acenaphthylene, Ac - acenaphthene, Fl - fluorene, Phen - phenanthrene, Ant - anthracene, Fluo - fluoranthene, Pyr - pyrene, B[a]A - benzo[a]anthracene, Ch - chrysene, B[a]P - benzo[a]pyrene

The mean content of individual PAHs in soils located closer to the edge of the roadway was higher by 9 to 333% than the mean content in soils located at a distance of 200 m from the roadway. As a rule, differences in the PAHs content between soils located 5 and 200 m

from the edge of the roadway were increasing along with the increase in the number of rings in the molecule of a compound. In Figure 1, the PAHs content in soils located 5 m from the edge of the roadway is presented in relative values - assuming that the content of individual hydrocarbons in the soils located at a distance of 200 m is 100%. Soil located closer to the edge of the roadway contained 9% more naphthalene (2-ring compound), 37-294% more 3-ring PAHs, 260-333% more 4-ring PAHs, and 324% more benzo[a]pyrene (5-ring compound).

As specified in the regulation on soil and earth quality standards [8], 1 kg of dry matter of soil from agricultural lands, taken from a depth of 0-0.3 m may contain no more than 0.1 mg of naphthalene, 0.1 mg of phenanthrene, 0.1 mg of anthracene, 0.1 mg of fluoranthene, 0.1 mg of chrysene, 0.1 mg of benzo[a]anthracene, and 0.03 mg of benzo[a]pyrene. In total, the permissible content of PAHs was exceeded in 11 soil samples collected at a distance of 5 m from the edge of the roadway and in 11 samples collected at a distance of 200 m (Table 3). That excess concerned, above all, the contents of phenanthrene, fluoranthene, benzo[a]anthracene, chrysene, and benzo[a]pyrene (between 7 and 11 soil samples), in other words compounds containing between 3 and 5 rings. Fewer soil samples were polluted with naphthalene and anthracene, that is compounds containing, respectively, 2 and 3 aromatic rings in a molecule.

Table 3

Number of soil samples where permissible content of PAHs, specified in regulation on soil and earth quality standards [8], was exceed

PAH	Distance from the roadway	
	5 m (n = 13)	200 m (n = 13)
Naphthalene	0	1
Phenanthrene	10	9
Anthracene	4	2
Fluoranthene	11	11
Benzo[a]anthracene	9	7
Chrysene	9	7
Benzo[a]pyrene	10	8

In own research, soil pollution particularly with compounds with a greater number of rings was found. It is an unfavorable situation, because the greater the number of rings in a molecule of aromatic hydrocarbon, the more harmful effect it has on living organisms [1 based on various sources, 9 based on various sources, 10].

Conclusions

1. Soils located closer to the edge of the roadway had a higher mean content of each of the 11 determined PAHs (naphthalene, acenaphthene, acenaphthylene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo[a]anthracene, chrysene, and benzo[a]pyrene) than soils located farther from the edge of the roadway.
2. Soils located at a distance of 5 m from the edge of the roadway contained 9% more naphthalene, 37-294% more 3-ring compounds, 260-333% more 4-ring compounds, and 324% more benzo[a]pyrene.

Acknowledgements

The research was financed by the science fund of the Polish Ministry of Science and Higher Education, as a research project No. 3101.

References

[1] Pufulete M, Battershill J, Boobis A, Fielder R. Regul Toxicol Pharmacol. 2004;40:54-66. DOI: 10.1016/j.yrtph.2004.04.007.
[2] Boonyatumanond R, Murakamib M, Wattayakorn G, Togo A, Takada B. Sci Total Environ. 2007;384(1-3):420-432. DOI: 10.1016/j.scitotenv.2007.06.046.
[3] Takada H, Onda T, Harada M, Ogura N. Sci Total Environ. 1991;107:45-69.
[4] Trang TTD, Byeong-Kyu L. Chemosphere. 2009;74:1245-1253. DOI: 10.1016/j.chemosphere.2008.11.035.
[5] Laskowski S, Trawczyńska A, Tołoczko W. Chem Inż Ekol. 2005;12(7):709-715.
[6] Kabata-Pendias A, Piotrowska M, Motowicka-Terelak T, Maliszewska-Kordybach B, Filipiak K, Krakowiak A, et al. Podstawy oceny chemicznego zanieczyszczenia gleb. Metale ciężkie, siarka i WWA. Warszawa: PIOŚ, IUNG; 1995.
[7] Filipek-Mazur B, Tabak M, Gorczyca O. Ecol Chem Eng A. 2013;20(6):631-641. DOI: 10.2428/ecea.2013.20(06)058.
[8] Regulation of the Minister of Environment of 9 September 2002 on soil and earth quality standards. 2002. Journal of Laws No. 165, item 1359.
[9] Tsai PJ, Shih TS, Chen HL, Lee WJ, Lai ChH, Liou SH. Atmos Environ. 2004;38:333-343. DOI: 10.1016/j.atmosenv.2003.08.038.
[10] Fisher TT, Law RJ, Rumney HS, Kirby MF, Kelly C. Ecotoxicol Environ Saf. 2011;74:2245-2251.

ZAWARTOŚĆ WIELOPIERŚCIENIOWYCH WĘGLOWODORÓW AROMATYCZNYCH W GLEBACH NARAŻONYCH NA EMISJE ZANIECZYSZCZEŃ KOMUNIKACYJNYCH

Katedra Chemii Rolnej i Środowiskowej, Wydział Rolniczo-Ekonomiczny
Uniwersytet Rolniczy im. Hugona Kołłątaja w Krakowie

Abstrakt: Celem badań było określenie wpływu emisji zanieczyszczeń komunikacyjnych na zawartość 11 wielopierścieniowych węglowodorów aromatycznych (WWA) w glebach, tj.: naftalenu, acenaftenu, acenaftylenu, fluorenu, fenantrenu, antracenu, fluorantenu, pirenu, benz(a)antracenu, chryzenu oraz benzo(a)pirenu. Materiał badawczy stanowiły próbki gleb pobrane z 13 punktów położonych wzdłuż drogi wojewódzkiej nr 957 na terenie Zawoi (południowa Polska, województwo małopolskie). W każdym punkcie próbki gleb pobrano z miejsc odległych o 5 i 200 m od brzegu jezdni. Zawartość WWA oznaczono techniką chromatografii gazowej z detekcją masową, po ekstrakcji do fazy stałej. Średnie zawartości poszczególnych WWA w próbkach pobranych bliżej jezdni były większe od średnich zawartości w próbkach pobranych w większej odległości. Różnice w zawartości WWA pomiędzy próbkami pobranymi w odległości 5 i 200 m od brzegu jezdni zwiększały się wraz ze zwiększaniem liczby pierścieni w cząsteczkach WWA - gleby położone w odległości 5 m od brzegu jedni zawierały o 9% więcej naftalenu, o 37-294% więcej związków 3-pierścieniowych, o 260-333% więcej związków 4-pierścieniowych i o 324% więcej benzo(a)pirenu.

Słowa kluczowe: wielopierścieniowe węglowodory aromatyczne, gleba, transport