7-nitrobenz(a)anthracene	-	-	0.326	-	0.130	-	0.261
6-nitrochrysene	-	0.348	-	0.109	0.761	-	1.304
6-nitrobenzo(a)pyrene	-	-	-	0.109	0.543	-	2.457

Cheung et al. (2009) [Emissions of Particulate Trace Elements, Metals and Organic Species from Gasoline, Diesel, and Biodiesel Passenger Vehicles and Their Relation to Oxidative Potential, Aerosol Science and Technology] tested three light-duty vehicles in five configurations in a chassis dynamometer to determine PAH emissions. The first vehicle was a diesel Honda with a three-stage oxidation system. Its main catalyst was replaced with a diesel particulate filter (DPF) and tested as a second configuration. The second vehicle was a gasoline-fueled Toyota Corolla with a three-way catalytic converter. The last vehicle was an older Volkswagen Golf, tested using petro-diesel in its original configuration, and biodiesel with an oxidation catalyst as an alternative configuration.

Each vehicle/configuration was driven on the chassis dynamometer using the same protocol: a variety of real-world driving cycles (Artemis Cycles) and the certification test (New European Driving Cycle). The three Artemis driving cycles (urban, rural road, and motorway) consist of frequent speed variation and stronger acceleration compared to the NEDC, and were designed to simulate typical driving conditions in Europe. The vehicle and the sampling system were pre-conditioned by running three extra urban driving cycles (EUDC), according to the specifications of the UNECE R83 regulation. PAH emissions were quantified by gas chromatography/mass spectrometry (GC/MS). Filters were extracted with methanol and methylene chloride using Soxhlet for PAH compounds. The extracts were combined then concentrated using a rotary evaporator then a nitrogen evaporator.

Table 111: Emission factors (ng/km) of 12 priority PAHs classified by the US EPA

	Accord Diesel	DPF-Accord	Corolla Gas	Golf Diesel	Golf Biodiesel
Phenanthrene	1885.863	9.654	48.840	3473.892	1098.541
Anthracene	98.832	NA	NA	238.534	207.170
Fluoranthene	152.642	NA	15.086	4291.934	3598.508
Pyrene	186.384	NA	11.650	3861.310	858.368
Benz(a)anthracene	70.297	NA	26.827	390.694	294.705
Chrysene	184.207	NA	67.863	1192.698	617.755
Benzo(b)fluoranthene	NA	NA	91.030	429.193	511.898
Benzo(k)fluoranthene	NA	NA	29.819	127.980	212.095
Benzo(a)pyrene	NA	NA	15.445	NA	154.446
Indeno(1,2,3-cd)pyrene	NA	NA	46.598	NA	241.353
Benzo(ghi)perylene	NA	NA	112.466	NA	828.643
Dibenz(ah)anthracene	NA	NA	21.460	NA	NA

Zielinska et al. (2009) [Phase and Size Distribution of Polycyclic Aromatic Hydrocarbons in Diesel and Gasoline Vehicle Emissions, Environmental Science and Technology] measured PAH emissions for a variety of military vehicles on a chassis dynamometer, including aircraft ground support equipment vehicles using gasoline, diesel, and JP8 fuels. The exhaust from the tested vehicle was passed to a dilution tunnel where it was diluted 30–40 times and collected using Micro-Orifice Uniform Deposit Impactor (MOUDI) fitted with aluminum substrates, an XAD-coated annular denuder, and a filter followed by a solid adsorbent. All MOUDI substrates were analyzed for polycyclic aromatic hydrocarbons (PAHs) by GC/MS. The test vehicles are shown below.

vehicle type[a]	fuel type	engine manufacturer	engine displacement	exhaust treatment
1993 Ford F-350	gasoline	Ford	5.8 L	catalytic converter
1996 Dodge Bobtail	diesel	Cummins	5.9 L	none
1986 Jeep Bobtail	diesel	Nissan	4.4 L	none
1992 Jammer	JP-8 aviation fuel	HATZ	1.27 L	none

[a] Bobtail vehicles tow aircraft, and Jammers lift munitions into aircraft.

The gas-phase components of the semivolatile PAHs were collected using a sorbent-coated annular denuder. The denuder sampler consisted of three stages; the first stage was an 8-channel denuder section (52 mm o.d., 600 mm length) coated with polystyrene−divinylbenzene resin XAD-4, which strips the gas-phase species from the airstream before collection of the particles on a second stage, consisting of a 47-mm Teflon-impregnated glass fiber (TIGF, T60X20) filter. The third stage consisted of polyurethane foam plugs (1 in. diameter) in combination with the 5 g of adsorbent resin XAD-4 (PUF/XAD/PUF "sandwich" cartridge) that was placed downstream of the filter to assess "blow off" or volatilization loss of semivolatile PAHs from the particles. In parallel, a medium-volume DRI fine particulate/semivolatile organic compound (FP/SVOC) sampler, using 90 mm TIGF (T60X40) filters backed by the PUF/XAD/PUF "sandwich" cartridge (10 g of XAD-4 resin between two 2-in. PUF plugs) was employed. The flow was set at approximately 90 L/min for the denuder and at 100 L/min for the FP/SVOC sampler.

Prior to sampling, the XAD-4 resin was cleaned by Soxhlet extraction with methanol followed by dichloromethane (CH2Cl2), each for 48 h. The cleaned resin was then dried in a vacuum oven heated at 40 °C and stored in sealed glass containers in a clean freezer. The PUF plugs were cleaned by Soxhlet extraction with acetone followed by extraction with 10% diethyl ether in hexane, as described in U.S. EPA Method TO-13. Prior to sampling, XAD-4 resin and PUF plugs were loaded into the glass sampling cartridges. The TIGF filters were cleaned by sonication in methanol for 10 min (twice), followed by two more 10-min sonications in CH_2Cl_2.

The SVOCs collected on each denuder-filter-PUF/XAD/PUF sampling train were extracted separately with high-purity, HPLC grade solvents. The denuder portion was extracted with cyclohexane immediately following the sample collection. Approximately 200 mL of cyclohexane was poured into the denuder section, which had been capped at one end. The other end was capped, and the denuder was manually inverted about 10 times. The solvent was drained and the procedure repeated two more times, using n-hexane for the last extraction. The PUF/XAD plugs were microwave-extracted with 10% diethyl ether in hexane, and the filters were microwave-extracted with dichloromethane.

The extracts were concentrated by rotary evaporation at 20 °C under gentle vacuum to ~1 mL and filtered through 0.20 μm of Anatop (Whatman International, Ltd.), rinsing the sample flask twice with 1 mL of CH_2Cl_2 each time. Approximately 50 μL of acetonitrile was added to the sample, and CH_2Cl_2 was evaporated under a gentle stream of nitrogen. The final volume was adjusted to 1 mL with acetonitrile. The sample was then analyzed by electron impact (EI) GC/MS technique, using an Ion Trap Varian Saturn 2000, operating in the selected ion storage (SIS) mode. Injections (1 μL) were made in the splitless mode onto a 30 m × 0.25 mm i.d. CPSil 8 fused-silica capillary column (Varian, Inc.).

Table 112: Distribution of PAH (ng/m^3) over MOUDI stages for 1996 Dodge Bobtail runs. (A-C) variable (95, 81, 54, and 27%) load; (D-F) low (27% load)

(A)									
Compound	**<.05**	**.05-.10**	**.10-.18**	**.18-.32**	**0.32-0.53**	**0.53-1.0**	**1.0-1.8**	**1.8-3.2**	**3.2-5.6**
Naphthalene	5.752	6.932	11.799	8.702	6.637	6.932	5.457	7.670	9.145
Methylnaphthalenes	6.342	5.162	8.997	12.537	8.702	3.687	4.277	3.982	6.195
Dimethylnaphthalenes	6.932	8.997	17.404	16.077	11.947	9.882	6.047	17.257	10.619
Trimethylnaphthalenes	44.100	6.932	8.702	12.537	11.062	8.112	9.292	30.531	14.454
Acenaphthylene	1.622	0.737	2.950	1.622	0.885	0.885	1.032	3.245	1.032
Acenaphthene	3.392	0.737	1.622	1.475	0.885	1.917	1.032	1.622	1.032
Fluorene		0.737	3.687	7.522	3.097	1.622	1.032	1.180	2.065
(B)									
Compound	**<.05**	**.05-.10**	**.10-.18**	**.18-.32**	**0.32-0.53**	**0.53-1.0**	**1.0-1.8**	**1.8-3.2**	**3.2-5.6**
phenanthrene	18.913	3.783	9.456	20.804	18.913	7.565		3.783	3.783

Methylphenanthrenes	68.085		34.043	160.757	90.780			3.783	3.783
Dimethylphenanthrenes	155.083	9.456	211.820	724.350	342.317	7.565		3.783	11.348
Fluoranthene	7.565		18.913	49.173	26.478			3.783	3.783
pyrene	18.913	11.348	60.520	153.191	75.650	9.456	9.456	9.456	11.348
methyl pyrene/methyl fluoranthene	30.260	24.586	132.388	308.274	124.823	15.130	13.239	17.021	15.130
(C)									
Compound	**<.05**	**.05-.10**	**.10-.18**	**.18-.32**	**0.32-0.53**	**0.53-1.0**	**1.0-1.8**	**1.8-3.2**	**3.2-5.6**
benzo[a]anthracene	0.957	2.154	11.011	14.601	7.899	0.718	1.197	1.676	1.676
chrysene	4.548	8.856	44.282	84.016	33.032	1.915	1.676	2.633	1.676
benzo[b+j+k]fluoranthene	1.676	2.394	16.516	30.399	15.080	1.436	1.197	1.676	1.676
benzo[e]pyrene	1.676	1.915	6.702	13.404	6.463	1.197	1.197	1.436	0.718
benzo[a]pyrene	0.718	0.718	2.154	4.548	1.676	1.197	0.718	1.197	1.676
benzo[ghi]perylene	2.154	0.718	1.676	4.548	2.154	1.197	0.718	1.915	1.676
coronene	2.154	0.000	1.197	2.633	1.676	0.718	1.197	1.436	1.676
(D)									
Compound	**<.05**	**.05-.10**	**.10-.18**	**.18-.32**	**0.32-0.53**	**0.53-1.0**	**1.0-1.8**	**1.8-3.2**	**3.2-5.6**
Naphthalene	3.805	5.929	8.761	1.593	3.009	3.805	3.628	3.628	4.867
Methylnaphthalenes	4.336	5.044	5.929	2.212	1.681	1.858	2.920	4.159	3.982
dimethylnaphthalene	4.159	5.929	11.416	4.336	2.832	28.584	4.690	3.628	5.221
trimethylnaphthalenes	11.416	6.903	7.168	1.593	5.487	2.389	7.168	8.053	9.115
Acenaphthylene	0.531	0.442	1.770	1.327	0.619	3.097	1.504	0.973	0.796
Acenaphthene	0.442	0.619	0.708	0.708	0.619	2.566	1.327	0.796	1.327
fluorene	1.770	0.442	1.062	0.708	-0.177	-1.504	0.973	0.796	0.973
(E)									
Compound	**<.05**	**.05-.10**	**.10-.18**	**.18-.32**	**0.32-0.53**	**0.53-1.0**	**1.0-1.8**	**1.8-3.2**	**3.2-5.6**
phenanthrene	6.052	1.702	2.459	1.135	0.946	0.946	1.135	1.324	2.080
Methylphenanthrenes	28.558	3.215	6.241	3.593	2.080	1.135	1.135	0.757	1.135
dimethylnaphthalene	69.976	8.132	36.312	14.563	1.702	1.135	3.026	1.324	2.648
fluoranthene	3.215		3.215	2.080	0.757	0.757	1.324	1.324	1.324
pyrene	10.213	3.783	12.671	8.511	0.946	1.135	1.891	1.324	2.459
methyl pyrene/methyl fluoranthene	30.827	26.288	61.655	45.012	5.296	5.106	5.485	5.296	5.296
(F)									
Compound	**<.05**	**.05-.10**	**.10-.18**	**.18-.32**	**0.32-0.53**	**0.53-1.0**	**1.0-1.8**	**1.8-3.2**	**3.2-5.6**
benzo[a]anthracene	1.120	1.707	4.747	1.813	0.480	0.107	0.747		0.587
chrysene	4.320	12.053	17.760	11.253	0.053	0.480		0.587	1.173
benzo[b+j+k]fluoranthene	1.493	3.787	3.253	1.813	0.480	0.480	0.587	0.587	0.800
benzo[e]pyrene	0.960	2.293	2.720	1.547	0.480	0.480	0.533		0.587

benzo[a]pyrene	0.373	1.547	1.547	0.693		0.480			0.267
benzo[ghi]perylene	0.373	0.907	0.640	0.693	0.480	0.480	0.800		0.907
coronene	0.587	0.907	0.427	0.053	0.693		0.800	0.587	1.227

Table 113: Comparison of samples collected with the denuder with samples collected in parallel with FP/SVOC sampler. (A) 1996 Dodge Bobtail, idle, denuder filter + denuder PUF/XAD/PUF vs FP/SVOC filter; (B) 1996 Dodge Bobtail, idle, denuder XAD portion vs. FP/SVOC PUF/XAD/PUF cartridge; (C) 1996 Dodge Bobtail, variable load, denuder filter + denuder PUF/XAD/PUF vs FP/SVOC filter; (D) 1996 Dodge Bobtail, high load, denuder XAD portion vs. FP/SVOC PUF/XAD/PUF cartridge (ng/m^3).

Compound, ng/m^3	(A) Dodge Bobtail, Idle		(B) Dodge Bobtail, Idle		(C) Dodge Bobtail, 95-27% Load		(D) Dodge Bobtail, 95-27% Load	
	DF+DP	FP/SVOC/ Filter	XAD Denude	FP/SVOC/ Filter	DF+DP	FP/SVOC/ Filter	XAD Denude	FP/SVOC/ Filter
Acenaphthylene	1.514	2.946	500.000	891.892	N/A	N/A	526.316	754.386
Acenaphthene	10.892	0.730	54.054	729.730	65.217	N/A	70.175	596.491
fluorene	1.432	0.703	1797.297	1418.919	117.391	26.087	1614.035	1192.982
phenanthrene	N/A	0.676	2121.622	2581.081	247.826	78.261	2964.912	2877.193
methylfluorenes	N/A	0.649	1081.081	2635.135	65.217	26.087	1052.632	2000.000
xanthone	0.676	2.946	189.189	783.784	65.217	39.130	192.982	385.965
methylphenanthrene	11.568	2.135	2364.865	2108.108	913.043	234.783	3456.140	1859.649
dimethylphenanthrene	2.135	0.622	1959.459	959.459	2543.478	1239.130	3385.965	964.912
anthracene	0.676	N/A	135.135	270.270	91.304	117.391	210.526	192.982
fluoranthene	N/A	1.432	121.622	135.135	182.609	104.348	140.351	87.719
pyrene	N/A	2.892	189.189	202.703	495.652	313.043	280.702	122.807
benzonaphthothiophene	13.757	0.676	N/A	27.027	169.565	195.652	52.632	N/A
methyl pyrene/methyl fluoranthene	1.432	0.676	162.162	67.568	795.652	821.739	175.439	70.175
benzo[c]phenanthrene	0.622	N/A	N/A	N/A	26.087	26.087	N/A	N/A
benzo[a]anthracene	0.622	N/A	N/A	N/A	39.130	52.174	N/A	N/A

chrysene	N/A	2.135	27.027	N/A	208.696	208.696	52.632	N/A
benzo[b+j+k]fluoranthene	12.243	0.649	N/A	N/A	65.217	52.174	N/A	N/A
benzo[e]pyrene	1.405	0.622	N/A	N/A	26.087	39.130	N/A	N/A
benzo[a]pyrene	N/A	N/A	N/A	N/A	26.087	26.087	N/A	N/A
indeno[1,2,3-cd]pyrene	0.622	0.676	N/A	N/A	26.087	N/A	N/A	N/A
benzo[ghi]perylene	0.676	3.595	N/A	N/A	26.087	N/A	N/A	N/A
dibenz[ah+ac]anthracene	13.000	0.676	N/A	N/A	N/A	N/A	N/A	N/A
coronene	0.622	0.676	N/A	N/A	N/A	N/A	N/A	N/A
Naphthalene	1881.443	N/A	5309.735	10088.496	986.047	18.605	8258.929	8482.143
Methylnaphthalenes	2216.495	N/A	15929.204	20707.965	855.814	18.605	14285.714	15848.214
biphenyl	103.093	N/A	2389.381	3185.841	46.512	N/A	2678.571	2678.571
dimethylnaphthalene	979.381	N/A	18318.584	25752.212	409.302	46.512	17410.714	19866.071
methylbiphenyls	77.320	N/A	5044.248	5840.708	251.163	18.605	4241.071	4687.500
trimethylnaphthalenes	541.237	N/A	13539.823	21238.938	241.860	139.535	11830.357	16741.071

Table 114: Comparison of samples collected with the denuder with samples collected in parallel with FP/SVOC sampler. (A) Ford F350, high load, denuder filter+denuder PUF/XAD/PUF vs FP/SVOC filter; (B) Ford F350, high load, denuder XAD portion vs. FP/SVOC PUF/XAD/PUF cartridge; (C) Ford F350, variable load, denuder filter + denuder PUF/XAD/PUF vs FP/SVOC filter; (D) Ford F350, variable load, denuder XAD portion FP/SVOC vs. PUF/XAD/PUF cartridge (ng/m^3).

	(A) Ford F350, 53% Load		(B) Ford F350, 53% Load		(C) Ford F350, 53-11% Load		(D) Ford F350, 53-11% Load	
Compound, ng/m^3	**DF+DP**	**FP/SVOC/ Filter**	**XAD Denude**	**FP/SVOC/ Filter**	**DF+ DP**	**FP/SVOC/ Filter**	**XAD Denude**	**FP/SVOC/ Filter**
phenanthrene	3.266	2.177	344.531	847.266	N/A	1.575	342.412	428.016
methylfluorenes	1.452	2.903	94.922	112.500	4.134	0.886	17.510	31.128
xanthone	N/A	3.629	158.203	14.062	0.295	3.642	15.564	11.673

methylphenanthrene	13.065	2.177	225.000	112.500	13.091	4.724	66.148	171.206
dimethylphenanthrene	16.331	N/A	63.281	28.125	12.795	1.181	11.673	17.510
anthracene	6.169	1.815	66.797	210.937	N/A	N/A	27.237	60.311
fluoranthene	5.806	1.452	42.187	63.281	N/A	1.575	60.311	42.802
pyrene	10.524	3.266	35.156	56.250	1.575	2.165	46.693	38.911
benzonaphthothiophene	2.903	N/A	N/A	N/A	0.787	N/A	N/A	N/A
methyl pyrene/methyl fluoranthene	26.855	4.718	N/A	17.578	19.783	2.953	7.782	11.673
benzo[c]phenanthrene	1.815	N/A	N/A	N/A	0.394	0.591	N/A	N/A
benzo[a]anthracene	7.258	4.718	N/A	N/A	N/A	N/A	5.837	N/A
chrysene	19.960	14.879	17.578	14.062	N/A	1.280	5.837	N/A
benzo[b+j+k]fluoranthene	77.298	68.589	N/A	N/A	2.461	2.165	N/A	N/A
benzo[e]pyrene	50.081	53.347	17.578	14.062	4.528	2.362	N/A	N/A
benzo[a]pyrene	80.565	86.008	N/A	14.062	3.248	1.575	N/A	N/A
indeno[1,2,3-cd]pyrene	27.218	38.468	N/A	N/A	1.280	0.492	5.837	N/A
benzo[ghi]perylene	38.105	45.000	N/A	N/A	1.870	N/A	N/A	N/A
dibenz[ah+ac]anthracene	13.427	7.984	N/A	N/A	0.591	N/A	N/A	3.891
coronene	18.145	14.879	N/A	N/A	2.264	0.591	N/A	N/A
Naphthalene	2530.120	N/A	55841.584	42178.218	39.796	5.102	9469.697	9621.212
Methylnaphthalenes	253.012	N/A	47524.752	10099.010	30.612	2.041	1969.697	1363.636
dimethylnaphthalene	72.289	N/A	8316.832	1782.178	32.653	3.061	151.515	303.030
trimethylnaphthalenes	N/A	N/A	9504.950	594.059	94.898	10.204	75.758	75.758

Hays et al. (2013) [Carbonaceous Aerosols Emitted from Light-Duty Vehicles Operating on Gasoline and Ethanol Fuel Blends, Environmental Science and Technology] examined the effects of fuel ethanol content (e0 versus e10 versus e85), operating conditions, and ambient temperature (−7 and 24 °C) on the PAH composition of the carbonaceous PM emitted from a set of three modern LDVs meeting U.S. Tier 2 emissions standards. Technical characteristics of the vehicles are shown below.

vehicle (mfr./model)	fuel system	odometer (km)	inertia weight (kg)	fuel capacity (L)	cylinders	displacement (L)
Chevrolet Impala LS	MFI flex-fuel	23 785	1814	64.4	6	3.5
Chrysler Town & Country	SFI flex-fuel	78 283	2155	75.7	6	3.3
Honda Civic LX	MFI	26 459	1361	49.2	4	1.8

[a] All vehicles tested were model year 2008 and had automatic transmissions. MFI − multiport fuel injection; SFI − sequential fuel injection. The Chevrolet and Chrysler vehicles were flex fuel vehicles.

Test vehicles were operated over the three-phase LA-92 unified driving cycle (UDC). Each LDV-fuel-temperature combination was tested in duplicate sequentially. LDV exhaust was directed to a dilution tunnel and constant volume sampling (CVS) system using an insulated transfer tube. Briefly, dilution air (21 m3/min; 21 °C) passed through a charcoal bed to stabilize hydrocarbons and then through a HEPA-filter to remove PM before mixing with the LDV raw exhaust. Particle emissions were collected on Teflon (R2PJ047, Pall Corporation, Ann Arbor, MI) positioned downstream of a PM2.5 cyclone (93 L/min; URG-2000–30-EP, URG, Chapel Hill, NC). Multiple four-point isokinetic probe assemblies were used that allowed separate and proportional PM2.5 sampling of each UDC phase.

Due to its sensitivity, thermal extraction gas chromatography–mass spectroscopy (TE-GC-MS) was selected to further examine the PM PAH composition. Briefly, filters were introduced to a glass TE tube and spiked with internal standard solution. After tube insertion, the TE unit (TDS2, Gerstel Inc., Germany) temperature was ramped from 25 to 300 °C at 10 °C/min and held constant at 300 °C for 5 min. A splitless-mode extraction was performed with He flowing continuously (50 mL/min) over the sample. Extract was directed through a heated (300 °C) capillary transfer line to a cryo-cooled (−100 °C) PTV inlet also operating in splitless mode. Following the TE step, the inlet was flash-heated to 300 °C at a rate of 702 °C/min. Sample was chromatographed on an ultralow bleed capillary column (DB5, Agilent Technologies, 30 m length, 0.25 µm film thickness and 0.25 mm i.d.). Helium was used as the carrier gas (1 mL/min). The GC oven temperature was programmed at 65 °C for 10 min and then ramped to 300 °C at 10 °C/min and held fixed for 41.5 min. The MS (5973, Agilent Technologies) was operated in scan mode (50–500 amu, 3 scans/s).

Table 115: PAH emissions

Compound	Phase	Temp.		concentration (ng/km)					
		(C)	Fuel	N	N Miss	Mean	Minimum	Median	Maximum
1-Methylchrysene	1	-7	E0	3	0	448.3	363.6	463.7	517.6
			E10	3	0	400.1	122.5	372.0	705.8
			E85	2	0	38.9	0.0	38.9	77.8
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
	2	-7	E0	3	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
	3	-7	E0	3	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
1-Methylnaphthalene	1	-7	E0	3	0	2011.0	1290.8	1447.1	3295.2
			E10	3	0	1533.6	352.2	1333.7	2915.0
			E85	2	0	577.5	0.0	577.5	1154.9
		24	E0	4	0	132.8	0.0	102.8	325.6
			E10	3	0	94.7	0.0	0.0	284.2
			E85	2	0	118.6	0.0	118.6	237.2
	2	-7	E0	3	0	87.5	0.0	71.0	191.5
			E10	3	0	83.9	0.0	115.6	136.2
			E85	2	0	82.0	0.0	82.0	164.1
		24	E0	4	0	24.8	0.0	25.7	47.8
			E10	3	0	25.7	0.0	36.1	41.0
			E85	2	0	0.0	0.0	0.0	0.0
	3	-7	E0	3	0	41.4	0.0	0.0	124.2
			E10	3	0	42.5	0.0	0.0	127.5
			E85	2	0	14.4	0.0	14.4	28.7
		24	E0	4	0	5.7	0.0	0.0	23.0
			E10	3	0	11.5	0.0	0.0	34.5
			E85	2	0	8.1	0.0	8.1	16.2
2,6-Dmethylnaphthalene	1	-7	E0	3	0	263.6	0.0	205.5	585.1

			E10	3	0	238.5	0.0	256.1	459.3
			E85	2	0	79.8	0.0	79.8	159.5
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	43.8	0.0	43.8	87.5
	2	-7	E0	3	0	9.9	0.0	0.0	29.6
			E10	3	0	5.0	0.0	0.0	14.9
			E85	2	0	8.6	0.0	8.6	17.3
		24	E0	4	0	3.7	0.0	0.0	14.9
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
	3	-7	E0	3	0	7.3	0.0	0.0	22.0
			E10	3	0	5.8	0.0	0.0	17.5
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
2-Methylnaphthalene	1	-7	E0	3	0	72.5	0.0	0.0	217.5
			E10	3	0	69.9	0.0	0.0	209.6
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
	2	-7	E0	3	0	8.5	0.0	0.0	25.5
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	11.7	0.0	11.7	23.5
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
	3	-7	E0	3	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
2-Methylnonadecane/Interference	1	-7	E0	3	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
	2	-7	E0	3	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0

	3	-7	E0	3	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
3-Methylnonadecane/Interference	1	-7	E0	3	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
	2	-7	E0	3	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
	3	-7	E0	3	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
9-Methylanthracene	1	-7	E0	3	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
	2	-7	E0	3	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
	3	-7	E0	3	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
Acenaphthene	1	-7	E0	3	0	557.6	278.2	312.3	1082.2
			E10	3	0	621.2	0.0	496.0	1367.6
			E85	2	0	147.7	0.0	147.7	295.3
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	46.7	0.0	0.0	140.2

			E85	2	0	0.0	0.0	0.0	0.0
	2	-7	E0	3	0	2.9	0.0	0.0	8.6
			E10	3	0	19.0	0.0	8.4	48.5
			E85	2	0	12.7	0.0	12.7	25.4
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	6.3	0.0	0.0	19.0
			E85	2	0	0.0	0.0	0.0	0.0
	3	-7	E0	3	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
Acenaphthylene	1	-7	E0	3	0	397.1	0.0	391.4	799.9
			E10	3	0	443.1	0.0	542.5	786.7
			E85	2	0	264.4	0.0	264.4	528.8
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
	2	-7	E0	3	0	12.8	0.0	0.0	38.3
			E10	3	0	11.1	0.0	0.0	33.4
			E85	2	0	35.1	0.0	35.1	70.2
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
	3	-7	E0	3	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
Anthracene	1	-7	E0	3	0	2342.0	1007.8	3003.8	3014.3
			E10	3	0	1258.6	288.3	1584.5	1902.9
			E85	2	0	165.3	0.0	165.3	330.5
		24	E0	4	0	30.0	0.0	0.0	120.1
			E10	3	0	77.9	0.0	0.0	233.7
			E85	2	0	0.0	0.0	0.0	0.0
	2	-7	E0	3	0	109.0	62.6	122.3	142.1
			E10	3	0	78.4	26.2	70.8	138.2
			E85	2	0	17.1	0.0	17.1	34.2
		24	E0	4	0	10.7	0.0	0.0	42.6
			E10	3	0	12.0	4.2	6.3	25.4
			E85	2	0	0.0	0.0	0.0	0.0
	3	-7	E0	3	0	40.3	0.0	38.8	82.1
			E10	3	0	27.1	0.0	0.0	81.3
			E85	2	0	2.2	0.0	2.2	4.4
		24	E0	4	0	4.9	0.0	0.0	19.8

			E10	3	0	0.9	0.0	0.0	2.7
			E85	2	0	0.0	0.0	0.0	0.0
Benz(a)anthracene	1	-7	E0	3	0	11753.2	8813.1	11100.6	15345.8
			E10	3	0	7905.9	2051.9	10331.6	11334.2
			E85	2	0	1576.8	1498.0	1576.8	1655.6
		24	E0	4	0	49.3	23.2	48.5	76.7
			E10	3	0	104.4	61.0	61.5	190.7
			E85	2	0	5.8	0.0	5.8	11.7
	2	-7	E0	3	0	200.8	111.6	142.3	348.4
			E10	3	0	56.2	19.0	40.5	109.0
			E85	2	0	14.8	12.4	14.8	17.2
		24	E0	4	0	9.1	0.0	2.2	32.0
			E10	3	0	9.9	4.1	4.2	21.3
			E85	2	0	1.0	0.0	1.0	2.0
	3	-7	E0	3	0	79.1	46.4	63.4	127.3
			E10	3	0	22.6	1.8	3.0	62.8
			E85	2	0	3.2	1.1	3.2	5.3
		24	E0	4	0	4.9	0.0	1.8	16.1
			E10	3	0	2.4	0.0	3.5	3.6
			E85	2	0	0.9	0.0	0.9	1.7
Benzo(a)pyrene	1	-7	E0	3	0	8065.1	4375.9	7141.5	12677.9
			E10	3	0	8978.6	1316.9	9207.5	16411.3
			E85	2	0	2647.4	2574.6	2647.4	2720.3
		24	E0	4	0	11.6	0.0	0.0	46.5
			E10	3	0	36.0	0.0	45.8	62.3
			E85	2	0	0.0	0.0	0.0	0.0
	2	-7	E0	3	0	32.2	21.2	31.6	43.8
			E10	3	0	16.5	0.0	18.1	31.4
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	3.7	0.0	0.0	14.9
			E10	3	0	2.1	0.0	0.0	6.3
			E85	2	0	0.0	0.0	0.0	0.0
	3	-7	E0	3	0	30.1	0.0	14.7	75.6
			E10	3	0	4.8	0.0	0.0	14.5
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	1.4	0.0	0.0	5.5
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
Benzo(b)fluoranthene	1	-7	E0	3	0	6549.9	3807.5	7558.9	8283.3
			E10	3	0	5436.9	1301.6	5130.8	9878.4
			E85	2	0	1564.9	1404.3	1564.9	1725.4
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
	2	-7	E0	3	0	67.1	27.5	54.8	118.9
			E10	3	0	10.5	0.0	0.0	31.4
			E85	2	0	0.0	0.0	0.0	0.0

		24	E0	4	0	5.8	0.0	0.0	23.4
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
	3	-7	E0	3	0	94.2	0.0	20.1	262.4
			E10	3	0	6.7	0.0	0.0	20.0
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
Benzo(e)pyrene	1	-7	E0	3	0	5568.2	2537.0	5959.5	8208.1
			E10	3	0	4276.0	1209.7	4030.2	7588.0
			E85	2	0	2351.4	2200.1	2351.4	2502.7
		24	E0	4	0	11.6	0.0	0.0	46.5
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
	2	-7	E0	3	0	67.7	23.3	42.2	137.7
			E10	3	0	19.2	6.3	24.2	27.2
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	3.7	0.0	0.0	14.9
			E10	3	0	2.1	0.0	0.0	6.3
			E85	2	0	0.0	0.0	0.0	0.0
	3	-7	E0	3	0	30.5	12.8	21.6	57.2
			E10	3	0	4.2	0.0	0.0	12.7
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	1.4	0.0	0.0	5.5
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
Benzo(ghi)fluoranthene	1	-7	E0	3	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
	2	-7	E0	3	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
	3	-7	E0	3	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
Benzo(ghi)perylene	1	-7	E0	3	0	11436.8	6446.2	11587.1	16277.1
			E10	3	0	12851.3	3261.7	13454.8	21837.5

			E85	2	0	12272.7	8379.0	12272.7	16166.3
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
	2	-7	E0	3	0	31.6	0.0	0.0	94.7
			E10	3	0	11.9	0.0	0.0	35.6
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
	3	-7	E0	3	0	28.8	0.0	0.0	86.4
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
Benzo(k)fluoranthene	1	-7	E0	3	0	7359.2	5030.8	8115.4	8931.5
			E10	3	0	7323.7	1470.0	6122.9	14378.2
			E85	2	0	1783.4	1694.3	1783.4	1872.4
		24	E0	4	0	15.5	0.0	0.0	62.0
			E10	3	0	20.3	0.0	0.0	61.0
			E85	2	0	0.0	0.0	0.0	0.0
	2	-7	E0	3	0	57.4	29.6	54.8	87.6
			E10	3	0	11.1	0.0	0.0	33.4
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	5.8	0.0	0.0	23.4
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
	3	-7	E0	3	0	64.8	18.3	21.6	154.4
			E10	3	0	6.0	0.0	0.0	18.1
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
Chrysene	1	-7	E0	3	0	14233.3	9398.4	10473.8	22827.8
			E10	3	0	8021.3	3057.8	10496.0	10510.2
			E85	2	0	1757.6	1494.1	1757.6	2021.1
		24	E0	4	0	64.7	34.9	60.2	103.4
			E10	3	0	149.3	76.3	76.8	294.8
			E85	2	0	24.8	10.9	24.8	38.7
	2	-7	E0	3	0	351.3	178.8	211.1	664.0
			E10	3	0	72.8	35.6	52.6	130.2
			E85	2	0	20.2	16.7	20.2	23.7
		24	E0	4	0	12.4	0.0	7.6	34.3
			E10	3	0	6.1	3.8	6.3	8.1
			E85	2	0	4.4	0.1	4.4	8.8
	3	-7	E0	3	0	157.3	82.0	91.6	298.4

			E10	3	0	32.2	2.6	8.3	85.7
			E85	2	0	2.6	2.1	2.6	3.1
		24	E0	4	0	7.0	0.0	6.1	15.7
			E10	3	0	6.6	5.5	7.1	7.2
			E85	2	0	3.1	1.3	3.1	4.8
Coronene	1	-7	E0	3	0	9036.5	6863.3	8251.7	11994.6
			E10	3	0	8961.3	1653.8	10804.1	14426.0
			E85	2	0	8914.1	5844.8	8914.1	11983.3
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
	2	-7	E0	3	0	14.1	0.0	0.0	42.2
			E10	3	0	25.8	0.0	0.0	77.4
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
	3	-7	E0	3	0	8.3	0.0	0.0	24.8
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
Cyclopentane(cd)pyrene	1	-7	E0	3	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
	2	-7	E0	3	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
	3	-7	E0	3	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
Dibenzo(a,e)pyrene	1	-7	E0	3	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0

	2	-7	E0	3	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
	3	-7	E0	3	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
Dibenzo(a,h)anthracene	1	-7	E0	3	0	610.3	517.6	649.2	664.0
			E10	3	0	538.1	0.0	290.9	1323.5
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
	2	-7	E0	3	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
	3	-7	E0	3	0	30.6	0.0	0.0	91.8
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
Dibenzofuran	1	-7	E0	3	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
	2	-7	E0	3	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
	3	-7	E0	3	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0

			E85	2	0	0.0	0.0	0.0	0.0
Fluoranthene	1	-7	E0	3	0	25608.1	11889.9	28838.7	36095.7
			E10	3	0	10817.0	2100.7	15060.5	15289.8
			E85	2	0	2675.9	2667.2	2675.9	2684.5
		24	E0	4	0	275.3	0.0	250.0	601.3
			E10	3	0	775.8	316.8	376.4	1634.2
			E85	2	0	222.2	127.6	222.2	316.8
	2	-7	E0	3	0	1775.5	842.4	899.4	3584.7
			E10	3	0	683.2	287.6	741.7	1020.2
			E85	2	0	154.4	133.4	154.4	175.5
		24	E0	4	0	45.7	0.0	21.8	139.2
			E10	3	0	114.5	32.7	131.6	179.3
			E85	2	0	31.5	24.2	31.5	38.8
	3	-7	E0	3	0	805.6	295.5	434.5	1687.0
			E10	3	0	246.0	26.9	250.2	461.0
			E85	2	0	34.5	30.3	34.5	38.8
		24	E0	4	0	36.8	0.0	33.5	80.0
			E10	3	0	137.0	27.8	40.8	342.4
			E85	2	0	12.9	7.1	12.9	18.8
Fluorene	1	-7	E0	3	0	1108.4	413.5	557.6	2354.1
			E10	3	0	912.9	73.6	922.6	1742.4
			E85	2	0	118.6	0.0	118.6	237.3
		24	E0	4	0	40.3	0.0	27.2	107.0
			E10	3	0	71.2	0.0	46.1	167.4
			E85	2	0	25.5	0.0	25.5	51.0
	2	-7	E0	3	0	9.1	0.0	7.8	19.5
			E10	3	0	22.0	0.0	17.0	49.0
			E85	2	0	5.5	0.0	5.5	10.9
		24	E0	4	0	1.1	0.0	0.0	4.5
			E10	3	0	7.1	0.0	0.0	21.2
			E85	2	0	0.0	0.0	0.0	0.0
	3	-7	E0	3	0	3.9	0.0	0.0	11.7
			E10	3	0	7.2	0.0	7.9	13.8
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.7	0.0	0.0	2.9
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	1.3	0.0	1.3	2.6
Indeno(1,2,3-cd)pyrene	1	-7	E0	3	0	10278.1	5128.7	11083.2	14622.3
			E10	3	0	13835.5	1868.2	14183.3	25455.1
			E85	2	0	6909.1	3885.2	6909.1	9932.9
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
	2	-7	E0	3	0	16.8	0.0	0.0	50.5
			E10	3	0	8.4	0.0	0.0	25.1
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0

			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
	3	-7	E0	3	0	19.8	0.0	0.0	59.4
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
Methyl-fluorene	1	-7	E0	3	0	841.8	498.7	822.4	1204.4
			E10	3	0	504.9	0.0	518.3	996.4
			E85	2	0	81.8	0.0	81.8	163.6
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	51.9	0.0	0.0	155.6
			E85	2	0	0.0	0.0	0.0	0.0
	2	-7	E0	3	0	10.8	0.0	0.0	32.3
			E10	3	0	9.9	0.0	0.0	29.7
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	2.8	0.0	0.0	11.2
			E10	3	0	10.0	0.0	15.0	15.1
			E85	2	0	0.0	0.0	0.0	0.0
	3	-7	E0	3	0	8.7	0.0	0.0	26.0
			E10	3	0	9.3	0.0	0.0	28.0
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	1.9	0.0	0.0	7.6
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
Naphthalene	1	-7	E0	3	0	2437.3	1746.9	1885.8	3679.2
			E10	3	0	1955.2	479.5	1717.5	3668.7
			E85	2	0	723.2	0.0	723.2	1446.5
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
	2	-7	E0	3	0	58.9	0.0	0.0	176.8
			E10	3	0	34.4	0.0	0.0	103.2
			E85	2	0	78.9	0.0	78.9	157.9
		24	E0	4	0	13.5	0.0	0.0	54.0
			E10	3	0	17.8	0.0	0.0	53.4
			E85	2	0	0.0	0.0	0.0	0.0
	3	-7	E0	3	0	38.8	0.0	0.0	116.5
			E10	3	0	39.9	0.0	0.0	119.8
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	14.6	0.0	0.0	43.8
			E85	2	0	0.0	0.0	0.0	0.0
Perylene	1	-7	E0	3	0	1717.1	1223.4	1762.2	2165.7
			E10	3	0	2345.6	336.9	1891.1	4808.7
			E85	2	0	420.6	373.1	420.6	468.1

		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
	2	-7	E0	3	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
	3	-7	E0	3	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
		24	E0	4	0	0.0	0.0	0.0	0.0
			E10	3	0	0.0	0.0	0.0	0.0
			E85	2	0	0.0	0.0	0.0	0.0
Phenanthrene	1	-7	E0	3	0	15020.3	6296.6	14117.2	24647.2
			E10	3	0	7105.3	1277.8	9627.2	10411.1
			E85	2	0	1649.0	1303.1	1649.0	1995.0
		24	E0	4	0	414.7	54.7	294.6	1015.0
			E10	3	0	1203.5	336.0	595.4	2679.0
			E85	2	0	406.0	383.3	406.0	428.7
	2	-7	E0	3	0	558.2	167.4	569.4	937.7
			E10	3	0	688.7	152.1	574.1	1339.8
			E85	2	0	192.2	145.3	192.2	239.0
		24	E0	4	0	24.7	0.0	13.6	71.6
			E10	3	0	147.3	22.7	68.1	351.1
			E85	2	0	27.4	20.4	27.4	34.5
	3	-7	E0	3	0	175.6	27.5	237.5	261.7
			E10	3	0	195.5	7.6	265.8	313.3
			E85	2	0	34.7	31.0	34.7	38.3
		24	E0	4	0	12.8	0.0	10.2	31.0
			E10	3	0	21.3	3.9	17.8	42.1
			E85	2	0	9.9	3.7	9.9	16.2
Pyrene	1	-7	E0	3	0	27768.2	12335.2	30832.3	40137.1
			E10	3	0	14157.6	2957.4	18788.2	20727.2
			E85	2	0	5083.2	3721.9	5083.2	6444.5
		24	E0	4	0	205.0	27.3	137.6	517.5
			E10	3	0	978.6	198.4	203.6	2533.8
			E85	2	0	157.6	91.2	157.6	223.9
	2	-7	E0	3	0	1286.8	858.7	967.8	2033.8
			E10	3	0	801.7	344.4	931.7	1129.0
			E85	2	0	232.5	143.6	232.5	321.4
		24	E0	4	0	43.7	0.0	37.2	100.5
			E10	3	0	136.0	28.5	79.6	299.8
			E85	2	0	33.4	20.1	33.4	46.7
	3	-7	E0	3	0	502.7	299.8	542.1	666.0
			E10	3	0	313.9	37.3	361.0	543.4

			E85	2	0	57.8	40.1	57.8	75.5
		24	E0	4	0	34.6	0.0	34.2	70.0
			E10	3	0	30.8	18.7	24.7	49.0
			E85	2	0	10.5	4.8	10.5	16.2

Devos et al. (2006) [Exhaust Emissions of PAHS of Passenger Cars, Polycyclic Aromatic Compounds] tested 13 gasoline and 17 diesel cars of different categories depending on European directives for exhaust emissions (ECE 1504, Euro 1, Euro 2, and Euro 3) for PAH emissions. testing was conducted on two type of driving cycles using a chassis dynamometer. The first two cycles were representative of the actual driving conditions in Europe, called urban and motorway VP low/high motorization (18.3/19.3 km/h, 945 s and 119.0/121.8 km/h, 729 s), under hot engine start conditions. The second type of driving cycle was a short cycle, called INRETS short urban free-flow, which was repeated 15 times (19.0 km/h, 2835 s) and carried out under cold or hot engine start conditions.

A Constant Volume Sampling (CVS) system was used for collecting exhaust emissions of the 16 PAHs listed by the U.S. Environmental Protection Agency (USEPA). PAHs were collected at the end of the dilution tunnel at room temperature using a filter and an absorber. The system consisted of two stainless steel cartridges separated by a stainless steel grid and filled respectively with 15 g of Teflon wool and 20 g of XAD2 Amberlite resin. PAHs on Teflon wool and XAD2 were extracted separately in cyclohexane by an ultrasonic method performed over 30 min at 37°C. After evaporation near to dryness, extracts were dissolved in n-octane. To eliminate polar compounds a clean-up was performed on silica cartridges with an elution by n-hexane. After evaporation, residues were dissolved in acetonitrile. All solvents used were of spectrometric grade.

PAH analysis was performed on a Merck-Hitachi chromatograph equipped with a LiChroCART 250-4 LiChrospher PAH column fed by an injection loop of 20 μ L and coupled with absorption and fluorescence spectrometers. Elution was performed using ACN/H_2O mobile phase at a flow rate of 1 mL/min.

Table 116: Mean distribution of PAHs for Euro 2 vehicles (gasoline and diesel)

PAH (ug/km)	Gasoline	Diesel
Naphthalene	0.736	1.625
Acenaphthene	0.074	0.148
Fluorene	0.035	0.094
Phenanthrene	0.702	2.278
Anthracene	0.025	0.054
Fluoranthene	0.119	0.563
Pyrene	0.124	0.435
Benz[a]anthracene	0.049	0.163
Chrysene	0.015	0.084
Benzo[b]fluoranthene	0.138	0.361
Benzo[k]fluoranthene	0.054	0.124
Benzo[a]pyrene	0.054	0.282
Indeno[1,2,3-cd]pyrene	0.336	0.534
Benzo[ghi]perylene	0.173	0.509
Dibenzo[ah]anthracene	0.049	0.094

Table 117: Average sums of the twelve less volatile PAHs according to the segmentation for gasoline (G) and diesel (D) cars

	Gasoline EURO 1	**Gasoline EURO 2**	**Gasoline EURO 3**	**Diesel 1504**	**Diesel EURO 1**	**Diesel EURO 2**	**Diesel EURO 3**
Cold short urban INRETS	1.299	1.286	0.758	3.695	0.460	0.379	0.054
Hot short urban INRETS	0.027	0.041	0.014	1.245	0.284	0.162	0.014
Urban VP I/h motorization	0.068	0.068	0.054	2.179	0.298	0.352	0.122
Motorway VP I/h motorization	0.041	0.068	0.230	1.435	0.541	0.108	0.027

Table 118: Average sums of the six carcinogenic PAHs according to the segmentation for gasoline (G) and diesel (D) cars

	Gasoline EURO 1	**Gasoline EURO 2**	**Gasoline EURO 3**	**Diesel 1504**	**Diesel EURO 1**	**Diesel EURO 2**	**Diesel EURO 3**
Cold short urban INRETS	7.841	4.300	4.132	26.138	4.806	5.143	1.096
Hot short urban INRETS	0.506	1.518	1.686	15.936	8.853	2.867	0.422
Urban VP I/h motorization	1.265	1.012	1.939	19.393	6.239	3.794	2.024
Motorway VP I/h motorization	0.422	0.843	1.096	22.681	7.167	3.457	0.927

Louis et al. (2016) [PAH, BTEX, carbonyl compound, black-carbon, NO2 and ultrafine particle dynamometer bench emissions for Euro 4 and Euro 5 diesel and gasoline passenger cars, Atmospheric Environment] examined PAH emissions from Euro 4 and Euro 5 vehicles equipped with different aftertreatment devices and technologies (Diesel vehicles with catalyzed or additive DPF and direct-injection gasoline vehicles).

Six in-use vehicles were studied: one Euro 5 gasoline vehicle with direct injection system (G-DI); two Euro 5 Diesel vehicles with additive particulate filter (DPF add); one Euro 5 Diesel vehicle with catalyzed particulate filter (DPF cat); one Euro 4 gasoline vehicle (G); and one Euro 4 Diesel vehicle with catalyzed particulate filter (DPF cat). Experiments were conducted using the real-world Artemis driving cycles.

Gas-phase PAHs were collected into ORBO 43 cartridges at flow rates up to 0.5 L/min. Particulate-phase PAHs were collected on quartz filters at flow rates up to 50 L/min. PAH analysis was performed using High Performance Liquid Chromatography/Fluorescence Detector. For the gas-phase species the NIOSH 5506 methods was used, while for the PM-phase species the NF x 43-025 methods was used.

Table 119: PAH emission factors

Driving cycle	Artemis urban hot start	Artemis urban cold start	Artemis road hot start	Artemis motorway hot start
Vehicle 1	Euro 5 Diesel additive DPF			
Naphthalene (gas) (mg/km)	< LQ	< LQ	< LQ	2 ± 0.3
Anthracene (ng/km)	15 ± 0.2	15 ± 0.4	30 ± 3	8 ± 2
Pyrene (ng/km)	109 ± 19	129 ± 2	40 ± 3	23 ± 2
Benz[a]anthracene (ng/km)	101 ± 22	93 ± 30	38 ± 11	12 ± 1
Vehicle 2	Euro 5 Diesel additive DPF			
Naphthalene (gas) (mg/km)	21 ± 6	29 ± 9	< LQ	7 ± 3
Anthracene (ng/km)	49 ± 17	153 ± 16	60 ± 4	23 ± 9
Pyrene (ng/km)	54 ± 30	147 ± 6	22 ± 12	8 ± 5
Benz[a]anthracene (ng/km)	116 ± 20	112 ± 2	41 ± 3	23 ± 6
Vehicle 3	Euro 4 Diesel catalyzed DPF			
Phenanthrene (ng/km)	709 ± 284	146 ± 37	124 ± 44	85 ± 20
Vehicle 4	Euro 5 Diesel catalyzed DPF			
Naphthalene (gas) (mg/km)	< LQ	36 ± 3	19 ± 14	1 ± 0.7
Phenanthrene (ng/km)	< LQ	< LQ	63 ± 10	46 ± 22
Vehicle 5	Euro 4 gasoline			
Naphthalene (gas) (mg/km)	35 ± 7	144 ± 26	7 ± 2	5 ± 1
Naphthalene (ng/km)	< LQ	< LQ	< LQ	151 ± 5
Phenanthrene (ng/km)	2 ± 0.2	943 ± 94	< LQ	22 ± 2
Anthracene (ng/km)	< LQ	137 ± 14	< LQ	9 ± 5
Pyrene (ng/km)	2 ± 0.2	63 ± 6	< LQ	14 ± 0.1
Benz[a]anthracene (ng/km)	< LQ	80 ± 8	< LQ	9 ± 6
Benzo[obj]fluoranthene (ng/km)	< LQ	< LQ	< LQ	53 ± 5
Vehicle 6	Euro 5 gasoline DI			
Naphthalene (gas) (mg/km)	38 ± 4	47 ± 25	28 ± 13	19 ± 13
Phenanthrene (ng/km)	< LQ	< LQ	< LQ	66 ± 34

Munoz et al. (2018) [Co-formation and co-release of genotoxic PAHs, alkyl-PAHs and soot nanoparticles from gasoline direct injection vehicles, Atmospheric Environment] examined PAH emissions from a fleet of 7 GDI vehicles representing Euro-3, -4, -5 and -6 technologies, as well as a Euro-5 diesel vehicle with integrated diesel particle filter (DPF). The vehicle characteristics are shown below.

	GDI-1	GDI-2	GDI-3	GDI-4	GDI-5	GDI-6	GDI-7	D-DPF
Name	Mitsubishi Carisma	VW Golf Plus	Opel Insignia	Volvo V60	Opel Zafira	Citröen C4	VW Golf VII	Peugeot 4008
Displacement (L)	1.834	1.390	1.598	1.596	1.598	1.199	1.395	1.560
Injection type	GDI	GDI	GDI	GDI	GDI	GDI	GDI	DI
Legislation	Euro-3	Euro-4	Euro-5	Euro-5	Euro-5	Euro-6	Euro-6	Euro-5
Power (kW)	90 (5500 rpm)	118 (5800 rpm)	125 (6000 rpm)	132 (5700 rpm)	125 (6000 rpm)	81 (5500 rpm)	110 (6000 rpm)	84 (3600 rpm)

Testing was performed on the world harmonized light vehicle test cycle (WLTC). The WLTC was driven under cold-start (cWLTC) and hot engine/catalyst conditions (hWLTC). It includes urban, extra-urban, highway and motorway driving at mean velocities of 26, 45, 61 and 94 km/ h with a total cycle time of 30 min. The steady-state cycle (SSC), represents steady driving at mean velocities of the four WLTC phases and an idling phase. Each phase is driven for 20 min. During SSC runs, the cruise control of the vehicle was used to keep the speed constant.

Diluted exhausts were sampled from a constant volume sampling (CVS) tunnel with an all-glass sampling device including filter-, condenser- and absorber units (XAD2) according to the filter/condenser method described in the European standard EN-1948-1. This allows quantitative sampling of complete exhausts including particle-bound, liquid and gaseous fractions. Analysis of PAHs is performed by gas chromatography (Fisons Instruments HRGC Mega 2, Rodano, Italy) on a 30 m × 0.25 µm x 0.10 µm capillary column (Restek, Bellefonte, USA). Detection and identification of compounds were achieved by high resolution mass spectrometry (Thermo Finnigan MAT 95, Bremen, Germany) in electron-impact ionization mode (GC/EI-HRMS).

Table 120: Emission factors (ng/km) for detected PAHs and alkyl-PAHs in all vehicles in the cold-start WLTC.

	GDI-1	GDI-2	GDI-3	GDI-4	GDI-5	GDI-6	GDI-7	GDI	D-DPF
	Mitsubishi Carisma	VW Golf	Opel Insignia	Volvo V60	Opel Zafira	Citröen C4	VW Golf VII	Mean	Peugeot 4008
PAH, ng/km	Euro-3	Euro-4	Euro-5	Euro-5	Euro-5	Euro-6	Euro-6		Euro-5
Naphthalene	163000	448000	429300	78800	92100	56500	96100	194800 ± 158000	5700
2-methyl-naphthalene	31700	58800	22000	16000	6400	8400	14100	22500 ± 16800	1500
1-methyl-naphthalene	21700	30300	16100	8720	4000	7700	11400	14300 ± 8480	900
2,6-dimethyl-naphthalene	3940	3810	640	3240	380	510	1500	2000 ± 1490	260
1,6-dimethyl-naphthalene	2490	7470	360	1840	400	590	1580	2104 ± 2310	310
1,2-dimethyl-naphthalene	1000	1690	190	500	59	190	790	630 ± 540	120
Acenaphthylene	3400	80100	4980	5920	1140	7640	7380	15800 ± 26300	3.7
Acenaphthene	1190	20600	1180	390	490	440	1140	3640 ± 6950	100
Fluorene	1110	8520	1020	2080	88	1360	2210	2340 ± 2600	270
Phenanthrene	6300	56800	400	14800	1860	20510	15900	16700 ± 17800	3020
Anthracene	1370	4680	490	1770	180	1400	1560	1640 ± 1360	370
3-methyl-phenanthrene	380	1310	290	1060	100	860	1310	760 ± 470	930
2-methyl-phenanthrene	420	1280	220	1370	130	1000	1670	870 ± 570	990
9-methyl-phenanthrene	310	561	93	500	15	430	540	350 ± 203	460
1-methyl-phenanthrene	260	634	100	610	9.1	520	670	400 ± 250	470
1,7-dimethyl-phenanthrene	250	115	7940	300	*6.9*	210	160	1280 ± 2720	150
2-methyl-anthracene	210	527	810	560	46	410	810	480 ± 270	250
retene	330	67	230	250	17	190	500	230 ± 150	78
Fluoranthene	3220	4860	1440	2280	270	760	1410	2030 ± 1460	4760
3-methylfluoranthene	28	66	44	47	2.8	1.5	56	35 ± 20	*0.9*
1-methyl-fluoranthene	15	73	31	23	2.5	*0.7*	28	25 ± 20	5.3
Pyrene	13750	3692	390	1600	*220*	1510	148	3240 ± 4420	3760

4-methyl-pyrene	110	67	45	83	*2*	46	72	61 ± 30	30
1-methyl-pyrene	50	36	36	38	*1.3*	21	40	32 ± 15	11
Benzo[a]anthracene	82	284	250	71	35	81	47	122 ± 90	6.7
Chrysene	180	408	310	130	50	130	88	186 ± 120	12.4
3-methyl-chrysene	110	30	30	27	*1.5*	46	160	60 ± 50	0.1
6-methyl-chrysene	28	*0.5*	-	7	*0.3*	*0.8*	25	8.9 ± 10	8
Benzo[b]fluoranthene	360	374	240	100	19	54	48	170 ± 140	8
Benzo[k]fluoranthene	86	122	110	38	25	18	22	60 ± 40	*1.3*
Benzo[a]pyrene	830	178	250	75	5	103	47	210 ± 260	5.5
Indeno[1,2,3-cd]pyrene	380	231	41	32	26	37	22	110 ± 130	*4.5*
Dibenzo[ah]anthracene	17	35	16	9	86	*0.7*	12	25 ± 30	*9.1*
Benzo[ghi]perylene	2040	285	*38*	92	*34*	87	65	377 ± 680	12

Table 121: Emission factors (ng km-1) for detected PAHs and alkyl-PAHs in all vehicles in the hot-start WLTC.

	GDI-1	**GDI-2**	**GDI-3**	**GDI-4**	**GDI-5**	**GDI-6**	**GDI-7**	**GDI**	**D-DPF**
PAH, ng/km	Mitsubishi Carisma	VW Golf	Opel Insignia	Volvo V60	Opel Zafira	Citröen C4	VW Golf VII	Mean	Peugeot 4008
	Euro-3	**Euro-4**	**Euro-5**	**Euro-5**	**Euro-5**	**Euro-6**	**Euro-6**		**Euro-5**
Naphthalene	138600	204300	15900	43800	12400	3066	25300	63300 ± 71600	1000
2-methyl-naphthalene	24300	23200	1700	12300	2900	217	6700	10200 ± 9300	500
1-methyl-naphthalene	15600	10500	900	6230	1800	*14*	2500	5400 ± 5360	300
2,6-dimethyl-naphthalene	6060	1143	10	3220	340	530	450	1680 ± 2040	42
1,6-dimethyl-naphthalene	4430	2753	190	1820	340	40	450	1430 ± 1530	46
1,2-dimethyl-naphthalene	1790	602	150	530	58	10	170	470 ± 580	16
Acenaphthylene	9760	15229	1170	4900	300	470	3400	5030 ± 5170	*0.6*
Acenaphthene	820	4403	56	290	160	*4.3*	230	850 ± 1470	13
Fluorene	1830	2518	540	2140	250	510	2050	1400 ± 870	60

Phenanthrene	26880	26318	260	11900	5880	8450	16260	13710 ± 9350	2700
Anthracene	2030	2955	350	2400	420	420	1160	1390 ± 990	210
3-methyl-phenanthrene	1250	540	180	1600	380	410	610	710 ± 780	160
2-methyl-phenanthrene	1540	547	200	1900	410	540	810	850 ± 580	150
9-methyl-phenanthrene	790	242	120	910	240	240	380	420 ± 280	54
1-methyl-phenanthrene	880	287	53	1060	210	290	480	470 ± 340	61
1,7-dimethyl-phenanthrene	580	47	4500	500	100	170	220	870 ± 1490	14
2-methyl-anthracene	210	224	450	920	100	110	570	390 ± 270	*2.6*
retene	720	77	83	180	130	110	90	200 ± 210	1.1
Fluoranthene	9150	1924	1590	2330	474	860	1020	2480 ± 2780	300
3-methylfluoranthene	130	29	0	53	10	1.6	*1.2*	32 ± 40	*0.9*
1-methyl-fluoranthene	46	9	0	50	2	1	2.9	16 ± 20	*0.2*
Pyrene	30850	1500	3610	2320	*200*	880	380	5680 ± 1030	*290*
4-methyl-pyrene	300	27	55	210	51	23	40	100 ± 100	9.8
1-methyl-pyrene	130	10	30	89	11	8.7	30	40 ± 40	3.9
Benzo[a]anthracene	210	37	50	150	18	9.4	30	70 ± 70	5.7
Chrysene	540	74	88	300	46	41.2	90	170 ± 170	6.4
3-methyl-chrysene	260	8	38	43	*1.4*	38	50	60 ± 80	*0.4*
6-methyl-chrysene	64	5	37	11	*0.3*	*0.9*	*1*	17 ± 20	9.6
Benzo[b]fluoranthene	930	60	9	200	*3.7*	17.2	34	180 ± 310	24
Benzo[k]fluoranthene	130	16	74	59	11	18.8	12	45 ± 40	*1.2*
Benzo[a]pyrene	1590	22	42	112	5	12.5	27	259 ± 540	10
Indeno[1,2,3-cd]pyrene	760	25	*15*	63	10	38.9	21	134 ± 250	*4.2*
Dibenzo[ah]anthracene	19	5	*250*	6	178	*0.8*	19	68 ± 90	*8.4*
Benzo[ghi]perylene	4480	46	*39*	151	*31*	308.7	46	729 ± 1530	*6.6*

Table 122: Emission factors (ng/km) for detected PAHs and alkyl-PAHs in all vehicles in the SSC.

	GDI-1	GDI-2	GDI-3	GDI-4	GDI-5	GDI	D-DPF
PAH, ng/km	Mitsubishi Carisma	VW Golf	Opel Insignia	Volvo V60	Opel Zafira	Mean	Peugeot 4008
	Euro-3	**Euro-4**	**Euro-5**	**Euro-5**	**Euro-5**		**Euro-5**
Naphthalene	40250	49300	8290	*110*	7340	21100 ± 19700	*100*
2-methyl-naphthalene	6300	4663	1030	*33*	*130*	2400 ± 2570	*100*
1-methyl-naphthalene	4050	1922	600	*18*	*100*	1300 ± 1520	*43*
2,6-dimethyl-naphthalene	690	325	*28*	*13*	*35*	200 ± 260	*14*
1,6-dimethyl-naphthalene	650	665	*24*	*10*	*37*	277 ± 310	*16*
1,2-dimethyl-naphthalene	490	132	*1.7*	*5*	*14*	130 ± 190	*4.6*
Acenaphthylene	650	4208	*6.6*	60	280	1040 ± 1600	*1.1*
Acenaphthene	310	986	87	*4.3*	*24*	280 ± 370	*6.5*
Fluorene	53	738	67	90	*74*	200 ± 270	*21*
Phenanthrene	900	7451	35	2720	*770*	2380 ± 2690	*170*
Anthracene	660	881	42	280	*64*	380 ± 330	*19*
3-methyl-phenanthrene	18.5	195	18	360	*53*	130 ± 130	*13*
2-methyl-phenanthrene	47.1	171	19	430	*56*	140 ± 150	*14*
9-methyl-phenanthrene	*9*	87	9	230	*33*	70 ± 80	*7.3*
1-methyl-phenanthrene	17.73	107	*2.7*	230	*29*	80 ± 80	*6.4*
1,7-dimethyl-phenanthrene	*6.5*	7	720	90	*15*	170 ± 280	*3.7*
2-methyl-anthracene	20	76	170	140	*15*	80 ± 60	*4.8*
retene	5.59	21	43	20	39	30 ± 10	*10*
Fluoranthene	*49*	606	*19*	360	*243*	250 ± 210	*62*
3-methylfluoranthene	*1*	4	0	10	*1*	3.5 ± 4.0	*1.6*
1-methyl-fluoranthene	*0.6*	*0.3*	0	4	*1*	1.2 ± 1	*0.3*
Pyrene	293	528	*55*	320	*488*	340 ± 170	*430*
4-methyl-pyrene	*2*	4	6	24	*4*	8.1 ± 8.0	*5.2*
1-methyl-pyrene	*1.2*	*0.4*	*0.4*	8	3	2.6 ± 3.0	*0.3*

Benzo[a]anthracene	*1.2*	*0.4*	3	3	14	4.3 ± 5.1	*1.1*
Chrysene	3	*1.7*	*1.3*	15	*5.5*	5.3 ± 5.1	*2.4*
3-methyl-chrysene	*1.2*	*0.3*	*0.8*	*0.4*	*3.4*	-	*0.7*
6-methyl-chrysene	*0.6*	*0.3*	-	*0.3*	*0.8*	0.4 ± 0.2	*4.4*
Benzo[b]fluoranthene	10	*0.8*	*4*	1	*9.2*	4.9 ± 3.8	*11*
Benzo[k]fluoranthene	*1.2*	*0.6*	*0.5*	*0.3*	6	1.6 ± 2.0	*2.2*
Benzo[a]pyrene	1	*0.5*	*3.9*	*0.5*	*12*	3.6 ± 4.3	*3*
Indeno[1,2,3-cd]pyrene	6	*0.9*	*8.9*	*0.6*	*15*	6.1 ± 5.2	*7.8*
Dibenzo[ah]anthracene	*0.4*	*0.7*	-	*0.2*	136	27 ± 54	*16*
Benzo[ghi]perylene	15	*1*	*24*	*2.2*	*75*	23 ± 27	*99*

Munoz et al. (2016) [Bioethanol Blending Reduces Nanoparticle, PAH, and Alkyl- and Nitro-PAH Emissions and the Genotoxic Potential of Exhaust from a Gasoline Direct Injection Flex-Fuel Vehicle, Environmental Science and Technology] examined the PAH and nitro-PAH emissions from a flex-fuel Euro-5 GDI vehicle operated with gasoline (E0) and two ethanol/gasoline blends (E10 and E85) under transient and steady driving conditions.

A Euro-5 flex-fuel GDI vehicle (Volvo V60) with a 1.6 L engine was used. Two driving cycles simulating transient and steady driving were applied. The worldwide harmonized light-duty vehicle test cycle (WLTC) was used, which includes urban, extra-urban, highway, and motorway driving. The cycle was investigated under cold- (cWLTC) and hot-start conditions (hWLTC). Furthermore, a steady-state cycle (SSC) representing mean velocities of the WLTC and idle was applied.

Diluted exhausts were sampled from a constant volume sampling (CVS) tunnel. Aliquots were collected in all-glass sampling devices including filter, condenser, and adsorber units (XAD2) according to the filter/condenser method described in the European standard EN-1948-1. This allows quantitative sampling of semivolatile compounds in combined samples, including particle-bound, liquid, and gaseous fractions.

The combined sample is extracted in a Soxhlet apparatus with dichloromethane. An aliquot of a mixture of those16 perdeuterated PAHs, and D10-2-methylnaphthalene (CIL, Andover, MA, USA), D12-9-methylanthracene, D12-2,6-dimethylnaphthalene and D9-1-methylpyrene is added to the samples as quantification standards. Furthermore, aliquots of a mixture containing D7-1-nitronaphthalene, D9-9-nitrophenanthrene, D9-2-methyl-1-nitronaphthalene and D9-1-nitropyrene and D11-6-nitrochrysene are added as quantification standards for nitro-PAHs. The extraction is followed by a multistep cleanup procedure with silica which allows the fractionation of PAHs and nitro-PAHs. Analyses of PAHs and nitro-PAHs are performed by gas chromatography (Fisons Instruments HRGC Mega 2, Rodano, Italy) on 30 m and 15 m capillary columns (Restek, Bellefonte, USA) for PAHs and nitro-PAHs, respectively.

Table 123: Emission factors (µg/km) for detected PAHs, alkyl-PAHs in complete Euro-5 vehicle exhausts (VOLVO V60, 1.6 L, 132 kW). Levels found in dilution air are reported as detection limits (Bold)

Compound, µg/km	WLTC (cold)	WLTC (hot)	SSC (hot)	WLTC (cold)	WLTC (hot)	SSC (hot)	WLTC (cold)	WLTC (hot)	SSC (hot)
Naphthalene	79	44	***0.1***	60	15	0.64	44	17	0.32
2-methyl-naphthalene	16	12	***0.033***	12	6.4	0.7	8.4	3.4	0.31
1-methyl-naphthalene	8.7	6.2	***0.018***	6.9	3.3	0.33	4.3	1.7	0.1
2,6-dimethyl-naphthalene	3.2	3.2	***0.013***	1.8	1.2	0.047	0.92	0.25	***0.014***
1,6-dimethyl-naphthalene	1.8	1.8	*0.01*	1	0.7	**0.013**	0.56	0.19	***0.011***
1,2-dimethyl-naphthalene	0.5	0.53	***0.005***	0.25	0.12	**0.006**	0.13	0.047	***0.005***
Acenaphthylene	5.9	4.9	0.058	2.5	0.89	0.013	2.1	0.046	0.009
Acenaphthene	0.39	0.29	***0.0043***	0.32	0.11	**0.005**	0.25	0.064	**0.0044**
Fluorene	2.1	2.1	0.087	0.63	0.49	**0.017**	0.69	0.28	**0.014**
Phenanthrene	15	12	2.7	3.2	4.6	**0.1**	14	3.5	0.54
Anthracene	1.8	2.4	0.28	**0.025**	**0.029**	**0.019**	**0.025**	**0.024**	**0.015**
3-methyl-phenanthrene	1.1	1.6	0.36	0.24	0.3	**0.008**	1.3	0.22	0.025
2-methyl-phenanthrene	1.4	1.9	0.43	0.26	0.35	**0.01**	1.3	0.3	0.035
9-methyl-phenanthrene	0.5	0.91	0.23	0.12	0.14	**0.006**	0.5	0.11	**0.0049**
1-methyl-phenanthrene	0.61	1.1	0.23	0.14	0.18	**0.005**	0.56	0.15	0.01
1,7-dimethyl-phenanthrene	0.3	0.5	0.086	0.041	0.063	**0.0033**	0.056	0.056	**0.0027**
2-methyl-anthracene	0.56	0.92	0.14	0.15	0.13	0.011	0.33	0.073	0.032
Retene	0.25	0.18	0.024	0.04	0.1	0.073	0.07	0.087	0.11
Fluoranthene	2.3	2.3	0.36	0.6	1.2	0.34	2.3	0.56	0.14
3-methylfluoranthene	0.047	0.053	0.01	**0.0004**	**0.0005**	**0.0003**	**0.00045**	**0.00043**	**0.00027**
1-methyl-fluoranthene	0.023	0.05	0.004	**0.0003**	**0.0004**	**0.0002**	**0.00034**	**0.00032**	**0.0002**
Pyrene	1.6	2.3	0.32	0.5	0.79	1.1	1.1	0.46	0.1
4-methyl-pyrene	0.083	0.21	0.024	0.037	0.035	**0.0012**	0.028	0.012	**0.001**
1-methyl-pyrene	0.038	0.089	0.0084	0.013	0.012	**0.0007**	0.014	0.0063	**0.0006**
Benzo(a)anthracene	0.07	0.15	0.0025	0.033	0.016	**0.0007**	0.021	0.0065	**0.0006**

Chrysene	0.13	0.3	0.015	0.046	0.041	0.003	0.046	0.027	0.001
3-methyl-chrysene	0.03	0.04	0.00043	0.002	0.005	**0.0005**	0.008	0.0066	**0.0004**
6-methyl-chrysene	0.01	0.01	0.00034	**0.001**	**0.001**	**0.0004**	**0.001**	**0**	**0.0003**
Benzo(b)fluoranthene	0.1	0.2	0.0009	0.048	0.009	**0.001**	0.02	0.0154	**0.001**
Benzo(k)fluoranthene	0.038	0.059	0.00032	0.009	**0.001**	**0.0004**	0.004	0.0002	**0.0003**
Benzo(a)pyrene	0.075	0.11	0.0005	0.11	0.024	0.014	0.022	0.011	**0.001**
Indeno(1,2,3-cd)pyrene	0.032	0.063	**0.0006**	0.023	**0.001**	**0.001**	0.002	**0**	**0.001**
Dibenzo(ah)anthracene	0.01	0.006	**0.00015**	**0.003**	**0.0003**	**0.0002**	**0.0003**	**0**	**0.0002**
Benzo(ghi)perylene	0.092	0.15	**0.0022**	**3.73**	**0.004**	**0.003**	**0.004**	**0**	**0.002**

Table 124: Emission factors (ng/km) for detected nitro-PAHs PAHs in complete Euro-5 vehicle exhausts (VOLVO V60, 1.6 L, 132 kW). Levels found in dilution air are reported as detection limits (bold).

Compound, ng/km	WLTC (cold)	WLTC (hot)	SSC (hot)	WLTC (cold)	WLTC (hot)	SSC (hot)	WLTC (cold)	WLTC (hot)	SSC (hot)
1-nitro-naphthalene	250	480	**4.8**	26	15	6.1	58	57	5.1
2-nitro-naphthalene	180	460	**2.6**	4.6	3.3	0.55	8.4	194	2.8
9-nitro-phenanthrene	3.8	13	**0.028**	0.4	2.7	0.04	**0.05**	**0.046**	**0.029**
3-nitro-phenanthrene	4.2	14	**0.042**	2.5	2.07	0.05	**0.5**	1.1	0
2-nitro-phenanthrene	2.4	9.6	**0.072**	5.7	1.7	0.09	**0.12**	1.5	1.1
2-nitro-anthracene	0.39	1.8	**0.025**	0	**0.81**	**0.03**	**0.04**	3.9	1.5
9-nitro-anthracene	5.7	10	**0.2**	2.4	3.3	0.25	**1.8**	14	0.2
1-nitro-fluoranthene	**0.0001**	1	**0.047**	0.1	**0.09**	**0.53**	0.08	2.8	2.2
2-nitro-fluoranthene	**0.0001**	**0.0001**	**0**	0.1	**0.16**	**0.11**	**0.14**	**0.1**	**4.2**
4-nitro-pyrene	**0.061**	**0.0001**	**0**	1.2	0.32	0.06	**0.08**	1.6	0.6
1-nitro-pyrene	11	39	**0.049**	0.9	0.4	0.06	1.26	5	0.1
2-nitro-pyrene	**0.0004**	**0.0004**	**0.2**	0.34	0.4	1.5	0.35	**0.3**	**14**
1,3-dinitro-pyrene	**0.0004**	**0.0004**	**0.2**	0.38	1.05	0.29	0.39	**0.4**	18

1,6-dinitro-pyrene	**0.006**	**0.0004**	**0.2**	6.5	0.46	0.3	**0.41**	**6.6**	14
6-nitro-chrysene	**0.0003**	**0.0003**	**0.2**	**0.26**	**0.31**	**0.2**	**0.27**	**0.3**	**4.9**

Munoz et al. (2018) [Effects of Four Prototype Gasoline Particle Filters (GPFs) on Nanoparticle and Genotoxic PAH Emissions of a Gasoline Direct Injection (GDI) Vehicle, Environmental Science and Technology] examined PAH emissions from a 1.6L Euro 5 GDI vehicle equipped with four prototype gasoline particle filters (GPFs).

The worldwide harmonized light-duty vehicle test cycle was used. The WLTC including urban, extra-urban, highway, and motorway driving was driven under cold (cWLTC) and hot-start conditions (hWLTC). Furthermore, a steady-state cycle (SSC) representing mean velocities of the four WLTC phases and an idle phase was applied. Four prototype ceramic wall-flow filters (GPFs) were tested on the reference vehicle and installed approximately 60 cm downstream of the three-way catalyst. Two filters were coated with noble metals to support oxidation (GPF-2, GPF-3); and two were noncoated filters (GPF-1, GPF-4).

An all-glass sampling device including filter-, condenser- and adsorber units (XAD2) was used to sample PAHs and alkyl-PAHs of diluted exhausts from a constant volume sampling (CVS) tunnel, according to the filter/condenser method described in the European standard EN-1948–1. Analysis of individual PAHs is performed by gas chromatography (Fisons Instruments HRGC Mega 2, Rodano, Italy) on a 30 m × 0.25 μm × 0.10 μm capillary column (Restek, Bellefonte, U.S.A.). Detection and identification were achieved by high resolution mass spectrometry (Thermo Finnigan MAT 95, Bremen, Germany) in electron-impact ionization mode (GC/EI-HRMS).

The internal standard method is used to quantify PAHs. Five concentrations containing deuterated PAHs, 16 native PAHs (Supelco, Bellefonte, U.S.A.) and a standard reference material (SRM) mix of 18 methyl-substituted PAHs from methyl-naphthalene to methyl-chrysene (LGC

Standards, Switzerland) were analyzed to determine respective calibration curves and response factors. For compounds identified by mass spectrometry but not present in labeled form, quantification was performed with relative response factors of PAHs or alkyl-PAHs with closest chromatographic retention time. Aliquots of $^{13}C_6$-naphthalene, $^{13}C_6$-phenanthrene and $^{13}C_3$-pyrene were placed on quartz swab and given to the condensate separator prior to each sampling. These compounds were used to calculate losses during sampling and workup. CVS blank samples were also collected to determine background air concentrations and with it detection limits of the methodology.

Table 125: Emission factors (ng/km) for detected PAHs and alkyl-PAHs in the reference vehicle without filter (GDI-R), with filters (GPF-1-4) and in the diesel vehicle with DPF (DPF) in the cWLTC. Levels found in dilution air are reported as detection limits (italics).

	GDI-R	GPF-1	GPF-2	GPF-3	GPF-4	GDI Mean (n=7)	DPF
Naphthalene	47770	14070	50270	69240	79670	194800 ± 158000	5700
2-methylnaphthalene	17010	2470	7610	4930	11230	22500 ± 16800	1500
1-methylnaphthalene	9630	1660	5200	3370	6980	14300 ± 8480	900
2,6-dimethylnaphthalene	4390	290	800	360	1960	2000 ± 1490	260
1,6-dimethylnaphthalene	2200	190	400	220	1120	2104 ± 2310	310
1,2-dimethylnaphthalene	1140	30	250	70	350	630 ± 540	120
Acenaphthylene	9990	1620	4070	1470	4390	15790 ± 26300	3.7
Acenaphthene	570	310	170	190	370	3640 ± 6950	100
Fluorene	2470	560	740	470	1140	2340 ± 2600	270
Phenanthrene	10820	4380	2830	9490	4970	16650 ± 17800	3020
Anthracene	1830	190	440	760	510	1640 ± 1360	370
3-methylphenanthrene	1900	130	130	1370	410	760 ± 470	930
2-methylphenanthrene	1980	160	120	1820	440	870 ± 570	990
9-methylphenanthrene	710	100	52.4	650	190	350 ± 203	460
1-methylphenanthrene	1240	*70*	86.3	860	330	400 ± 250	470
1,7-dimethylphenanthrene	350	70	53.6	860	150	1280 ± 2720	150
2-methylanthracene	1950	21.8	89.6	620	310	480 ± 270	250
Retene	15.3	16.6	20	91	190	230 ± 150	78
Fluoranthene	2580	1290	380	18770	730	2030 ± 1460	4760

3-methylfluoranthene	57.4	0.8	17.7	210	36.3	35 ± 20	0.9
1-methylfluoranthene	85	0	11.6	120	19.9	25 ± 20	5.3
Pyrene	4020	6510	1330	10580	880	3240 ± 4420	3760
4-methylpyrene	220	17.3	13.4	135.2	30.7	61 ± 30	30
1-methylpyrene	140	10.6	10.4	72.5	25.6	32 ± 15	11
Benzo(a)anthracene	290	1.1	41	56.7	76.4	122 ± 90	6.7
Chrysene	420	36.8	74.1	78.9	140	186 ± 120	12.4
3-methylchrysene	43.1	13.8	20.8	0.8	10	60 ± 50	0.1
6-methylchrysene	0	0	5	0.2	0	8.9 ± 10	8
Benzo(b)fluoranthene	250	39.7	140	52.6	120	170 ± 140	8
Benzo(k)fluoranthene	52.2	2.1	2	14.8	20.8	60 ± 40	1.3
Benzo(a)pyrene	210	21.6	34.3	24.4	100	210 ± 260	5.5
Indeno(1,2,3-cd)pyrene	8.4	10.1	12.7	11.9	11.3	110 ± 130	4.5
Dibenzo(ah)anthracene	13.1	28.5	28.9	33.7	32	25 ± 30	9.1
Benzo(ghi)perylene	190	84.2	170	10.2	63.2	377 ± 680	12

Table 126: Emission factors (ng/km) for detected PAHs and alkyl-PAHs in the reference vehicle without filter (GDI-R), with filters (GPF-1-4) and in the diesel vehicle with DPF (DPF) in the hWLTC. Levels found in dilution air are reported as detection limits (italics).

	GDI-1	GPF-1	GPF-2	GPF-3	GPF-4	GDI Mean (n=7)	DPF
Naphthalene	120	13650	13610	3040	10090	63300 ± 71600	1000
2-methylnaphthalene	1530	1730	4140	240	3700	10200 ± 9300	500
1-methylnaphthalene	1070	700	2120	170	1770	5400 ± 5360	300
2,6-dimethylnaphthalene	910	240	920	9	930	1680 ± 2040	42
1,6-dimethylnaphthalene	500	180	520	15.3	550	1430 ± 1530	46
1,2-dimethylnaphthalene	260	30	170	3.4	160	470 ± 580	16
Acenaphthylene	1620	590	1420	150	1390	5030 ± 5170	0.6
Acenaphthene	100	340	310	58.9	110	850 ± 1470	13
Fluorene	970	520	860	210	920	1400 ± 870	60
Phenanthrene	6450	4090	4470	4580	4480	13710 ± 9350	2700
Anthracene	540	230	340	390	450	1390 ± 990	210
3-methylphenanthrene	770	90	310	650	440	710 ± 780	160
2-methylphenanthrene	800	110	390	760	560	850 ± 580	150
9-methylphenanthrene	280	26.8	130	370	340	420 ± 280	54
1-methylphenanthrene	440	52	140	400	340	470 ± 340	61
1,7-dimethylphenanthrene	160	21.3	130	190	240	870 ± 1490	14
2-methylanthracene	470	26	120	190	160	390 ± 270	2.6

Retene	31.9	16.1	20	210	290	200 ± 210	1.1
Fluoranthene	1170	510	1260	840	2710	2480 ± 2780	300
3-methylfluoranthene	30.2	1.2	18.7	10.3	12.3	32 ± 40	0.9
1-methylfluoranthene	41.5	5	19.7	17.3	19.1	16 ± 20	0.2
Pyrene	1620	420	1160	940	14880	5680 ± 1030	290
4-methylpyrene	100	1.1	27	40.5	100	100 ± 100	9.8
1-methylpyrene	54.2	1.1	17.4	34.1	61.6	40 ± 40	3.9
Benzo(a)anthracene	87.5	1.1	18.3	24	51.8	70 ± 70	5.7
Chrysene	140	15	51.1	58.3	230	170 ± 170	6.4
3-methylchrysene	19.5	3.2	21.5	5.8	170	60 ± 80	0.4
6-methylchrysene	0	0.2	5.3	0.2	30	17 ± 20	9.6
Benzo(b)fluoranthene	86.4	2.7	27.7	18.3	580	180 ± 310	24
Benzo(k)fluoranthene	8.3	2.1	2.1	6.1	43	45 ± 40	1.2
Benzo(a)pyrene	190	2.1	1.1	42	360	259 ± 540	10
Indeno(1,2,3-cd)pyrene	5.8	9.8	9.9	11.6	600	134 ± 250	4.2
Dibenzo(ah)anthracene	14.3	27.6	27.9	32.8	31	68 ± 90	8.4
Benzo(ghi)perylene	52.1	8.3	8.4	43.5	2420	729 ± 1530	6.6

Table 127: Emission factors (ng/km) for detected PAHs and alkyl-PAHs in the reference vehicle without filter (GDI-R), with filters (GPF-1-4) and in the diesel vehicle with DPF (DPF) in the SSC. Levels found in dilution air are reported as detection limits (italics). SSC values in GPF-2 are not reported.

	GDI-R	**GPF-1**	**GPF-3**	**GPF-4**	**GDI Mean**	**DPF**
Naphthalene	630	800	*56.1*	370	21100 ± 19700	100
2-methylnaphthalene	320	20.7	*23.2*	58.2	2400 ± 2570	100
1-methylnaphthalene					1300 ± 1520	43
2,6-dimethylnaphthalene	130	12.5	*14*	13.6	200 ± 260	14
1,6-dimethylnaphthalene	50	10.8	*12.1*	11.8	277 ± 310	16
1,2-dimethylnaphthalene	0	7.1	*7.9*	7.7	130 ± 190	4.6
Acenaphthylene	10	*4.1*	0	0	1040 ± 1600	1.1
Acenaphthene	260	13.8	10	110	280 ± 370	6.5
Fluorene	*0*	12.5	*4.2*	0	200 ± 270	21
Phenanthrene	80	9.9	*11*	44.2	2380 ± 2690	170
Anthracene	300	110	130	120	380 ± 330	19
3-methylphenanthrene	150	6.6	50	48.7	130 ± 130	13
2-methylphenanthrene	91	10.4	*11.6*	11.3	140 ± 150	14
9-methylphenanthrene	76	12.9	*14.4*	14	70 ± 80	7.3

1-methylphenanthrene	0	6.3	*7*	6.9	80 ± 80	6.4
1,7-dimethylphenanthrene	47	6.9	*7.7*	7.5	170 ± 280	3.7
2-methylanthracene	2.7	*2.9*	10	0	80 ± 60	4.8
Retene	4	11	12.4	12	30 ± 10	10
Fluoranthene	12.4	29.6	100	32.2	250 ± 210	62
3-methylfluoranthene	9	0.6	0	0	3.5 ± 4.0	1.6
1-methylfluoranthene	10.7	1.6	0	0	1.2 ± 1	0.3
Pyrene	260	18.1	1500	130	340 ± 170	430
4-methylpyrene	20	0.8	9.3	10	8.1 ± 8.0	5.2
1-methylpyrene	10.6	0.4	7.4	0	2.6 ± 3.0	0.3
Benzo(a)anthracene	29.4	0.8	0.9	0	4.3 ± 5.1	1.1
Chrysene	40.5	1.5	4.8	0	5.3 ± 5.1	2.4
3-methylchrysene	0.1	0.5	0.5	0	-	0.7
6-methylchrysene	0	0.1	0.2	0	0.4 ± 0.2	4.4
Benzo(b)fluoranthene	1.2	1.9	2.1	0	4.9 ± 3.8	11
Benzo(k)fluoranthene	0.5	1.4	1.6	0	1.6 ± 2.0	2.2
Benzo(a)pyrene	1.3	1.5	33.8	0	3.6 ± 4.3	3
Indeno(1,2,3-cd)pyrene	0.9	6.7	7.5	7.3	6.1 ± 5.2	7.8
Dibenzo(ah)anthracene	3.6	19	21.2	20.6	27 ± 54	16
Benzo(ghi)perylene	1.3	5.7	6.4	10	23 ± 27	99

Li et al. (2018) [Effect of biodiesel on PAH, OPAH, and NPAH emissions from a direct injection diesel engine, Environmental Science and Pollution Research] examined PAH, oxy-PAH, and nitro-PAH emissions from a direct injection diesel engine fueled with diesel fuel, waste cooking oil biodiesel (B100) and their two blends (B20 and B50). Experiments were conducted at a steady engine speed of 1800 rpm and at 20%, 50%, and 80% loads, corresponding to the brake mean effective pressures (BMEP) of 0.16, 0.41, and 0.56 MPa, respectively.

Samples were analyzed by using a gas-chromatography mass-spectrometry (GC/MS, 7890C/5975A, Agilent) to determine the concentration of PAH, OPAH, and NPAH compounds in PM.

Table 128: Brake-specific emissions of individual PAH, OPAH, and NPAH for the tested fuels at different loads (µg/kWh)

	20% Load				50% Load				80% Load			
Compound	D	B20	B50	B100	D	B20	B50	B100	D	B20	B50	B100
Naphthalene	82.828	51.515	30.303	13.131	51.675	26.794	21.053	11.483	44.231	53.846	40.385	12.500
Acenaphthylene	42.424	29.293	29.293	33.333	34.450	27.751	23.923	24.880	61.538	55.769	49.038	32.692
Acenaphthene	86.869	62.626	47.475	8.081	65.072	29.665	27.751	8.612	78.846	69.231	53.846	11.538
Fluorene	62.626	57.576	35.354	16.162	72.727	33.493	28.708	17.225	73.077	66.346	53.846	25.000
Phenanthrene	153.535	107.071	57.576	28.283	158.852	65.072	46.890	27.751	193.269	125.962	92.308	50.962
Anthracene	61.616	43.434	39.394	48.485	49.761	36.364	30.622	43.062	79.808	76.923	65.385	51.923
Fluoranthene	57.576	42.424	37.374	35.354	48.804	34.450	26.794	26.794	80.769	67.308	63.462	38.462
Pyrene	91.919	67.677	43.434	67.677	78.469	40.191	34.450	21.053	104.808	96.154	75.000	31.731
Benzo[a]anthracene	36.364	26.263	18.182	5.051	46.890	17.225	13.397	1.914	45.192	40.385	30.769	4.808
Chrysene	41.414	28.283	25.253	3.030	35.407	22.967	17.225	1.914	46.154	40.385	40.385	3.846
Benzo[b]fluoranthene	52.525	29.293	16.162	20.202	28.708	14.354	12.440	20.096	25.962	22.115	11.538	23.077
Benzo[k]fluoranthene	57.576	35.354	23.232	37.374	36.364	21.053	19.139	27.751	45.192	42.308	32.692	42.308
Ben=o[a]pyrene	34.343	20.202	15.152	15.152	18.182	N/A	13.397	13.397	23.077	22.115	26.923	17.308
1,4-Naphthoquinone	16.162	10.101	23.232	23.232	17.225	13.397	20.096	17.225	23.077	22.115	25.000	22.115
1-Naphthaldehyde	4.040	6.061	9.091	8.081	4.785	10.526	18.182	5.742	22.115	33.654	37.500	15.385
9-Fluorenone	37.374	50.505	55.556	53.535	36.364	57.416	64.115	47.847	57.692	69.231	81.731	61.538
9,10-Anthraquinone	39.394	56.566	65.657	50.505	48.804	59.330	71.770	43.062	53.846	75.962	105.769	70.192
Benzanthrone	24.242	29.293	29.293	26.263	33.493	24.880	34.450	25.837	38.462	46.154	57.692	40.385
Benz[a]anthracene-7,12-dione	26.263	26.263	37.374	26.263	24.880	39.234	44.019	11.483	25.000	44.231	53.846	31.731
9-Nitrophenanthrene	4.242	2.929	2.323	2.929	3.062	2.488	2.584	2.201	3.846	5.096	4.038	3.654
3-Nitrophenanthrene	2.424	1.414	1.313	2.121	1.914	2.105	1.435	1.435	7.212	3.365	2.788	2.692
3-Nitrofluoranthene	13.131	9.091	8.384	8.687	9.665	7.751	6.794	7.081	11.442	12.115	11.635	11.538
1-Nitropyrene	14.949	10.707	9.495	7.778	11.196	9.282	8.230	8.230	15.385	14.712	13.942	12.212

Su et al. (2019) [Experimental study of particulate emission characteristics from a gasoline direct injection engine during starting process, International Journal of Automotive Technology] examined the PM-phase PAH emissions from a GDI engine during starting period. The engine used in this investigation was an in-line four cylinders, turbo-charged VW1.4L GDI engine. Technical characteristics of the engine are shown below.

Engine parameters	Specifications
Bore × Stroke	75.6 mm × 76.5 mm
Displacement	1.4 L
Compression ratio	10 : 1
Injector	Multi-hole nozzle
Combustion system	Charge motion-guided GDI
Rated power	96 kW / 5000 rpm
Peak torque	220 N·m / 1750 rpm

Soluble organic fraction (SOF) was extracted from the filter with methylene chloride by a Soxhlet extraction system. Then it was condensed to 1ml. GC-MS (7000B GC-QQQ, Agilent) was used to analyze PAHs qualitatively and quantitatively. Temperature programming was that GC temperature began from 70 °C (held for 3 minutes), then increased at the speed of 15 °C/min to 200 °C (held for 4 minutes), then continued at the speed of 5 °C/min to 250 °C (held for 4 minutes), and finally ramped up at the speed of 8 °C/min to 300 °C (held for 8 minutes). In order to carry out quantitative analysis of PAHs, GC–MS was calibrated with a standard solution containing 16

EPA-PAH compounds in acetonitrile solvent. 7 concentrations were selected for the standard solution: 10 ng/mL, 20 ng/mL, 50 ng/mL, 100 ng/mL, 200 ng/mL, 500 ng/mL, 1000 ng/mL.

PAH emissions were investigated as a function of the effect of the coolant temperature on PM emissions over the first 40 seconds after engine started. Under warm start conditions, coolant was heated up to the required temperature by a heating system before engine started. The coolant was heated with a heater and circulated by a pump between the external cooling system and the engine's internal coolant system. When the temperature reached the set temperature, the heating was stopped and the engine was started. This method was more effective than running the engine to a fixed warm start condition. All experiments were carried out at ambient temperature of 20oC.

Table 129: Effect of coolant's temperature on specific PAHs (ppb)

	20 °C		80 ° C	
PAHs	0-40s	0-13s	0-40s	0-13s
Naphthalene	234.7694	229.3199	232.4619	168.5608
Acenaphthene	121.1519	138.5174	115.9772	95.05225
Acenaphthylene	30.33246	30.56977	15.69721	16.28117
Fluorene	174.0621	139.9412	157.6534	158.3625
Phenanthrene	1450.35	1036.288	1565.835	1478.511
Anthracene	182.6688	124.2805	189.3758	200.6932
Pyrene	714.8916	374.2228	530.6484	372.3832
Fluoranthene	711.9429	389.6127	440.8393	317.8445
Chrysene	1174.564	826.531	739.771	362.3203
Benzo[a]Anthracene	903.9747	720.8923	579.3117	392.6003
Benzo[b]Fluoranthene	2242.059	1451.373	1125.684	546.5593
Benzo[a]Pyrene	522.5437	369.6014	282.7292	138.5229
Benzo[k]Fluoranthene	508.4908	360.389	288.2625	140.603
Dibenzo[a,h]Anthracene	88.98867	123.8099	113.58	68.25127
Indeno[1,2,3-cd]Pyrene	1834.64	1029.154	628.1894	282.3369
Benzo[g,h,i]Perylene	1751.326	930.9953	594.698	259.6976

Hao et al. (2018) [Characterization and carcinogenic risk assessment of polycyclic aromatic and nitro-polycyclic aromatic hydrocarbons in exhaust emission from gasoline passenger cars using on-road measurements in Beijing, China, Science of the Total Environment] investigated PAH and nitro-PAH emissions from 16 gasoline passenger cars encompassing five emission standards and two driving conditions. Experiments were conducted on-road in Beijing.

In total, 16 vehicles were selected from the most common in-use gasoline passenger cars, including vehicles that met five different emission standards (China 1 to China 5). The specifications of the vehicles are shown below.

Number	Emission standard	Model year	Fuel	Car model	Engine model	Rate power/kW	GVW/kg	Odometer/km	Engine displacement/L
1	China 1[a]	2002	Gasoline	SY6480A1BG-MG	XG491Q-ME	76	2800	159,179	2.2
2		2001	Gasoline	SGM7160SLXAT	L01	76	1458	160,149	1.6
3		2000	Gasoline	HFJ6350C	DA462Q	35.5	1460	270,149	0.9
4	China 2[a]	2005	Gasoline	FV7160C1XE3	BJG109522	66	1545	127,301	1.6
5		2003	Gasoline	BJ6486B1DWA-1	BJ491EQ1	76	2715	78,206	2.2
6	China 3[b]	2007	Gasoline	FV7160C1XE	BJG486022	66	1545	154,147	1.6
7		2007	Gasoline	HFJ6376E3	DA465Q	35.5	1530	131,199	0.9
8		2006	Gasoline	SGM7201SXAT	T20SED	94	1925	214,447	2.0
9		2008	Gasoline	LZW6376CV3Q	LJ465Q3-1AE6	63	1550	91,203	1.0
10	China 4[b]	2010	Gasoline	DC7237DT	PSA3FY10XP01	123	1580	24,299	2.3
11		2008	Gasoline	HFJ637D4	DA465Q	35.5	1530	152,603	1.0
12		2010	Gasoline	HFJ637D4	DA465Q	35.5	1560	76,869	1.0
13		2013	Gasoline	DFL7151MAL2	HR15	76	1490	31,020	1.5
14	China 5[b]	2014	Gasoline	SC6418HVB5	JL473Q	68	1880	2619	1.2
15		2014	Gasoline	SC6649D4	4G15V	72	1850	3690	1.5
16		2013	Gasoline	BYD7150A	BYD473QE	75	1585	62,600	1.5

[a] Without after-treatment.
[b] With three-way catalytic converters.

The driving route for the onboard measurement was designed to simulate real traffic conditions in Beijing and included highway and nonhighway roads. The total length of the route was approximately 35 km, consisting of 15 km of nonhighway roads and 20 km of highways in northwest Beijing, mainly Lianhuachi Road, west 5th Ring Road and Fushi Road. All of the tested vehicles were tested in parallel two times on the two types of roads.

The particulate phase was collected on a 47 mm quartz filter (QF, 2500QAT-UP, PALL Corp., USA), and the gas phase was sampled by three-stage polyurethane foam (PUF) cartridges. The exhaust was first passed through the QF, followed by passage through the three-stage PUF. The dilution ratios were approximately 8:1. The flow rate of the sampling was controlled at approximately 3 L/min, and the flow meter used in this work was calibrated with a BIOS Defender 530 (Drycal Technology Inc., USA) before each test. To ensure that the PAH and NPAH contents measured in the laboratory were within the detection limits of the instruments, the sampling time was set at 30–40 min. All samples were collected under hot, stabilized conditions. The PAHs and NPAHs were analyzed using an HPLC system (Agilent 1200, Santa Clara, CA, USA) equipped with a UV detector (Agilent G1314A, Santa Clara, CA, USA) to detect at 220 nm, 230 nm, 254 nm and 290 nm. In total, 16 PAHs and 9 NPAHs were quantified.

Table 130: PAH and nitro-PAH emissions

Compounds (µg/km)			Nap	Act	Flr	Acl	Phe	Ant	Flu	Pyr	Chr	BaA	BbF	BkF	BaP	DBahA	BghiP	IP	5-NAcp	1-Npyr	6-NChr
China 1	NHW	Gas	3.9±0.4	0.3±0.1	2.2±0.8	11.9±3.9	0.2±0.1	48.9±15.2	0.1±0.04	0.5±0.3	0.2±0.1	6±5.8	6.9±6.2	4.3±3	521.5±384.6	104.2±46	4.8±1.7	0.6±0.7	5.8±4.7	1.4±0.9	101.7±65.8
		Particulate	0.1±0.03	0.1±0.002	0.1±0.02	ND	0.1±0.025	ND	0.1±0.02	0.1±0.02	0.3±0.4	1.6±1.4	11±8.1	129.7±124.8	3.1±4.2	5425.4±647.9	ND	0.8±1.1	0.1±0.01	ND	9.3±13.1
		Total TEQBaP	3.9±0.3	0.3±0.1	2.2±0.8	11.9±3.9	0.2±0.1	48.9±15.2	0.1±0.1	0.5±0.3	0.5±0.2	7.5±5.1	17.9±14.1	134±121.7	524.5±380.5	5529.6±650.9	4.8±1.7	1.4±0.9	5.8±4.7	1.4±0.9	110.9±72.7
	HW	Gas	2.3±0.6	0.3±0.2	1.8±0.3	10.3±2.9	0.1±0.1	44.6±15	0.1±0.01	0.4±0.05	0.2±0.05	4.9±3	3.8±2.7	18.5±16.2	457.7±309.8	1295.4±20.2	4.6±1.6	0.3±0.2	3.8±3.6	0.9±0.7	80.3±19.1
		Particulate	0.1±0.01	0.1±0.001	0.1±0.003	0.1±0.006	ND	ND	ND	0.1±0.001	0.1±0.01	0.7±1	13±9.2	69.1±18.7	0.2±0.2	3269.5±484	ND	0.8±1.1	0.1±0.005	0.1±0.04	ND
		Total TEQBaP	2.3±0.6	0.3±0.2	1.8±0.2	10.3±2.9	0.1±0.1	44.6±15	0.1±0.01	0.4±0.05	0.2±0.04	5.6±2	16.8±11.8	87.5±33.5	457.8±309.9	4564.8±348.5	4.6±1.6	1.1±0.9	3.8±3.6	1±0.8	80.3±19.1
China 2	NHW	Gas	3.7±3.4	0.3±0.3	3±4.7	13.3±20.4	0.3±0.3	106.2±40.5	0.1±0.2	0.6±1.1	0.3±0.6	7.7±3.8	9.9±6	10.6±7.4	1026±765.1	136.3±189.1	5.8±7.6	0.2±6.2	8.9±0.8	2.2±1.5	128.3±290.1
		Particulate	0.2±0.1	0.1±0.003	0.1±0.04	ND	0.2±0.1	ND	0.1±0.1	0.2±0.1	0.1±0.0003	3.5±3.5	56.4±29.5	117.5±62.3	ND	6805.3±1865.2	ND	ND	ND	ND	ND
		Total TEQBaP	3.8±3.5	0.3±0.3	3±4.8	13.3±20.4	0.4±0.5	106.2±40.5	0.2±0.2	0.7±1.2	0.3±0.6	11.2±0.4	66.3±35.5	128.1±69.8	1026±765.1	6941.6±1933.3	5.8±7.6	0.2±6.2	8.9±0.8	2.2±1.8	128.3±331.1
	HW	Gas	2.9±0.2	0.2±0.04	2.2±0.2	8.7±4.2	0.7±0.5	67.1±31	0.1±0.02	0.5±0.002	0.3±0.001	5.3±5.2	8.1±0.9	8.2±0.3	565.8±3.8	109±3.9	4.9±0.4	1.2±0.9	7.3±2.2	1.1±0.1	111.1±4.2
		Particulate	0.1±0.04	0.1±0.001	0.1±0.02	ND	0.8±0.8	ND	0.1±0.02	0.1±0.1	0.1±0.001	2±1.4	17.1±17.1	38.7±38.7	ND	2932.7±2932.6	ND	ND	0.1±0	0.1±0.1	17.8±17.7
		Total TEQBaP	3±0.2	0.2±0.04	2.2±0.2	8.7±4.2	1.5±1.3	67.1±31	0.2±0.04	0.6±0.1	0.3±0.002	7.2±3.8	25.1±16.1	46.8±39	565.8±3.8	3041.7±56.4	4.9±0.4	1.2±0.9	7.4±2.2	1.2±0.2	128.9±21.9
China 3	NHW	Gas	1±0.2	0.1±0.03	2.5±1.7	10±5.6	0.4±0.3	32±17.1	0.1±0.1	1.4±1.2	0.7±0.6	21.3±18.5	11.8±14.3	9.2±10	582.7±280.4	331.2±314.8	16.6±17.1	1.6±1.7	1.5±1.3	2.2±1.8	267.3±280.7
		Particulate	0.1±0.02	0.1±0.007	0.1±0.1	0.1±0.1	0.1±0.1	2.3±4	0.1±0.002	ND	0.1±0.03	0.4±0.5	68.2±60.6	186.5±616.9	113.3±253.3	3691.6±2973.9	ND	3±2.6	0.1±0.2	0.4±0.6	ND

		Total TEQBaP	1.1±0.2	0.1±0.04	2.6±1.7	10±5.5	0.5±0.3	34.3±17.3	0.1±0.1	1.4±1.2	0.7±0.6	21.6±18.4	80±55.7	195.7±612.9	696±393.4	4022.8±2976.1	16.6±17.1	4.5±2.2	1.6±1.3	2.5±1.9	267.3±280.7
	HW	Gas	0.6±0.2	0.1±0.02	2.2±1.5	8±5	0.3±0.3	24.6±15.6	0.1±0.04	0.9±0.8	0.5±0.4	14.2±13.8	7±10.7	5.2±6.4	663.8±1081.4	240±250.8	13.1±13.8	2.5±3.8	0.8±0.8	1.5±1.3	192.8±207.7
		Particulate	0.1±0.004	0.1±0.0001	0.1±0.01	ND	ND	ND	ND	ND	0.1±0.01	0.9±1.2	40.7±62.2	92.7±81.6	5.5±158.6	2796.4±1647.1	ND	1.4±0.8	0.1±0	0.1±0.1	ND
		Total TEQBaP	0.6±0.2	0.1±0.023	2.2±1.5	8±5	0.3±0.3	24.6±15.6	0.1±0.04	0.9±0.8	0.5±0.4	15±13.5	47.7±73	97.8±86.6	669.2±1233.9	3036.3±1375.1	13.1±13.8	3.8±4.3	0.8±0.8	1.5±1.3	192.8±207.7
China 4	NHW	Gas	0.9±0.3	0.2±0.1	2.4±0.9	8.7±3.3	0.5±0.3	30.9±11.3	0.2±0.1	1±0.4	0.4±0.1	14.8±8.2	5±1.3	6.8±2.9	739.1±219.8	112.7±24.1	5.9±1.6	0.4±0.4	2±1.6	1.4±0.5	67.7±8.3
		Particulate	0.1±0.01	0.1±0.0002	0.1±0.03	ND	0.1±0.003	ND	0.4±0.4	ND	0.1±0.01	0.1±0.03	53.9±31.3	34.2±32.2	124.9±117.7	4576.2±835.1	ND	3.1±1.8	ND	0.3±0.3	0.5±0.7
		Total TEQBaP	0.9±0.3	0.2±0.1	2.5±0.9	8.7±3.3	0.5±0.3	30.9±11.3	0.5±0.5	1±0.4	0.4±0.1	14.8±8.2	58.9±31.8	40.9±34.9	864±285.3	4688.8±835.5	5.9±1.6	3.5±1.8	2±1.6	1.6±0.8	68.2±9
	HW	Gas	1.1±0.9	0.2±0.1	2.1±1.1	8.6±5.4	0.3±0.2	29.7±17.9	0.1±0.005	0.8±0.6	0.3±0.2	5.3±3.4	7.2±4.7	4.3±1.6	588.6±224.2	152.8±112.8	8.9±7.3	0.2±0.2	0.9±0.7	1.3±0.8	61±93.6
		Particulate	0.1±0.001	0.1±0.002	0.2±0.1	0.1±0.01	0.1±0.04	1.2±1.1	ND	ND	ND	ND	ND	93.7±135.2	ND	2920.7±1167.5	ND	7.7±5.6	0.1±0.1	0.2±0.5	ND
		Total TEQBaP	1.1±0.9	0.2±0.1	2.2±1.04	8.6±5.4	0.4±0.1	30.8±17.5	0.1±0.01	0.8±0.6	0.3±0.2	5.3±3.3	7.2±4.4	98±135.5	588.6±224.2	3073.5±1169.6	8.9±7.3	7.8±5.5	1±0.6	1.5±0.9	61±93.6
China 5	NHW	Gas	1.4±1.9	0.1±0.7	1.6±2.6	6.9±4.5	0.3±0.1	26.7±37.9	0.1±0.01	0.5±0.6	0.2±0.2	3.9±2.2	5±3.9	5.6±3	426.7±579.2	65±108.4	5.3±5.8	1.4±1.2	1.4±0.8	1.5±0.4	66.8±73
		Particulate	0.1±0.01	0.1±0.003	0.1±0.1	ND	0.1±0.04	1.5±1.5	ND	ND	ND	ND	66±13.1	ND	ND	3423.2±1011.6	ND	2.2±2.1	ND	ND	ND
		Total TEQBaP	1.4±0.1	0.1±0.04	1.7±0.2	6.9±0.3	0.3±0.1	28.2±3.3	0.1±0.01	0.5±0.04	0.2±0.02	3.9±2.6	70.9±9.3	5.6±1.7	426.7±69.8	3488.2±946.6	5.3±0.3	3.5±0.8	1.4±0.9	1.5±1.3	66.8±0.7
	HW	Gas	1.2±0.7	0.2±0.1	1.1±0.97	6.7±3.3	0.2±0.1	23.4±8.7	0.1±0.004	0.7±0.4	0.2±0.1	6.8±6.5	20.6±22.3	7.9±6.3	278.4±675.2	160.2±101.1	8.1±6.1	ND	1.5±1.6	1±1.2	75.6±99.1
		Particulate	ND	0.1±0.003	0.1±0.1	ND	ND	0.1±0.05	ND	ND	ND	ND	ND	93.9±93.9	ND	2184.4±2184.4	10±9.9	0.8±0.8	0.1±0	ND	ND
		Total TEQBaP	1.2±0.2	0.2±0.1	1.2±0.5	6.7±3.5	0.2±0.1	23.5±10.4	0.1±0.001	0.7±0.5	0.2±0.2	6.8±6	20.6±4.3	101.8±94.9	278.4±630.1	2344.6±2285.4	18±3.2	0.8±0.8	1.6±0.1	0.93±0.7	75.6±116.6

Nap: Naphthalene; Act: Acenaphthene; Flr: Fuorene; Acl: Acenaphthylene; Phe: Phenanthrene; Ant: Anthracene; Flu: Fluoranthene; Pyr: Pyrene; Chr: Chrysene; BaA: Benzo[a]anthracene; BbF: Benzo[*b*]fluoranthene; BkF: Benzo[*k*]fluoranthene; BaP: Benzo[a]pyrene; DBahA: Dibenz[*a*,*h*]anthracene; BghiP: Benzo[*ghi*]perylene; IP: Indeno[1,2,3-*cd*]pyrene; 5-NAcp: 5-Nitroacenaphthene; 9-NAnt: 9-Nitroanthracene; 3-Nphe: 3-Nitrophenanthrene; 1,3-Npyr: 1,3-Nitropyrene; 3-Nflu: 3-Nitrofluoranthene; 6-NChr: 6-Nitrochrysene; 7-NBaA: 7-Nitrobenz[*a*]anthracene; 6-NBaP: 6-Nitrobenzo[*a*]pyrene

He et al (2010) [Characteristics of polycyclic aromatic hydrocarbons emissions of diesel engine fueled with biodiesel and diesel, Fuel] examined gas- and PM-phase PAH emissions from a diesel engine fueled with diesel fuel and B100 (100% soybean oil biodiesel), B20 (20% soybean oil biodiesel + 80% fossil diesel).

Tests were performed on a direct injection, turbocharged EURO II diesel engine (FAW-WDEW 4CK, China), with the following characteristics: four-cylinders; bore and stroke of 110 × 125 mm; total displacement of 4.75 L; compression ratio of 16.8; rated power of 117 kW at 2300 r/min; maximum torque of 580 Nm at 1400 r/min; traditional mechanical injection system; and without EGR (exhaust gas recirculation) or any other after-treatments. Testing was performed on the ISO 8178 C18-mode steady state cycle.

PAHs samples of both gas-phase and particle-phase were collected by using a PAHs sampling system at a temperature below 52 °C. Sample gas was drawn from the tailpipe and diluted in an ejection dilutor (Dekati, Finland), which can control the dilution ratio around 8. Particle-phase PAHs were collected on a fiberglass filter, which was pre-cleaned in a muffle at 450 °C for 8 h before sampling. Gas-phase PAHs were collected by a "PUF/XAD-2/PUF" cartridge (Supelco ORBO-1500, USA), as recommended by the manufacturer. The sampling flow rate of particle-phase and gas-phase PAHs was 35 and 5 L/min, respectively and the sampling time was 30 min.

The sampled filters were extracted in an ultrasonic extractor for 3 times (30 min for each time) and the sampled cartridges were extracted in a Soxhlet extractor for 24 h with dichloromethane. Both the particle-phase and gas-phase PAHs extract was then concentrated, followed by silica gel cleanup procedure using column chromatography to remove potential interferences prior to analysis. The eluent was reconcentrated to exactly 1.0 mL and collected by a volumetric flask for the next analysis.

The analytical method for PAHs was based on the EPA method TO-13A. The PAHs contents were determined by a gas chromatograph/mass spectrometer (GC/MS) (Agilent 6890N/5795C, USA). The GC was equipped with a capillary column (HP-5MS, 30 m × 0.25 mm × 0.25 μm) and the oven was heated from 80 to 160 °C at 20 °C/min, and 160–280 °C at 5 °C/min, then held at 280 °C for 10 min. Helium was used as carrier gas at a flow rate of 1 mL/min. The transfer line to MS was at 250 °C and the ion source of MS was electron impact (EI) at 230 °C. The PAHs were qualified by using the selected ion monitoring (SIM).

In order to quantify the samples, the GC/MS was calibrated with a commercial standard mixture (Supelco EPA 610 PAH MIX, USA), which contains 16 PAH compounds, that are Naphthalene (Nap), Acenaphthylene (AcPy), Acenaphthene (Acp), Fluorene (Flu), Phenanthrene (PA), Anthracene (Ant), Fluoranthene (FL), Pyrene (Pyr), Benzo[*a*]anthracene (BaA), Chrysene (CHR), Benzo[b]Fluoranthene (BbF), Benzo[k]Fluoranthene (BkF), Benzo[*a*]Pyrene (BaP), Indeno[1,2,3-cd]Pyrene (IND), Dibenzo[a,h]Anthracene (DBA) and Benzo[g,h,i]Perylene (BghiP). Five-point calibration curves were constructed and the correlation coefficient was more than 0.999.

Table 131: The five most abundant PAHs in gas-phase and particle-phase for D, B20, and B100 fuels

Fuel	Gas-phase PAHs			Particle-phase PAHs		
	PAH	BSE (μg/kW h)	Percentage (%)	PAH	BSE (μg/kW h)	Percent-age (%)
D	Naphthalene	98.7	59.1	Phenanthren e	37.5	51
	Phenanthrene	15.5	9.3	Pyrene	13.3	18.1
	Fluorene	10.8	6.5	Fluoranthene	6.2	8.4

	Pyrene	7.9	4.8	Naphthalene	5.7	7.8
	Acenaphthylene	6.2	3.7	Anthracene	3.7	5.1
B20	Nap	67.8	42	Phenanthrene	15.2	31.8
	Phenanthrene	23.1	14.4	Pyrene	11.3	23.6
	Pyrene	11.9	7.4	Fluoranthene	5.9	12.3
	Fluorene	9.5	5.9	Naphthalene	2.9	6.1
	Chrysene	8.9	5.5	Chrysene	2.7	5.6
B100	Naphthalene	71.8	45.5	Phenanthrene	11.7	32.1
	Fluorene	24.9	15.8	Naphthalene	5.9	16.2
	Phenanthrene	24.7	15.7	Pyrene	4.9	13.6
	Pyrene	9.1	5.8	Fluoranthene	4	10.9
	Acenaphthylene	5.3	3.4	Fluorene	1.6	4.4

Table 132: Total PAH emissions at different engine conditions (μg/m^3)

Engine Condition	PAH	D	B20	B100
Mode 1	Gas-phase	43.565	22.043	18.913
	Particle-phase	16.565	11.739	6.261
	Total	60.130	33.783	25.174
Mode 2	Gas-phase	40.957	34.957	33.000
	Particle-phase	11.870	7.565	7.304
	Total	52.826	42.522	40.304
Mode 3	Gas-phase	24.652	25.174	24.130
	Particle-phase	7.826	7.304	5.217
	Total	32.478	32.478	29.348
Mode 4	Gas-phase	14.478	9.130	8.348
	Particle-phase	3.652	3.652	4.174
	Total	18.130	12.783	12.522
Mode 5	Gas-phase	4.826	8.870	15.391
	Particle-phase	10.565	3.783	3.913
	Total	15.391	12.652	19.304
Mode 6	Gas-phase	10.826	21.652	22.565
	Particle-phase	7.696	4.565	3.000
	Total	18.522	26.217	25.565
Mode 7	Gas-phase	20.478	13.696	13.957
	Particle-phase	8.348	7.174	5.087

	Total	28.826	20.870	19.043
Mode 8	Gas-phase	19.696	7.304	14.348
	Particle-phase	10.957	1.696	1.957
	Total	30.652	9.000	16.304

Vojtisek-Lom et al (2017) [Blends of butanol and hydrotreated vegetable oils as drop-in replacement for diesel engines: Effects on combustion and emissions, Fuel] examined PAH emissions from a diesel engine with different alcohol and diesel fuels.

A water-cooled inline six-cylinder turbocharged 2001 model year 5.9-liter Iveco Tector F4a E0681B C109 diesel engine with intercooler, bore 102 mm, stroke 120 mm, compression ratio 17:1, max power 176 kW @ 2700 min−1, max torque 810 Nm @ 1250–2100 min−1, common rail, Euro3 compliant, ECU Iveco RDC7 ELT 3.1 was used. The engine operated without any exhaust aftertreatment devices, with approximately 1900 operating hours accumulated, was operated on a four-quadrant transient heavy-duty engine dynamometer (DynoExact 220 kW, AVL), in the following test sequence: WHTC as preconditioning, cold WHTC, subsequent WHTC (warm but not a fully stabilized warm), multiple hot-start WHTC, and WHSC (World Harmonized Steady-State Cycle).

Several renewable fuels were tested: a market-grade biodiesel (methyl esters of primarily rapeseed oil), a paraffinic diesel fuel made from renewable sources (NExBTL, Neste Oil, Finland, provided directly by Neste Oil), and two isomers of butanol, n-butanol and isobutanol. Biodiesel (further referred to as B100) and NExBTL (further referred to as HVO) were used both neat (B100 and HVO100) and blended at 30% by volume with diesel fuel (B30 and HVO30). NExBTL was also used in blends of 30% n-butanol with 70% HVO (referred to as nBu30), and 30% isobutanol with 70% HVO (referred to as iBu30). Neat diesel fuel used as a reference (referred to as B0).

The diluted exhaust was sampled with a standard gravimetric sampling system on 47 mm diameter quartz fiber (Tissuquartz, Pall) at a nominal flow rate of 40 dm3/min. Prior to extraction, recovery standards, deuterated PAHs (1,4-dichlorbenzene-D8, naphthalene-D8, acenaphthene-D10, phenanthrene-D10, chrysene-D12 and perylene-D12), 6-nitrochrysene-D11 and ααα (20R)-cholestane-D2, were added to filters. The filters were extracted three times for 30 min under ultrasonic agitation; once with 20 mL of mixture of dichloromethane with hexane (v/v 1:1) and then twice with 20 mL of dichloromethane. The extracts were pooled and then dried under a stream of nitrogen to 1 mL.

The extracts were then fractionated by flash chromatography in a glass column filled with 10 g of Al2O3 (Aluminum oxide 90 standardized, for column chromatographic adsorption analysis according to Brockmann, activity II - III). Analysis was carried out by GC–MS (Agilent, 7890A, 5975C). A capillary column HP5-MS, 1 µm film thickness, 0.32 mm i.d., 30 m length was used. A sample volume of 2 µL was injected into a split/splitless injector, operated in the splitless mode at a temperature of 280 °C for non-polar compounds and at 260 °C for other compounds. The carrier gas was helium at a flow rate of 4 ml min−1. For analysis of nitrated PAHs, the temperature program was started at 70 °C for 2 min, a gradient of 20 °C min−1 was used up to 150 °C, then a gradient of 5 °C min-1 was used up to 300 °C and then the temperature was held for 14 min. The MS was operated in SIM mode with *m*/*z* 173, 211, 223, 247, 273, 275, 284, 292 and 297.

Table 133: Emissions of individual PAHs across different fuels for the hot-start WHTC (µg/kWh)

PAH, µg/kWh	B0, PM2.5	B30, PM2.5	B100, PM2.5	HVO30, PM2.5	HVO100, PM2.5	iBu30-HVO70, PM2.5	nBu30-HVO70, PM2.5
Fluorene	0.151	0.120	0.090	0.211	0.181	0.060	0.060
Phenanthrene	7.500	2.982	1.506	15.934	7.560	1.536	1.446
Anthracene	0.873	0.542	0.181	1.928	1.054	0.241	0.151
Fluoranthene	8.404	21.084	3.584	13.373	4.518	2.952	2.018
Pyrene	14.247	27.560	5.030	17.711	5.361	3.494	2.349
Benz[a]anthracene	1.114	1.054	0.843	0.512	0.211	0.361	0.331
Chrysene+triphenylene	0.873	0.783	0.572	0.542	0.181	0.241	0.181
Benzo[b+j+k]fluoranthene	0.151	0.211	0.211	0.090	0.271		
Benzo[e]pyrene	0.301	0.392	0.301	0.211	0.060	0.060	0.060
Benzo[a]pyrene	0.120	0.151	0.181	0.120			
Indeno[1,2,3-c,d]pyrene	0.090	0.060	0.060	0.090			
Dibenzo[a,h]anthracene							
Benzo[g,h,i]perylene	0.090	0.060	0.090	0.151			

Ahmed et al. (2018) [Emissions of particulate associated oxygenated and native polycyclic aromatic hydrocarbons from vehicles powered by ethanol/gasoline fuel blends, Fuel] characterized emission factors for oxygenated polycyclic aromatic hydrocarbons (OPAHs) and PAHs determined from two different fuel flexible light duty vehicles operated at −7 °C in the New European Driving Cycle (NEDC) and at +22 °C in the Artemis Driving Cycle (ADC).

Testing was made on two flex fuel passenger cars a Saab 95 (FFV1) and a Volvo V50 (FFV2) (both Euro 4). Three gasoline/ethanol fuel blends were tested: Swedish commercial petrol (5% ethanol in gasoline (E5) and ethanol fuels (E85 and winter quality E70 with 85% and 70%) ethanol in gasoline, respectively. The sampling was performed using a constant volume sampling system (CVS) with a dilution of the exhaust applied. Particulate exhaust samples were collected on Teflon coated glass fiber filters (Pallflex Inc T60A20, Putnam, USA).

Filter parts (about one quarter of each filter) were spiked with a mixture of six perdeuterated surrogate internal standards: phenanthrene-D10, pyrene-D10, benzo[a]anthracene-D12, B[a]P-D12, benzo[ghi]perylene-D12 and anthraquinone-D8 prior to extraction. The samples were extracted using an accelerated solvent extraction system (ASE 200, Dionex Corporation, Sunnyvale, CA, USA) with toluene: methanol (Tol: MeOH, 9:1) as extraction solvent. The extract was evaporated to approximately 5 ml under a gentle gas stream of nitrogen in a water bath heated to about 60 °C. The extracts were then transferred to disposable test tubes and further evaporated to 0.5 ml. Clean-up was performed using silica solid phase extraction (SPE) cartridges (100 mg, Isolute, IST, UK) with toluene as mobile phase.

A hyphenated High Performance Liquid Chromatography Gas Chromatography/Mass Spectrometry (LC-GC/MS) system was used for the analysis of OPAHs and PAHs. This system consists of an auto sampler (CMA/200 micro sampler, CMA Microdialysis AB, Sweden), a HPLC pump (Varian Inc, Palo Alto, CA, USA), an UV detector (SPD-6A, Shimadzu, Japan) and a normal phase LC column (Nucleosil 100-5NO2 124 × 4.6 mm, 5 µm) which was coupled to an Agilent 6890 N gas chromatograph (Agilent Technologies, Palo Alto, CA, USA) fitted with a DB-17MS column (60 m × 0.25 mm i.d. x 0.1 µm film thickness) and interfaced with an Agilent 5973 N MSD (Agilent Technologies).

Table 134: Average PAH emission factors in ng/km

Compound	NEDC E5 −7 °C		NEDC E70 −7 °C		NEDC E85 −7 °C		ADC E5 +22 °C		ADC E85 +22 °C	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Phenanthrene	1340	389	2770	569	2590	1390	47	23	45	43
Anthracene	176	26	545	107	550	356	20	5	15	15
cyclopentaphenanthrene	42	9	325	124	209	176	2	1	2	2
Fluoranthene	1600	297	7030	1340	3020	3830	30	13	32	28
Pyrene	1690	993	9590	1810	4290	4130	46	24	38	34
Benz[a]fluorene	177	213	1080	921	142	107	3	2	2	2
Benz[b]fluorene	257	188	1120	955	212	242	3	1	1	1
Benzo[ghi]fluoranthene	951	608	1230	352	3340	745	20	4	24	18
Benz[a]anthracene	483	354	1540	1850	930	373	17	5	15	13
Chrysene	2290	1320	7600	8920	4380	2190	99	33	74	65
Benzo[b]fluoranthene	1900	1650	5770	6780	4107	843	116	15	116	100
Benzo[k]fluoranthene	1270	1260	3500	4220	2290	488	47	9	44	39
Benzo[e]pyrene	1450	1120	6780	7340	6280	2020	88	15	87	73
Benzo[a]pyrene	2760	2570	11600	13500	10100	2990	92	23	74	62
Perylene	430	453	1930	2350	1320	460	10	4	8	7
Indeno[1,2,3-cd]fluoranthene	63	63	63	67	61	14	4	3	2	2
Indeno[1,2,3-cd]pyrene	1020	1030	2660	2530	3530	816	84	67	38	28
Dibenzo[a,h]anthracene	44	41	77	80	65	38	3	3	1	1
Benzo[ghi]perylene	1070	1190	3660	2680	6570	1830	114	85	55	43
Dibenzo[a,l]pyrene	18	6	63	75	51	30	2	1	1	0.3
Dibenzo[a,e]pyrene	72	33	95	74	98	95	16	13	3	2
Coronene	1090	1410	2220	426	5800	3200	332	271	42	45
Dibenzo[a,i]pyrene	64	56	203	201	194	156	28	17	2	1

Dibenzo[a,h]pyrene	15	10	21	20	22	14	1	1	1	

Lin et al. (2019) [Assessment of PM2.5 and PAH content in PM2.5 emitted from mobile source gasoline-fueled vehicles in concomitant with the vehicle model and mileages, Chemosphere] examined the PAH emissions from gasoline vehicles with different model years and mileage. Three vehicles were tested for Euro 3 and Euro 4, five vehicles for Euro 5, and four vehicles for Euro 6. A list of the test vehicles is shown below.

No. of vehicles	Brand	Year	Displacement (c.c)	Total Kilometers (Km)
1	TOYOTA	2004	1998	11,266
2	TOYOTA	2004	1798	143,331
3	SUZUKI	2004	1328	155,779
4	TOYOTA	2012	1798	9488
5	TOYOTA	2004	1497	130,713
6	NISSAN	2015	1598	26,984
7	TOYOTA	2014	1987	157,148
8	MITBISHI	2000	2378	46,932
9	TOYOTA	2004	1998	130,304
1	TOYOTA	2016	1978	23,683
11	TOYOTA	2006	1496	102,286
12	CMC Motor	2009	1998	998,857
13	TOYOTA	2010	1978	144,008
14	TOYOTA	2014	1987	194,229
15	TOYOTA	2014	1987	38,447

For analyzing PAH, the sample was separated in a Soxhlet extractor with a blended dissolvable (n-hexane and dichloromethane; vol/vol, 1:1; 500ml each) for 24 h. The PAH substance was regulated by HP gas chromatograph (GC) (HP 5890A; Hewlett Packard, Wilmington, DE, USA), a mass selective detector (MSD) (HP 5972), and a PC workstation (Aspire C500; Acer, Taipei, Taiwan). The extract was concentrated and cleaned up by utilizing a silica segment loaded with silica gel particles positioned under a layer of Na_2SO_4 and specifically reconcentrated with ultra-pure nitrogen to precisely 0.2 mL for GC/MS analysis.

Table 135: PAH emission factors of PM2.5 in the exhaust of gasoline vehicles (ng/L-Fuel)

Compounds, ng/L-Fuel	Mean	SD	RSD (%)
naphthalene	0.111	0.0752	53.3
acenaphthylene	0.00592	0.00422	47.6
acenaphthene	0.00532	0.00389	37.2