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Studies of Levels of Polycyclic Aromatic Hydrocarbons in Soils Subjected to Anthropopressure in the City of Poznań

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Abstract

TLC, GC and HPLC methods were employed to determine the concentrations of 16 PAHs in the surface level of soils subjected to a differentiated level of anthropopressure from the Poznan municipal area. PAH pollution was confirmed, primarily local pollution of soils at car and bus wash sites and fuel pumping stations and garden sites located in communal garden plots situated on previously recultivated areas. Research on such a broad scale was undertaken for the first time as well as a discussion in consideration of legal norms in force in Poland and worldwide. A low PAH level in the soils of the Poznan municipal area is confirmed by their biodegradation combined with the surface soil layer.

Keywords: soils, PAH analysis, comparison.

Introduction

Over the last several decades, an increased level of environmental pollution by toxic chemical substances has been noted, to which belong, among others, polycyclic aromatic hydrocarbons (PAHs). The PAH source in the natural environment is industrial development, and mainly the intensive growth of automotive transportation. The upper surface soil layer is particularly susceptible to the accumulation of prevailing quantities of these compounds. Depending on the pH, the time of year and the geomorphologic nature of the soil, PAH cumulation will occur with varying intensity and levels of resultant biodegradation. Among the most important processes causing PAH breakdown in the environment are evaporation, leaching, sorption, solar ray induced photolysis, oxidation reactions, substitution and addition as well as microbiological changes.

Research by Lane and Katz [1] conducted on chosen PAHs, employing artificial solar light, allowed for a determination of their half-life. The shortest half-life is exhibited by anthracene (0.2 hours), the time for the most carcinogenic benzo(a)pirene {B(a)P} is 5.3 hours., and the longest amounting to 21.1 hours is characteristic of benzo(e)pyrene {B(e)P}. The half-life of PAHs in the presence of ozone (sample - 0.2 ppm) and artificial sunlight is much shorter and for anthracene {An} is 0.15 hours, for benzo(a)pyrene {B(a)P} 2.75 hours and for benzo(e)pyrene {B(e)P} 5.38 hours. Additional reactions are primarily those with oxygen leading to the formation of benzoquinones or benzene ring cleavage.

Characteristic of PAHs is the reaction with nitrogen oxides and dilute nitric acid, a result of which is the formation of very strong carcinogenic nitrate derivatives. The presence of SO_2 and SO_3 results in the formation of such derivatives as sulfinic, sulfonic and disulfonic acids as well as other unidentified compounds.

The decomposition of aromatic compounds depends on the presence of atmospheric oxygen, which has been confirmed in the research of Maliszewska-Kordybach [2] conducted on agricultural areas. It has been determined that grasslands are characterized by higher PAH content than arable land. The lower content of these compounds in arable land, also noted in several other papers [3, 4], is the result of their greater aeration as well as losses of the lighter polycyclic aromatic hydrocarbons, due to a more frequent mixing of soils, resulting in more intensive biodegradation.

Many authors [5, 6] confirm the existence of various bacterial strains and fungi, which metabolize carbohydrates with one, two and three aromatic rings. These microorganisms have a cooxidation potential, thus they can oxidize existing carbohydrates to additional ones, rather than just to elemental carbon. Groenwegen and Sttop [7] isolated soil bacteria, which utilize napthalene (Na), phenathrene (Phen) and anthracene (An) for their development, while at the same time cooxidizing fluorene (Flu), fluoranthene (Fl) and pyrene (Pyr). The soil bacteria are more effective in their decomposition of polycyclic aromatic hydrocarbons including B(a)P in its naturally occurring environment, the soil, than in nutrient crops.

A significant factor influencing the content of PAHs in soils is their physical-chemical properties, and, above all, their content of organic substances (OM), which determine the extent of the soil's sorption of these compounds [2, 6, 7]. According to the data presented by Maliszewka-Kordybach [2], it occurs that in soils with more OM, PAH concentrations are higher than in those with lower ones. The scope and speed of the changes described are determined by the content of polycyclic aromatic hydrocarbons in soil, and are thus decisive as to their ecotoxilogical action. The OM has become the basis of Polish recommendations for PAH amounts in agriculturally exploited soils.

The research hitherto conducted on PAHs, as a rule, concerns primarily areas used for agricultural purposes [2, 8, 9, 10], communal garden plots [11, 12], areas under legal protection [13, 14,15], areas around thermo-electric power stations [16], municipal agglomerations [12, 13] as well as heavily traveled communications routes [17] and racetracks [18]. It should be stressed that results were obtained by means of various sampling methods and various analytical techniques. Research often consisted of only B(a)P determinations and in the event of determining PAH sums, this number fluctuated from 6 to 16.

Information about the content of PAHs in arable soils is particularly important due to the potential threat not only to soil ecosystems but to human health [8]. This question has been considered in detail in the research of the Institute of Soil Science and Plant Cultivation in Pulawy, Poland. Included in the research were agriculturally exploited soils having various levels of industrialization in the area of the Lublin voivodship as well as areas of northern and eastern Poland [2, 8, 9, 10]. The degree of PAH soil pollution was estimated on the basis of a classification system for agriculturally used soils proposed by the Institute of Soil Science and Plant Cultivation in Pulawy [8, 10]. A summary of 13 PAHs from the US EPA list were determined, with the exception of napthalene {Na}, acenapthalene {Acn} and acenapthylene {Ace}, normalized with relation to the soil, with a 2.0% OM content. An average content of Σ PAH Sof of 364 µg/kg was determined, which coincided with the content of these compounds in soils used for agriculture in other European countries such as Great Britain, Germany and the Czech Republic [3, 4, 8, 19]. The lowest average content of Σ PAHs was registered in the soils of northeastern Poland, the greatest in the northwestern areas. The data found in the "Institute of Soil Science and Plant Cultivation" papers shows that non-polluted soils, having a Σ PAH content < 600 µg/kg, constituted almost 80% of the total, whereas soils with II^0 (second degree) pollution (Σ PAH 600-1000 ug/kg) make up 12%. A further 8% corresponded to soils polluted to III^0 with a Σ PAH content of 1000-5000 µg/kg, a considerable part of which were found in the vicinity of local sources of PAH emission. Similar research conducted on agriculturally used soils in the area of Zabrze (city of south Poland) showed an average PAH content of 7000 µg/kg [8].

Testing of soils from the areas of garden plots performed in the municipal area of Poznan [11] indicated that the average 6 PAH content is within 184 to 494 µg/kg. Similar studies have been conducted on soils originating in communal garden plots around Krakow (city of south Poland) [12], where the average content of Σ 6 PAHs amounted to 930 µg/kg. Wcislo [13] published a review of literature considering holistically conducted research over a number of years on polycyclic aromatic hydrocarbons in unpolluted and polluted soils and urban agglomerations. The content of B(a)P in soils from the Biatowieza (city of eastern Poland) area amounted to 8.2 µg/kg (Σ 7 PAH 190 µg/kg), from the Beskidy area from 1.5 to 6.5, whereas in the Wisla area, it was 37.4 µg/kg (Σ 7 PAH 380 µg/kg). These are values describing unpolluted lands.

Polluted lands, in the first place, are those of industrial areas and urban agglomerations, which by virtue of their function are endangered by anthropopressure, where the PAH content in soils increases considerably. An example of this action is the PJock Petrochemical Works, in whose vicinity from 11,000 to 15,000 µg/kg B(a)P have been found. This value is considerably lower at a distance of approximately 5 km from the emission center where it is less than 2,000 µg/kg. Soils sampled in the vicinity of the Czechowice refinery (south Poland) are characterized by an unusually high B(a)P content of up to 33,100 µg/kg. B(a)P concentrations in the soils from the Bytom vicinity were from 1,000 to 2,600 µg/kg, in the vicinity of Zabrze from 94 do 813 µg/kg, within the Krakow area from 60 to 337 µg/kg, and in Katowice from 903 to 982 µg/kg. The content of Σ PAH was not determined everywhere, and in those cases where it was, it was found to differ both in amount as well as in composition of individual compounds. In soils originating from the city of Krakow the Σ 6 PAH was from 382 to 3411 µg/kg, in the Zabrze vicinity from 705 to 29 143 µg/kg, from within the Lodz municipal area from 60 to 650 µg/kg, and from Czestochowa approximately 800 µg/kg. In soils sampled in Krakow, near streets with large concentrations of vehicular traffic, three compounds were dominant, perylene (Per), chrysene (Ch) and fluoranthene (Fl) [12]. Analysis of soil samples including 13 PAH determinations were conducted within the municipal areas of Zabrze, Bytom and Katowice [13]. The largest concentration of Σ 13 PAHs was noted in Katowice, from 11,994 to 12,194 µg/kg. Within this same region, this amount was from 7,246 to 7,900 µg/kg (Bytom), and in Zabrze, from 3,357 to 4,186 µg/kg.

Swietlik *et al.* [16] conducted research on the content of 15 PAHs in soils surrounding the "Radom" thermo-electric power station. It was found that 4-ring hydrocarbons formed the basis of 42 do 82% of the total content of the tested polycyclic aromatic hydrocarbons whereas the 5-ring ones were found half as often, and 6-ring hydrocarbons accounted for only from 4 to 6% of the total. The summative content of PAHs determined was within 11 to 189 µg/kg. Such a low content level of the investigated compounds over the whole area of the "Radom" thermo-electric power station leads, according to-the authors, to the conclusion that the work of the staJon does not endanger agricultural production.

The influence of automotive transport on PAH content in soils originating from the perimeter in the vicinity of the parking lot of the Gdansk airport (north Poland) terminal was the subject of research by Wodecki *et al.* [17]. The authors confirmed a systematic drop in the content of PAHs determined with an increased distance from the roadside, as well as a distinct influence of the parking lot on the content of determined compounds. What is more, it was shown that it is mainly the surface layer that is polluted to a depth of 1 m.

Accumulation of 6 PAH in soils from the area of the "Poznari" racetrack was the subject of studies conducted at the Institute of Water and Soil Analysis [18]. Two sampling sites were chosen at the racetrack site, from the starting line and from a site lying along the track. At the start line, the place was mostly endangered by concentrations of B(a)P pollution, which accounted for 276 µg/kg, and that of Fl, amounting to 261 µg/kg. It was also determined that as the distance from the track increased, the content of specific tested compounds decreased considerably.

Purpose of this Study

The purpose of this study is to determine the **PAH** levels at 100 sites throughout the city of Poznan in the surface layer of the soil subjected to various levels of anthropopressure; to present for the first time the results of 16 PAH determinations obtained for the samples of soils tested in the years 1995-1997; to show correspondence between the results obtained by means of three analytical methods: TLC, GC and HPLC; and to compare the results obtained for soils from the Poznan area with the data in the literature for Polish soils, mainly on Silesia and Southern Poland and the data on urban agglomerations.

Methods and Materials

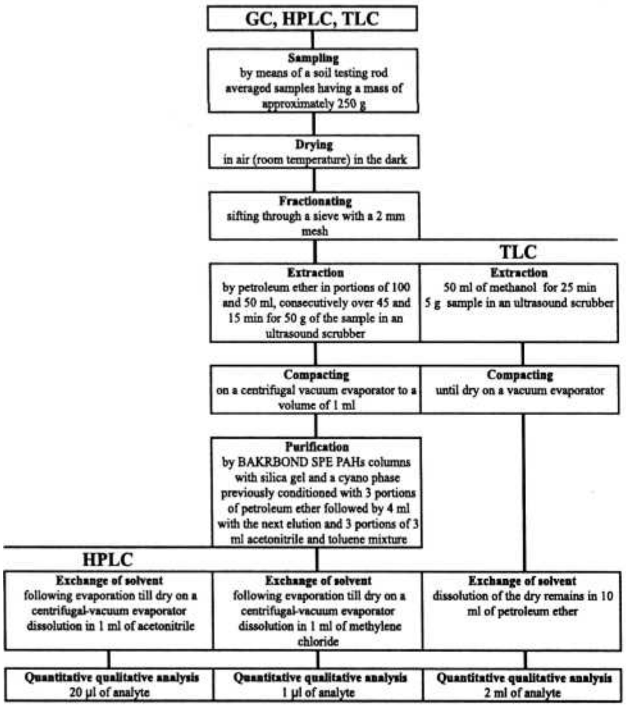
Chromatographic methods, and particularly those of thin-layer chromatography, gas chromatography and highly efficient liquid chromatography are presently among the most popular techniques for PAH determination. Nevertheless, in order to maximally use the potential of these techniques, particular attention should be paid to the proper preparation of samples for analysis. This procedure is based on several stages, i.e. sampling, drying, isolating from the matrix, purification, concentration and quantitative and qualitative analysis.

The sampling stage, followed by sample preparation (always being the initial part of analytical procedure) is particularly important. Mistakes made in these phases may disrupt the course of the analytical process and thus distort the end result of the analysis.

A soil sampling rod was used by means of which an initial sample was taken from the surface layer of soil from one site in the tested area. This sample consisted of the total volume of the soil sampling rod. From the combination and mixing of 10 original samples, an average sample having a mass of approximately 0.25 kg of soil was obtained. Following delivery to the laboratory, the sample was cleaned of rocks and vegetative detritus, following which it was dried in darkness at room temperature for approximately 48 hours.

Soil samples from fuel stations, at crossroads with heavy automotive traffic, at squares and parking lots, were taken from the surface layer at a depth of 0-20 cm. The subjects of testing were soils originating from CPN fuel stations at Glowna Str. and at the crossing of Wyspiafiskiego Str., Matejki and Chelmonskiego, as well as soils sampled from the crossroads of Serbska Str., Lechicka, the crossroads of Libelta Str. and Aleja Niepodleglosci and Slowianska Str. and Urbanowska. Baltycka Str. was chosen as a very busy communications artery. Among the tested rondos and squares were: Kolegiacki Square, Wolnosci Square and Cyryla Ratajskiego Square, as well as the square at Ratajskie Circus. Samples of soils from automobile parking lots came from Zlotowska II Str., Grunwaldzka Str. - at Collegium Chemicum, as well as the vicinity of the bus terminal in Poznan. Samples from the gravel racecourse of the "START" sports club in Gniezno (city near Poznan) were taken: the first from the racetrack at a distance of 5 m in front of the starting line as well as two samples from the green, one in line with the starting line and 5 m from it, the other 5 m onto the green, on a line directly across the green from the start line. Samples of soils from communal gardens were taken from communal garden plots at Zlotowska Str. as well as gardens at Battycka Str. Finally, testing was conducted on soil from the run-off canal of the car wash located on the grounds of the Collegium Minus of Adam Mickiewicz University at Wieniawskiego 1, Str.

Further analytical procedures on the tested sample are presented on the diagram below:



Recommended Analytical Procedure for PAH Testing in Soils

A qualitative and quantitative analysis was conducted to determine 16 PAHs from the EPA list [21]: (Na) Naphthalene, Acenaphthylene (Ace), Acenaphthene (Acn), Fluorene (Flu), Phenanthrene (Fen), Anthracene (An), Fluoranthene (Fl), Pyrene (Pir), Benzo(a)anthracene B(a)A, Chrysene (Ch), Benzo(b)fluoranthene B(b)F, Benzo(k)fluoranthene (B(k)F, Benzo(a)pyrene B(a)P, Indeno(l,2,3-cd.)pyrene (IP), Dibenzo(a,h)anthracene B(a,h)A and Benzo(g,h,i)perylene Bghi)P.

A Shimadzu chromatograph with a Supelcosil column (150 mm length and a diameter of 4 mm - PAHs C_{18}) was used to separate the determined PAHs by the HPLC method. The mobile phase employed an acetonitrile-water system administered in a gradient of concentrations from 45 do 95% of acetonitrile over a time of 35 minutes at a through flow rate of 1.3 to 1.5 ml/minute Identification of peaks of particular PAHs was conducted by means of a UV diode-array detector (SPD-M10AV) using two wavelengths of 254 and 300 nm, respectively.

Separation, identification and quantitative determination by the GC method was conducted by means of an FID detector and a DB-1301 capillary column with a length of 30 m. and a diameter of 0.25 µ^n. Injection was performed by the cold on-column technique, using two temperature schedules. The first of these employs as follows: an initial temperature of 70°C for 1 minute, a temperature rise of 10°C/min to 130°C followed by a subsequent temperature rise at a rate of 3°C/minute, rising to a final temperature of 290°C, to be sustained for 12 minutes. Total separation of the 16 determined PAHs occurred within 70 minutes. The second temperature schedule was characterized by a shorter time (35 minutes) and started at a temperature of 100°C for 1 minute, followed by a temperature rise of 8°C/minute to 300°C and sustained for 9 minutes.

In order to determine and separate PAHs by the TLC method, a bi-directional chromatographic technique was employed [21] and the plates covered with a mixture of aluminum oxide and acetylated cellulose. A quantitative assessment was conducted by comparing the intensity of spot fluorescence for individual compounds in UV light.

Every soil sample was analyzed by the HPLC and GC method, employing the two aforementioned temperature programs. Comparing the results obtained by various techniques allowed for a satisfactory correspondence of results obtained.

Recommended Documents which Provide the Legal Basis for the Discussion of Results

The magnitudes of permissible concentrations serve as direct means for evaluating the level of pollution of the soil environment by polycyclic aromatic hydrocarbons at the stage of their determination and in recultivation processes. Among the data found in the literature there exist differences in the determination of allowable concentrations of sums, individual PAHs as well as numbers of determinations. In the Netherlands list [20], there was a proposal to determine 10 PAHs as well as their summations. Among these are: An, B(a)A, B(k)F, B(a)P, Ch, Fen, Fl, IP, B(ghi)P and Na. The Berlin List [20] is based on the recommendation of the American Environmental Protection Agency (US EPA) [21], which shows the determinations of 16 PAHs, having various amounts of aromatic hydrocarbons as particles together with their summations. To this group belong: Na, Ace, Acn, Flu, Fen, An, Fl, Pir, Ch, B(a)A, B(b)F, B(k)F, B(a)P, IP, B(ah)A as well as B(ghi)P.

Poland is subject to the recommendations of the "IUNG" [8] for soils employed for agricultural purposes, comparing the summative concentrations of PAHs with relation to the content in soil of organic substances (OM). The benchmark value has been set at 2.0% OM, which approximates the average content in the soils of our country. Soils have been divided into groups: 0 is the so-called "natural content," in which the value of 2 PAHs amounts to < 100 as well as I and II, which comprise unpolluted or slightly polluted soils, where the value of 2 PAHs fluctuates from 100 to 600 µg/kg. Among polluted soils have been included those where the 2 PAHs is between 600 to 1,000 µg/kg and among the extremely polluted ones, this value exceeds 1,000 Mg/kg. Soils containing above 10,000 µg/kg 2 PAHs are unsuitable for agricultural purposes.

Due to the fact that since 1994 Poland has been affiliated with the European Union, The State Inspectorate of Environmental Protection [20] has presented guidelines for soil pollution based on solutions employed by those countries. In establishing amounts of allowable pollution concentrations, the following elements have been considered:

- the nature of the land area subject to pollution,
- the hydro-geological properties of lands, which deter mine the rate of diffusion and proliferation of pollu tion,
- the depth to which pollution occurs, something deci sive of the environmental threat posed.

To account for the nature of the land development and use during the setting of norms for concentrations of polluting substances, a division into areas denoted as A,B and C has been performed.

Area A includes, among others, those protected by law, mining areas, sources of mineral waters, areas that are the sources of natural underground water reservoirs.

Area B includes cultivated lands, woodland areas, housing construction zones, recreational areas, rest areas and places of public utility.

Area C includes industrial sites, liquid and solid fuel storage depots, communications routes (roads and racettracks), locomotive garages, waste disposal sites, military bases, airfields and areas of industrial crop cultivation.

An additional element differentiating the borderline concentration of particular areas is the depth to which the pollution occurs. Due to the nature of the areas requiring a uniform purity over the whole cross-section, area A is not further subdivided into classes according to depth. Areas B and C, on the other hand, have been further subdivided into three depth zones.

In area B, Zone 1 has been designated to include depths of 0.0 to 0.3 m due to the reach of the root system of most of the cultivated plants grown there. Zone 2 has

Table 1. Allowable concentrations of PAH pollution of lands according to "PIOŚ", according to which a discussion of results has been conducted.

No.	Parameter	Lands									
		Area A	Area B					Area C			
		Units for Lands [mg/kg d.m.]									
		Depth [m ppt]									
			0-0.30	0.30-15		> 15		0-2	2-15		> 15
		Water Permeability of Lands [m/s]									
				To	Below	To	Below		To	Below	
				1 x 10^{-7}		1 x 10^{-7}			1 x 10^{-7}		
1.	Na	0.1	0.1	5	20	10	40	50	10	40	*
2.	Fen	0.1	0.1	5	20	10	40	50	10	40	*
3.	An	0.1	0.1	5	20	10	40	50	10	40	*
4	Fl	0.1	0.1	5	20	10	40	50	10	40	*
5	Ch	0.1	0.1	5	20	10	40	50	10	40	*
6	B(a)A	0.1	0.1	5	20	10	40	50	10	40	*
7	B(a)P	0.01	0.01	5	10	5	40	50	5	40	*
8	B(a)F	0.1	0.1	5	10	5	40	50	5	40	*
9	B(ghi)P	0.1	0.1	10	10	5	40	50	5	100	*
10	PAH Send	1	1	20	40	20	200	250	20	200	*

d.m. = dry mass

been designated to include depths of 0.3 to 15.0 m, due to the indirect action on living organisms as well as the protection of underground waters, and Zone 3, which extends below a depth of 15 m.

In area C, Zone 1 has been designated to include depths from 0.0 to 2.0 m, in which an increased level of pollution is allowable in connection with the activity conducted thereon, as well as Zone 2 at a depth of from 2.0 to 150 m, which is supposed to protect underground waters from pollution, as well as Zone 3, below a depth of 15 m. Zones B and C have been further subdivided into those soils that are permeable and less permeable.

An evaluation of the pollution level is based on guidelines suggested by the State Inspectorate of Environmental Protection ("PIOŚ") [20], which considers criteria concerning Area C, and in the case of communal garden plots, Area B.

Table 1 shows allowable levels for PAH pollutant concentrations in areas A, B and C, according to "PIOŚ" guidelines.

The PAH concentrations obtained by the gas chromatography technique (GC) and liquid chromatography (HPLC) have been considered in the Tables, including parameters of descriptive statistics: average (x ar.), minimum (min), maximum (max) values as well as standard deviations (S_x).

Results and Discussion

a) Soil samples from fuel stations.

On the basis of soil sample testing from the grounds around the fuel station located at Wyspianskiego Str., it is clear that the highest concentrations were those of Acn (17.782 mg/kg) and Fl (26.012 mg/kg). The concentration of B(a)P was 7.194 mg/kg, and the level of the remaining polycyclic aromatic hydrocarbons was found to be between 0.288 and 7.194 mg/kg. The summative concentration of 16 PAHs did not exceed 250 mg/kg, an allowable value in the recommendations of "PIOŚ"

Soil samples taken at the fuel station located at Glowna Str. are characterized by a differentiated content of the tested compounds, and in particular, a very high content of volatile hydrocarbons. The concentration of the dominant Acn amounted to 296 mg/kg, i.e. exceeding the value of 50 mg/kg allowable for each compound. This value, which is approximately 39% of the content of the sums of all PAHs was decisive in exceeding the allowable recommended value for the sum of PAHs in the soils tested at this station.

b) Soil samples at busy crossroads.

In the Poznan area, samples were taken as well at crossroads with large concentrations of traffic, at Rataje Circus, a square lying on a very busy thoroughfare, as well as other squares located in the city center. Within these samples was found the greatest content of such volatile hydrocarbons as Ace, Acn and Flu, quantities amounting to several ten thousands μg/kg as well as similar amounts of Fl. The concentrations of remaining PAHs fluctuated within several hundred to several thousand. The content of carcinogenic B(a)P was greatest in the sample gathered at Rataje Circus and amounted to 4,443 μg/kg. IP was found in similar

Table 2. The results of PAH determinations in soil samples (n=5) from CPN fuel stations at Glowna Str. in Poznań.

Hydrocarbon Tested for	PAH Content μg/kg d.m.							
	GC technique				HPLC technique			
	X_{av}	min	max	S_x	X_{av}	min	max	S_x
Na	4858	2710	6430	1668	4945	3500	6300	1175
Ace	41004	30000	59000	11726	38480	30000	49000	9138
Acn	295748	218480	380000	74016	308970	218480	380000	73978
Flu	88404	78600	106000	10414	84495	78600	93000	6116
Fen	46214	30270	63000	12248	45623	33270	55000	9080
An	83824	44400	113000	27051	74470	47300	103420	25075
Fl	36612	28040	48000	9905	36112	28500	47600	8989
Pir	79216	63000	105500	18139	80920	63800	98700	15681
B(a)A	30458	23890	39000	5997	32725	24800	37500	5861
Ch	32818	27900	43300	6509	32540	27900	39300	4961
B(b)F	7654	7110	8300	554	7795	7100	8620	733
B(k)F	2830	2410	39400	629	3160	2500	3940	719
B(a)P	12882	10200	16150	2199	13065	10800	15400	1935
IP	547	410	656	100	583	480	687	103
D(a.h)A	181	120	298	68.6	182	120	298	79.2
B(ghi)P	129	100	152	19.4	131	18	152	18.2

Table 3. Results of PAH determinations in soil samples (n=5) taken at the fuel station at the crossroads of Wyspianskiego, Matejki and Chetmonskiego Str. (Poznan).

Hydrocarbon Tested for	PAH Content μg/kg s.m.							
	GC Method				HPLC Method			
	X_{av}	min	max	S_x	X_{av}	min	max	S_x
Na	2692	2600	2790	76.6	2525	1990	2790	361
Ace	3190	3100	3300	74.2	3095	2730	3300	257
Acn	17782	16260	20500	1946	17090	16260	19200	1410
Flu	3174	2800	3920	453	2707	2100	3100	426
Fen	3190	2580	3690	453	3045	2580	3560	406
An	1841	1610	2020	172	1846	1610	2020	198
Fl	26012	22520	29800	3632	25337	22550	29800	3181
Pir	2224	2050	2500	181	2207	2050	2500	205
B(a)A	2572	2290	2700	162	2552	2290	2650	175
Ch	638	480	745	106	656	480	745	119
B(b)F	1646	1180	2100	345	1662	1180	2100	388
B(k)F	1570	1280	1920	275	1562	1280	1920	283
B(a)P	7194	5600	8520	1045	6665	5600	7430	806
IP	3200	2900	3600	264	3280	3040	3600	233
D(a.h)A	288	260	320	27.8	262	220	310	36.8
B(ghi)P	433	325	520	82.4	388	325	500	79.2

Table 4. The results of PAH determinations in soils (n=5) from the crossing at Serbska and Lechicka Str.

Hydrocarbon Tested for	PAH Content µg/kg d.m.							
	GC Method				HPLC Method			
	X_{av}	min	max	S_x	X_{av}	min	max	S_x
Na	622	533	694	60.7	698	597	968	180
Ace	6567	2065	8730	2735	7485	6970	8500	699
Acn	36706	32200	41050	4132	32420	28880	35600	2770
Flu	13214	9580	18550	3272	12450	11500	12900	640
Fen	7464	5020	9700	2056	6850	4800	8900	1960
An	2438	1900	3410	650	2547	2100	2990	416
Fl	16450	12700	18900	2323	17125	12700	20000	3150
Pir	4918	3030	5480	2057	4690	3900	5480	814
B(a)A	5980	3700	7510	1445	6825	5400	7820	1076
Ch	1797	1130	2300	431	1852	1400	2300	369
B(b)F	681	600	870	113	690	610	810	90.3
B(k)F	173	110	233	46.0	158	126	190	34.7
B(a)P	1936	1080	3300	834	2045	1600	2400	342
IP	2789	2210	3600	669	2913	2210	3300	610
D(a.h)A	203	151	290	54.8	190	168	213	24.6
B(ghi)P	167	102	240	62.5	167	102	220	49.8

Table 5. The results of PAH determination in soil samples (n=5) from the crossing at Libelta Str. and Aleja Niepodleglosci.

Hydrocarbon Tested for	PAH Content µg/kg d.m.							
	GC technique				HPLC technique			
	X_{av}	min	max	S_x	X_{av}	min	max	S_x
Na	5400	4800	6010	494	5135	4800	5600	384
Ace	17340	14200	23000	3389	17340	15400	19200	1568
Acn	43018	32040	60300	11548	43810	32040	54200	10730
Flu	10764	9120	12000	1275	9855	9120	11000	883
Fen	5508	4620	6800	983	5097	4300	6500	965
An	3766	2880	4320	538	3707	3360	4100	392
Fl	11682	10600	12600	810	12075	10900	12700	826
Pir	2580	1820	3460	632	2702	1990	3100	492
B(a)A	7052	6060	8000	722	7675	7200	7520	586
Ch	1654	1490	2000	203	1712	1500	2000	209
B(b)F	884	610	1020	169	856	690	1020	134
B(k)F	915	720	1200	176	907	720	1100	155
B(a)P	2624	2120	3100	361	2512	2220	3000	355
IP	2468	1990	2650	272	2550	2100	2800	308
D(a,h)A	207	180	269	38.2	217	183	256	32.3
B(ghi)P	1202	980	1480	186	1202	1100	1300	89.6

Table 6. Results of PAH determinations in soil samples (n=5) from the crossing of Słowiańska and Urbanowska Str.

Hydrocarbon Tested for	PAH Content μg/kg d.m.							
	GC technique				HPLC technique			
	X_{av}	min	max	S_x	X_{av}	min	max	S_x
Na	344	290	410	54.9	336	290	410	51.5
Ace	900	810	1010	90.5	867	816	990	82.3
Acn	20776	18100	24300	2691	20875	18200	23300	2097
Flu	1660	1320	2310	387	1717	120	2100	409
Fen	1824	1415	2210	325	1603	1120	2100	409
An	851	515	1220	299	807	515	980	202
Fl	13098	11590	15100	1334	12687	12100	13900	825
Pir	833	665	1150	211	814	665	950	129
B(a)A	807	660	970	115	793	710	880	78.5
Ch	399	295	490	81.0	405	335	485	78.6
B(b)F	287	195	325	53.5	273	195	310	53.5
B(k)F	326	280	390	39.9	347	290	420	56.2
B(a)P	372	290	460	68.9	359	310	425	49.7
IP	974	790	1180	172	208	175	260	39.6
D(a,h)A	212	170	270	48.7	248	175	300	52.7
B(ghi)P	240	160	310	68.2	972	880	1100	94.3

Table 7. Results of PAH determinations in soil samples from (n=5) Kolegiacki Square.

Hydrocarbon Tested for	PAH Content μg/kg d.m.							
	GC technique				HPLC technique			
	X_{av}	min	max	S_x	X_{av}	min	max	S_x
Na	1286	1200	1440	100	1292	1210	1400	97.4
Ace	2568	2090	3100	426	2447	2100	2950	387
Acn	20452	17500	25360	3184	20490	17800	25360	3474
Flu	1271	1010	1516	218	1342	1160	1530	189
Fen	2480	1780	3200	595	2297	1900	3100	542
An	2477	1430	3070	672	2602	2190	3030	419
Fl	20732	17280	25300	3053	19120	16400	22700	2861
Pir	4824	3680	6140	958	4767	3980	5600	716
B(a)A	3632	2990	4240	551	3505	2290	4130	828
Ch	1884	1590	2710	197	1827	1590	2020	206
B(b)F	568	360	710	136	517	390	710	149
B(k)F	611	516	708	81.4	610	516	708	83.0
B(a)P	2872	2630	3600	385	2910	2630	3180	224
IP	1586	1260	2100	330	2490	2160	2850	309
D(a.h)A	2542	2000	2850	341	371	295	460	67.8
B(ghi)P	356	290	460	75.0	1437	1180	1950	349

Table 8. Results of PAH determinations in soil samples (n=5) from Wolności Square.

Hydrocarbon Tested for	PAH Content µg/kg d.m.							
	GC technique				HPLC technique			
	X_{av}	min	max	S_x	X_{av}	min	max	S_x
Na	1710	1080	2090	386	1575	1080	1900	364
Ace	2082	1120	2700	666	1827	1120	2450	574
Acn	14156	12600	16260	1514	13575	12500	15700	1486
Flu	3120	2580	3760	541	3105	2880	3360	216
Fen	6326	5450	6920	703	622	5450	6920	763
An	728	530	950	169	825	590	1100	210
Fl	22092	18550	28700	4206	19675	14300	26700	5159
Pir	464	310	680	150	481	430	530	40.9
B(a)A	938	830	1190	148	950	870	1060	79.5
Ch	602	410	775	147	640	460	765	133
B(b)F	320	284	366	32.4	365	320	440	53.4
B(k)F	323	182	395	82.2	282	182	360	56.8
B(a)P	426	260	515	101	481	430	560	57.2
IP	703	662	757	39.3	768	622	980	146
D(a,h)A	93.4	78.0	118	17.4	102	86.0	120	14.8
B(ghi)P	405	315	550	87.0	416	320	510	82.5

Table 9. Results of PAH determinations in soil samples from (n=5) Cyryla Ratajskiego Square.

Hydrocarbon Tested for	PAH Content µg/kg d.m.							
	GC technique				HPLC technique			
	X_{av}	min	max	S_x	X_{av}	min	max	S_x
Na	1044	975	1170	87.0	1115	990	1200	93.3
Ace	12804	11010	16220	2152	13177	11010	16200	2283
Acn	32246	26480	43000	6328	34787	27600	40800	6265
Flu	15184	13220	17330	1872	15040	13220	17000	2039
Fen	3894	3100	4260	493	3560	2920	4120	639
An	1712	1320	2160	327	1832	1380	2100	328
Fl	10592	7800	13600	2471	9895	8100	12900	2097
Pir	2330	2100	2700	265	2400	2100	2630	230
B(a)A	2274	1900	2750	349	2432	2050	2630	259
Ch	1404	1360	1500	56.8	1452	1360	1590	105
B(b)F	1505	1060	1695	258	1373	1060	1645	275
B(k)F	625	400	900	192	598	400	815	170
B(a)P	4443	3815	4800	378	4511	4325	4700	177
IP	2788	2100	3350	538	2620	2400	2850	184
D(a,h)A	404	360	425	26.3	430	390	520	57.6
B(ghi)P	519	420	630	91.3	598	430	760	136

Table 10. Results of determining PAH in soil samples (n=5) from Rataje Circus.

Hydrocarbon Tested for	PAH Content μg/kg d.m.							
	GC Method				HPLC Method			
	X_{av}	min	max	S_x	X_{av}	min	max	S_x
Na	2859	1995	3500	552	2706	1995	3200	529
Ace	1306	1086	1500	178	1186	960	1395	197
Acn	20198	18400	22600	1669	21062	19600	23640	1786
Flu	6400	5220	7340	862	6287	5400	7100	744
Fen	4920	3800	5570	875	4970	4100	5570	624
An	20573	16130	29310	5436	19017	16070	26300	4877
Fl	31708	25260	36300	4263	29080	25260	33700	3719
Pir	21634	16600	27900	4205	21420	19800	24210	2014
B(a)A	25948	20580	37800	5881	27932	20900	34400	6355
Ch	12351	10100	14720	2023	12905	11200	14720	1443
B(b)F	6266	5070	7330	802	5742	4900	6800	910
B(k)F	1661	1460	1775	126	1722	1500	1950	188
B(a)P	5484	5340	5680	131	5377	5200	5550	146
IP	1476	1290	1600	125	1467	1350	1600	107
D(a,h)A	878	690	1040	139	805	680	990	136
B(ghi)P	988	890	1020	55.4	967	890	1020	57.3

Table 11. Results of PAH determinations in soil samples (n=5) from Baltycka Str. from the roadside of the Gniezno-Warszawa route.

Hydrocarbon Tested for	PAHS Content μg/kg d.m.							
	GC technique				HPLC technique			
	X_{av}	min	max	S_x	X_{av}	min	max	S_x
Na	3096	1710	4500	1297	3042	1960	4320	1012
Ace	20916	12460	29680	7984	19705	12460	29600	7538
Acn	7892	6900	9040	961	9000	7000	12600	2513
Flu	2610	1950	3400	603	2725	1950	3450	714
Fen	1592	1150	1950	339	1562	1150	1980	357
An	1734	1465	2480	421	1757	1500	2100	264
Fl	12626	8860	15840	2854	11457	9600	13100	1673
Pir	1540	1330	1930	250	1552	1330	1820	224
B(a)A	1736	1160	2400	540	1482	1160	2100	432
Ch	290	204	334	52.9	286	252	320	28.4
B(b)F	308	248	338	36.0	343	270	503	107
B(k)F	303	126	493	146	313	194	370	82.6
B(a)P	953	699	1270	265	929	703	1200	207
IP	331	245	532	123	442	240	736	236
D(a,h)A	175	110	220	47.4	164	120	220	44.7
B(ghi)P	200	160	270	44.6	199	163	250	36.8

Table 12. The results of PAH determinations in soil samples (n=5) from the parking lot at Złotowska Str.

Hydrocarbon Tested for	PAH Content μg/kg d.m.							
	GC technique				HPLC technique			
	X_{av}	min	max	S_x	X_{av}	min	max	S_x
Na	474	300	600	112	470	340	580	103
Ace	4650	3600	5800	831	4740	3700	5400	767
Acn	7910	6060	9530	1583	8140	7180	9310	980
Flu	2851	1990	3290	503	2830	2100	3250	504
Fen	2114	1690	2600	366	2095	1690	2420	318
An	625	525	750	81.6	618	525	725	84.0
Fl	14074	12700	14700	839	13067	11200	14530	1455
Pir	1208	1081	1360	103	1262	1081	1360	131
B(a)A	2394	2020	2980	466	2660	2020	3220	542
Ch	2385	1950	2936	438	2497	2050	2890	402
B(b)F	1438	1130	1900	317	1397	1130	1820	297
B(k)F	290	200	355	66.2	305	250	355	44.2
B(a)P	1358	1070	1790	290	1347	1110	1630	218
IP	648	545	713	66.3	675	590	740	70.3
D(a.h)A	109	85	128	21.6	111	86.0	130	20.2
B(ghi)P	134	110	165	24.2	136	118	155	16.6

Table 13. Results of PAH determinations in soil samples from (n=5) the parking lot near Collegium Chemicum of Adam Mickiewicz University near Grunwaldzka 6, Str.

Hydrocarbon Tested for	PAH Content μg/kg d.m.							
	GC technique				HPLC technique			
	X_{av}	min	max	S_x	X_{av}	min	max	S_x
Na	491	390	625	100	426	326	515	80.7
Ace	2750	1970	4100	858	2870	2100	3580	687
Acn	35250	31000	45000	5640	36337	32250	41100	4382
Flu	3150	2630	3740	469	3472	2630	4220	675
Fen	1420	1300	1470	71.1	1411	1300	1470	77.9
An	3500	2690	4440	718	3332	2690	4440	763
Fl	18554	13540	23000	4291	18660	13540	22500	4419
Pir	5572	4400	6270	907	5715	4780	6620	829
B(a)A	6918	5200	8200	1217	7240	5200	8870	1559
Ch	3110	2010	4600	1003	3075	2100	4300	981
B(b)F	2284	1880	2850	380	2175	1850	2560	363
B(k)F	191	122	260	61.7	214	135	256	53.6
B(a)P	1350	1020	1680	296	1277	1050	1680	276
IP	3720	2630	4360	706	3862	2630	4400	835
D(a,h)A	134	107	180	27.2	146	127	160	14.1
B(ghi)P	368	305	502	85.1	371	312	502	89.5

Table 14. The results of PAH determinations of soil samples (n=5) from the parking lot near the Poznan municipal bus terminal.

Hydrocarbon Tested for	PAH Content μg/kg d.m.							
	GC technique				HPLC technique			
	X_{av}	min	max	S_x	X_{av}	min	max	S_x
Na	287	260	310	21.1	291	260	310	21.7
Ace	1390	1250	1600	129	1410	1290	1600	134
Acn	3728	3400	4100	254	3735	3400	4100	293
Flu	6246	5800	6800	403	6187	5800	6800	429
Fen	748	701	790	33.2	760	740	790	23.7
An	1154	920	1340	189	1137	920	1270	164
Fl	16480	14700	19000	1626	15475	14700	16400	704
Pir	1552	1270	1840	211	1525	1300	1840	230
B(a)A	2622	2050	3090	451	2565	2050	3010	468
Ch	986	840	1140	107	1030	960	1140	77.5
B(b)F	2180	1860	2400	239	2132	1860	2330	231
B(k)F	1274	1120	1460	172	1227	1120	1460	159
B(a)P	1914	1650	2140	208	2005	1740	2140	181
IP	2260	1670	2630	416	2167	1670	2630	417
D(a,h)A	254	190	310	54.1	242	199	310	48.2
B(ghi)P	1236	1060	1420	128	1240	1060	1470	169

Table 15. Results of PAH determinations in soil samples (n=5) from the gravel racetrack in front of the starting line.

Hydrocarbon Tested for	PAH Content μg/kg d.m.							
	GC technique				HPLC technique			
	X_{av}	min	max	S_x	X_{av}	min	max	S_x
Na	742	610	870	113	748	635	800	77.4
Ace	1742	1104	2640	575	2535	1900	3300	592
Acn	12816	10770	13700	1170	13342	13000	13700	286
Flu	16048	14400	19240	1942	17371	16000	19200	1538
Fen	3588	2680	4180	632	3787	3370	4060	295
An	1570	1245	1870	305	1513	1270	1860	279
Fl	8544	8200	9000	313	8357	8200	8490	121
Pir	553	490	610	51.0	524	490	578	37.7
B(a)A	2121	1900	2520	249	2122	1900	2520	288
Ch	1364	1250	1580	127	1317	1280	1350	33.0
B(b)F	2112	1480	2600	410	2245	2080	2500	196
B(k)F	827	695	1040	149	743	695	800	54.1
B(a)P	1391	1215	1490	126	1450	1360	1490	61.6
IP	1947	1480	2280	305	1567	510	1930	704
D(a,h)A	114	980	130	12.8	113	105	120	7.5
B(ghi)P	213	180	230	21.5	236	224	260	16.2

Table 16. Results of PAH determinations in soil samples from (n=5) the stadium green of the gravel racetrack (Site 1).

Hydrocarbon Tested for	PAH Content μg/kg d.m.							
	GC technique				HPLC technique			
	X_{av}	min	max	S_x	X_{av}	min	max	S_x
Na	123	112	135	9.7	119	112	128	7.3
Ace	345	310	370	28.3	363	310	405	39.4
Acn	3542	2900	4200	549	3822	3100	4430	606
Flu	1110	760	1870	469	997	810	1260	209
Fen	935	715	1070	142	922	800	1020	130
An	169	120	215	35.8	165	152	190	16.7
Fl	11912	10300	14640	1722	12350	11600	13800	998
Pir	253	220	280	26.4	273	240	330	41.5
B(a)A	602	515	750	95.4	666	616	750	62.7
Ch	542	450	630	75.9	497	450	520	32.0
B(b)F	716	610	810	89.8	763	735	810	32.5
B(k)F	444	320	570	90.7	440	410	460	24.5
B(a)P	1550	1320	1660	144	1632	1595	1660	27.2
IP	739	680	815	60.5	700	1610	790	75.2
D(a,h)A	64.8	36.0	90.0	22.4	78.5	73.0	90	7.7
B(ghi)P	133	105	165	25.6	145	136	160	10.5

Table 17. Results of PAH determinations in soil samples (n=5) from the stadium green of the gravel racetrack (Site 2).

Hydrocarbon Tested for	PAH Content μg/kg d.m.							
	GC technique				HPLC technique			
	X_{av}	min	max	S_x	X_{av}	min	max	S_x
Na	583	480	675	86.2	653	610	685	33.7
Ace	2756	2050	3420	585	3095	2780	3420	285
Acn	9230	6400	10500	1697	10375	10100	10700	275
Flu	4174	3850	4950	459	4437	3950	4980	449
Fen	1706	1580	1990	164	1797	1660	1990	153
An	880	630	1050	173	935	830	1040	110
Fl	15330	12800	16900	1710	16217	14550	16900	1117
Pir	1966	1600	2300	269	2267	2020	2630	268
B(a)A	2754	2050	3400	629	2327	2050	2600	213
Ch	1134	865	1450	252	1227	1120	1300	84.1
B(b)F	601	360	1110	292	1037	980	1110	53.9
B(k)F	1112	481	1600	449	487	440	535	39.2
B(a)P	1417	1230	1600	139	1528	1415	1610	93.3
IP	988	960	1020	29.4	996	960	1036	37.2
D(a,h)A	76.4	50.0	104	21.1	71.0	65.0	80.0	6.5
B(ghi)P	139	98.0	205	41.5	139	110	166	22.9

Table 18. Results of PAH determinations in soil samples (n=5) taken near the car wash.

Hydrocarbon Tested for	PAH Content µg/kg d.m.							
	GC technique				HPLC technique			
	X_{av}	min	max	S_x	X_{av}	min	max	S_x
Na	2344	2000	2700	304	2127	1660	2650	413
Ace	21874	17800	25350	3207	22370	18300	24800	2833
Acn	160814	140000	190000	20643	145792	113100	165000	23381
Flu	19344	14300	23400	3756	16635	11120	20600	4003
Fen	9022	6820	11050	1875	8047	6230	9900	1631
An	6032	3480	9700	2473	5665	4050	7100	1255
Fl	14666	11520	17330	2821	15927	13600	19230	2482
Pir	10700	7250	12820	2512	10232	8260	12820	1900
B(a)A	13094	9730	19300	3732	12067	9830	14700	2217
Ch	8718	6300	10230	1553	8762	7700	9750	899
B(b)F	4051	3350	5140	839	3960	3160	5140	877
B(k)F	1912	1060	2650	654	1660	1060	2552	650
B(a)P	7340	6700	8630	751	7067	6250	7900	706
IP	6705	5485	8060	956	6530	5820	7700	812
D(a,h)A	364	225	525	121	367	310	460	68.9
B(ghi)P	1975	940	1280	132	1050	960	1120	68.3

Table 19. Results of PAH determinations in soil samples (n=5) from the communal garden adjacent to Złotowska Str.

Hydrocarbon Tested for	PAH Content µg/kg d.m.							
	GC technique				HPLC technique			
	X_{av}	min	max	S_x	X_{av}	min	max	S_x
Na	634	490	800	133	665	505	720	106
Ace	2070	1650	2700	426	2417	1900	3250	582
Acn	15162	9900	25670	6595	13490	10180	16600	2740
Flu	1961	1120	2510	622	1810	1120	2310	501
Fen	447	390	500	49.1	511	400	685	122
An	593	500	675	82.8	648	510	750	111
Fl	8442	6500	11000	2171	7500	6500	8300	848
Pir	1056	860	1250	141	1047	860	1150	130
B(a)A	851	710	950	102	871	805	965	77.6
Ch	303	230	412	71.5	403	240	662	186
B(b)F	322	276	345	26.8	319	276	340	29.3
B(k)F	165	115	220	45.2	169	135	205	31.7
B(a)P	1226	1120	1450	152	1167	980	1320	149
IP	287	210	330	48.1	330	280	385	43.0
D(a,h)A	56.6	40.0	73.0	12.3	65.2	60.0	73.0	6.4
B(ghi)P	94.8	80.0	126	17.9	101	85.0	126	18.8

Table 20. Results of PAH in soil samples (n=2) from the communal garden plot at Bałtycka Str.

Hydrocarbon Tested for	PAH Content µg/kg d.m.							
	GC technique				HPLC technique			
	X_{av}	min	max	S_x	X_{av}	min	max	S_x
Na	207	153	277	46.2	236	181	277	48.5
Ace	1461	1200	1900	267	844	153	1590	766
Acn	4531	3145	6600	1405	1445	1200	1900	328
Flu	2342	1970	2930	426	2305	2050	2800	343
Fen	5070	4020	6800	1044	4587	3350	5700	962
An	7082	6130	8120	874	6772	6130	8120	926
Fl	11612	9980	16600	2821	12145	9980	16600	3009
Pir	1447	1020	1950	447	1205	700	1800	466
B(a)A	3376	2675	4200	720	3747	3100	4200	465
Ch	208	128	270	62.5	195	128	270	60.2
B(b)F	164	127	210	40.8	152	106	210	43.3
B(k)F	429	260	530	101	377	260	470	104
B(a)P	545	485	612	47.3	545	490	610	51.9
IP	634	515	740	80.9	610	460	700	104
D(a,h)A	213	150	274	55.1	193	150	245	39.8
B(ghi)P	212	120	295	66.2	191	120	260	58.0

concentrations to B(a)P, whereas among the 16 tested PAHs, all tested samples showed minimal values of D(a,h)A. The summative content of all the tested compounds, despite their relatively high content, did not exceed a value of 250 µg/kg. The results of testing were included in Tables 4 through 11.

c) **Soil samples from municipal parking lots, car washes and a gravel racetrack.**

Parking lots in the city center were another group of sites from which soil samples were taken. Tests have shown that in this case as well, the dominant hydrocarbon was Fl, and its content was at a level of several-score thousand. The sum of all PAHs was from 43.340 to 88.055 mg/kg. The next place chosen for testing was the car park located near Collegium Minus of Adam Mickiewicz University. In this case, there was a decided dominance of Acn, and its content was approximately 161 mg/kg, which surpassed the allowable amounts of 50 mg/kg for this hydrocarbon.

As a result of tests on soil samples originating from the gravel racetrack of the sports club "START" in Gniezno, it was determined that the content of summative PAHs is relatively low and is 53.215 mg/kg in the sample taken from the gravel racetrack and 22.267 and 44.561 mg/kg in samples coming from the stadium's green. The results of PAH determinations are included in Tables 12 through 18.

d) Soil samples from communal garden plots.

The PAH content in soil samples originating from the area of the communal garden plots situated in the urban-industrial agglomeration of the city was differentiated. The soil originating from garden plots found at Battycka Str. are characterized by a preponderance of Fl and An pollution at levels of 12.154 and 7.082 mg/kg. Soil samples coming from communal garden plots adjacent to Zlotowska Str. showed a preponderance of Acn 15.162 mg/kg. Summative concentrations of polycyclic aromatic hydrocarbons determined in soils originating from communal garden plots was in excess of the 20 mg/kg concentration, being the allowable amount for Area B. There is a distinct influence of emission from traffic on the concentration of polycyclic aromatic hydrocarbons in the soi-ls of gardens situated on the roadside green. The results of PAH determinations are listed in Tables 19 through 20.

Results obtained by the thin-layer chromatography technique (TLC) were approximately 40% lower than those obtained by GC and HPLC techniques. The reason for this is another procedure of preparing the sample, and the result is in half-amounts. Comparative results are presented in Table 21.

Interpretation of Results

This paper has presented the results of polycyclic aromatic hydrocarbons near the areas of communications routes, fuel stations, car washes and a gravel racetrack, which comprise Area C, as well as from communal garden plots included in Area B. In the group of soils ori-

Table 21. Comparison of results of PAH determinations by gas chromatography (GC) and thin layer chromatography techniques (TLC).

Sampling Site	Method of determination	Fl µg/l	B(a)P µg/l	B(b)F µg/l	B(k)F µg/l	IP µg/l	BghiP µg/l
„Batory" Fuel Station	GC	1017	144	69	108	81	58
	TLC	850	85	45	55	50	30
CPN near Airport	GC	1600	101	150	62	30	30
Ławica	TLC	750	58	75	38	22	16
CPN in Swarzedz	GC	533	82	99	84	105	71
	TLC	190	45	35	52	50	35
Ławica Airport	GC	113	80	65	51	38	30
1000 m. in front of runway	TLC	50	35	35	30	20	15
Ławica Airport	GC	122	122	53	52	30	30
"Meteo" Fuel Station	TLC	44	64	25	22	12	18

ginating from the municipal center, testing sites included were the crossroads of busy streets, rondos and squares as well as parking lots. In analyzing the results of PAH determinations of soil samples originating from the Poznan city center, it has been determined that volatile aromatic hydrocarbons are dominant among the 16 determined compounds. Their concentration is within several or several thousand µg/kg. These samples contain similar amounts of Fl, whereas the concentration of Ch, B(a)A, B(a)P, B(b)F and B(ghi)P fluctuated between several hundred to several thousand µg/kg. The summative content of PAHs determined at the crossing of Urbanowska and Slowianska Str. was 44.56 mg/kg, at the crossing of Libelta Str. and AJeja Niepodlegtosci - 118.4 mg/kg, at Rataje Circus - 155.8 mg/kg. and at Kolegiacki Square - 93.3 mg/kg. These values are higher than those obtained in the urban areas of Katowice, Zabrze, Bytom, Lodz and Krakow [13]. British researchers who tested soils with relation to their content for 16 PAHs in areas subjected to their action in Great Britain [23] stated that the highest concentrations were those of Fl and Fen at 55.3 and 50.7 mg/kg, respectively; Pir, B(a)A and Ch were within 20 to 39 mg/kg, and B(a)P was found in concentrations of 13.8 mg/kg. It is evident from these comparisons that urban areas in Poland are also subjected to anthropopressure characterized by a considerably lower value of polycyclic aromatic hydrocarbons [24, 25, 26].

In analyzing the data originating from tests of soils sampled in the area around fuel stations it may be stated, that only in one case (the CPN at Giowna Str. - Table 2) did the dominant Acn appearing in amounts of 295.7 mg/kg surpass the 250 mg/kg value allowable for £ PAHs in this area. Another site where a preponderance of Acn was noted, the car wash, showed a concentration of 160.8 mg/kg.

The summative content of PAHs in samples originating from the stadium of the gravel racetrack is low, and the dominant Fl occurs at levels of 8.500 to 15.330 mg/kg.

Soils coming from communal garden plots situated within the municipal area of Poznan exceeded a value of 1 mg/kg, which was the allowable amount according to the State Inspectorate of Environmental Protection [20] and, by the same token, disqualified it as an agricultural land according to the norms of the Institute of Soil Science and Plant Cultivation (IUNG) (10 mg/kg Σ PAH). Similar testing was conducted on the communal garden plots within the Krakow [12] municipal area, which showed a content of Σ PAHs 930 µg/kg.

A comparison of the tabulated results obtained from this research with those described by cited authors, allows for the statement that PAH content determinations are much higher than those found in literature, probably because they were obtained from lands particularly subjected to pollution.

1600 determinations of individual PAHs in soil samples from the municipal area of Poznan and the gravel raceway in Gniezno indicate an exclusively local site-based anthropopressure as well as satisfactory progress in its biodegradation.

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