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Russia's black carbon emissions: focus on diesel sources

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I. Emissions standards and emission factors

Table S1. Emission standards for on-road vehicles in the EU and Russia.

Passenger cars*	Introduced in the EU	Introduced in Russia	Heavy-duty diesel engines	Introduced in the EU	Introduced in Russia
Euro 1	1992	-	Euro I	1992	-
Euro 2	1996	2006	Euro II	1996	2006
Euro 3	2000	2008	Euro III	2000	2008
Euro 4	2005	2013	Euro IV	2005	2013
Euro 5	2009	2014	Euro V	2008	2016
Euro 6	2014	n/a	Euro VI	2013	n/a

* By convention, light-duty vehicles are marked with Arabic numerals while Roman numbers are used for heavy-duty vehicles (trucks and buses).

Table S2. COPERT and NIIAT emission factors and BC speciation for hot operation stage.

Type	Subcategory	COPERT EF, g/km			Blended NIIAT EFs, g/km			EC/PM*	OC/EC*
Cars		Urban	Rural	Highway	Urban	Rural	Highway		
Euro 0		0.271	0.199	0.146	0.250	0.150	0.170	0.55	0.70
Euro 1		0.07	0.057	0.087	0.073	0.040	0.050	0.70	0.40
Euro 2		0.058	0.047	0.045	0.073	0.040	0.050	0.80	0.23
Euro 3		0.035	0.029	0.038	0.053	0.030	0.030	0.85	0.15
Euro 4		0.034	0.029	0.025	0.016	0.090	0.090	0.87	0.13
Euro 5		0.003	0.002	0.002	0.004	0.002	0.002	0.20	2.00
LCV									
Euro 0		0.281	0.285	0.337	0.290	0.210	0.230	0.55	0.70
Euro 1		0.099	0.07	0.118	0.087	0.060	0.100	0.70	0.40
Euro 2		0.099	0.07	0.118	0.087	0.060	0.100	0.80	0.23
Euro 3		0.066	0.047	0.079	0.057	0.040	0.060	0.85	0.15
Euro 4		0.035	0.024	0.041	0.033	0.020	0.030	0.87	0.13
Euro 5		0.002	0.001	0.001	0.002	0.001	0.002	0.20	2.00
Trucks									
Euro 0	<=7,5 t	0.4	0.297	0.211	0.543	0.180	0.180	0.50	0.80
Euro I	<=7,5 t	0.157	0.116	0.09	0.360	0.140	0.140	0.65	0.40
Euro II	<=7,5 t	0.069	0.056	0.064	0.220	0.080	0.080	0.65	0.40
Euro III	<=7,5 t	0.082	0.061	0.04	0.153	0.060	0.060	0.70	0.30
Euro IV	<=7,5 t	0.017	0.014	0.015	0.030	0.010	0.010	0.75	0.25
Euro V	<=7,5 t	0.021	0.018	0.015	0.030	0.010	0.010	0.75	0.25
Euro 0	7,5 - 12 t	0.423	0.301	0.201	0.893	0.400	0.400	0.50	0.80
Euro I	7,5 - 12 t	0.262	0.182	0.129	0.640	0.330	0.330	0.65	0.40
Euro II	7,5 - 12 t	0.115	0.087	0.098	0.230	0.100	0.100	0.65	0.40
Euro III	7,5 - 12 t	0.133	0.095	0.062	0.153	0.060	0.060	0.70	0.30

Euro IV	7,5 - 12 t	0.027	0.021	0.02	0.030	0.010	0.010	0.75	0.25
Euro V	7,5 - 12 t	0.034	0.026	0.021	0.030	0.010	0.010	0.75	0.25
Euro 0	12 - 14 t	0.452	0.32	0.232	1.073	0.550	0.550	0.50	0.80
Euro I	12 - 14 t	0.28	0.199	0.147	0.697	0.480	0.480	0.65	0.40
Euro II	12 - 14 t	0.128	0.095	0.109	0.310	0.180	0.180	0.65	0.40
Euro III	12 - 14 t	0.141	0.099	0.071	0.193	0.130	0.130	0.70	0.30
Euro IV	12 - 14 t	0.03	0.023	0.02	0.040	0.020	0.020	0.75	0.25
Euro V	12 - 14 t	0.036	0.028	0.023	0.040	0.020	0.020	0.75	0.25
Euro 0	> 14 t	0.625	0.439	0.29	1.073	0.550	0.550	0.50	0.80
Euro I	> 14 t	0.386	0.271	0.175	0.697	0.480	0.480	0.65	0.40
Euro II	> 14 t	0.164	0.118	0.129	0.310	0.180	0.180	0.65	0.40
Euro III	> 14 t	0.199	0.139	0.087	0.193	0.130	0.130	0.70	0.30
Euro IV	> 14 t	0.039	0.029	0.023	0.040	0.020	0.020	0.75	0.25
Euro V	> 14 t	0.049	0.037	0.028	0.040	0.020	0.020	0.75	0.25
Buses									
Euro 0	<=15 t	0.858	0.574	0.388	0.880	0.270	0.295	0.50	0.80
Euro I	<=15 t	0.294	0.221	0.173	0.650	0.215	0.230	0.65	0.40
Euro II	<=15 t	0.142	0.114	0.107	0.398	0.195	0.175	0.65	0.40
Euro III	<=15 t	0.146	0.11	0.099	0.197	0.105	0.100	0.70	0.30
Euro IV	<=15 t	0.035	0.027	0.022	0.040	0.025	0.025	0.75	0.25
Euro V	<=15 t	0.042	0.031	0.038	0.037	0.025	0.025	0.75	0.25
Euro 0	15 - 18 t	0.767	0.52	0.312	1.523	0.430	0.500	0.50	0.80
Euro I	15 - 18 t	0.412	0.294	0.217	0.890	0.310	0.400	0.65	0.40
Euro II	15 - 18 t	0.197	0.157	0.138	0.680	0.310	0.270	0.65	0.40
Euro III	15 - 18 t	0.195	0.148	0.108	0.250	0.130	0.120	0.70	0.30
Euro IV	15 - 18 t	0.049	0.037	0.027	0.050	0.030	0.030	0.75	0.25
Euro V	15 - 18 t	0.055	0.042	0.036	0.050	0.030	0.030	0.75	0.25
Euro 0	>18 t	0.957	0.675	0.395	1.523	0.430	0.500	0.50	0.80
Euro I	>18 t	0.517	0.37	0.227	0.757	0.310	0.400	0.65	0.40
Euro II	>18 t	0.265	0.212	0.174	0.583	0.310	0.270	0.65	0.40
Euro III	>18 t	0.24	0.17	0.125	0.250	0.130	0.120	0.70	0.30
Euro IV	>18 t	0.06	0.045	0.029	0.050	0.030	0.030	0.75	0.25
Euro V	>18 t	0.066	0.049	0.04	0.050	0.030	0.030	0.75	0.25

Sources: (Emisia, 2015;NIIAT, 2012).

* EC/PM and OC/EC speciation factors are derived from the COPERT model.

II. Activity data

Table S3. Number of active diesel vehicles by type and emission standard in Russia, 2014.

	Cars	LCVs	Trucks	Buses
Euro 0	100 620	150 345	470 737	24 994
Euro 1	103 529	119 732	43 093	10 038
Euro 2	113 576	94 135	173 337	17 541
Euro 3	144 298	140 923	293 520	49 725
Euro 4	691 199	353 189	271 189	19 481
Euro 5	329 941*	58 703	77 404	1 615
Total	1 483 163	917 027	1 329 280	123 394

* - includes 2110 Euro 6 cars
Calculated based on (Avtostat, 2015).

Table S4. The annual average distance traveled by type of vehicles, thousand $kmyr^{-1}$.

	Cars	LCVs	Trucks	Buses
NIIAT (1998)	15 10 for 5-year old Russian cars 10 for 10-year old foreign cars		35 in cities 60 suburban 100 intercity	Russian: 50 in cities 65 suburban 80 intercity Foreign: 60 in cities 80 suburban 105 intercity
NIIAT (2008)	14-16 owned by individuals 25-30 owned by companies		30-40	40-50
Avtostat (2010)	16.7 15.3 Russian 18 foreign-made	55	63	65
ICCT (2015)	10	10	13-38	56

Table S5. Average number kilometers traveled by type of vehicles.

Vehicle type	Subsector	Emission standard	Annual kilometers traveled
Passenger Cars	Diesel 1,4 - 2,0 l	Conventional	10 000
	Diesel 1,4 - 2,0 l	PC Euro 1 - 91/441/EEC	10 000
	Diesel 1,4 - 2,0 l	PC Euro 2 - 94/12/EEC	15 000
	Diesel 1,4 - 2,0 l	PC Euro 3 - 98/69/EC Stage2000	15 000

	Diesel 1,4 - 2,0 l	PC Euro 4 - 98/69/EC Stage2005	18 000
	Diesel 1,4 - 2,0 l	PC Euro 5 - EC 715/2007	20 000
Light Commercial Vehicles	Diesel <3,5 t	Conventional	37 000
	Diesel <3,5 t	LD Euro 1 - 93/59/EEC	37 000
	Diesel <3,5 t	LD Euro 2 - 96/69/EEC	55 000
	Diesel <3,5 t	LD Euro 3 - 98/69/EC Stage2000	55 000
	Diesel <3,5 t	LD Euro 4 - 98/69/EC Stage2005	66 000
	Diesel <3,5 t	LD Euro 5 - 2008 Standards	73 000
Heavy Duty Trucks	Rigid <=7,5 t	Conventional	42 000
	Rigid <=7,5 t	HD Euro I - 91/542/EEC Stage I	42 000
	Rigid <=7,5 t	HD Euro II - 91/542/EEC Stage II	63 000
	Rigid <=7,5 t	HD Euro III - 2000 Standards	63 000
	Rigid <=7,5 t	HD Euro IV - 2005 Standards	75 000
	Rigid <=7,5 t	HD Euro V - 2008 Standards	84 000
	Rigid 7,5 - 12 t	Conventional	42 000
	Rigid 7,5 - 12 t	HD Euro I - 91/542/EEC Stage I	42 000
	Rigid 7,5 - 12 t	HD Euro II - 91/542/EEC Stage II	63 000
	Rigid 7,5 - 12 t	HD Euro III - 2000 Standards	63 000
	Rigid 7,5 - 12 t	HD Euro IV - 2005 Standards	75 000
	Rigid 7,5 - 12 t	HD Euro V - 2008 Standards	84 000
	Rigid 12 - 14 t	Conventional	42 000
	Rigid 12 - 14 t	HD Euro I - 91/542/EEC Stage I	42 000
	Rigid 12 - 14 t	HD Euro II - 91/542/EEC Stage II	63 000
	Rigid 12 - 14 t	HD Euro III - 2000 Standards	63 000
	Rigid 12 - 14 t	HD Euro IV - 2005 Standards	75 000
	Rigid 12 - 14 t	HD Euro V - 2008 Standards	84 000
	Rigid 14 - 20 t	Conventional	42 000
	Rigid 14 - 20 t	HD Euro I - 91/542/EEC Stage I	42 000
	Rigid 14 - 20 t	HD Euro II - 91/542/EEC Stage II	63 000
	Rigid 14 - 20 t	HD Euro III - 2000 Standards	63 000
	Rigid 14 - 20 t	HD Euro IV - 2005 Standards	75 000
	Rigid 14 - 20 t	HD Euro V - 2008 Standards	84 000
Buses	Urban Buses Midi <=15 t	Conventional	43 000
	Urban Buses Midi <=15 t	HD Euro I - 91/542/EEC Stage I	43 000
	Urban Buses Midi <=15 t	HD Euro II - 91/542/EEC Stage II	65 000
	Urban Buses Midi <=15 t	HD Euro III - 2000 Standards	65 000
	Urban Buses Midi <=15 t	HD Euro IV - 2005 Standards	78 000
	Urban Buses Midi <=15 t	HD Euro V - 2008 Standards	87 000
	Urban Buses Standard 15 - 18 t	Conventional	43 000
	Urban Buses Standard 15 - 18 t	HD Euro I - 91/542/EEC Stage I	43 000
	Urban Buses Standard 15 - 18 t	HD Euro II - 91/542/EEC Stage II	65 000
	Urban Buses Standard 15 - 18 t	HD Euro III - 2000 Standards	65 000

Urban Buses Standard 15 - 18 t	HD Euro IV - 2005 Standards	78 000
Urban Buses Standard 15 - 18 t	HD Euro V - 2008 Standards	87 000
Urban Buses Articulated >18 t	Conventional	43 000
Urban Buses Articulated >18 t	HD Euro I - 91/542/EEC Stage I	43 000
Urban Buses Articulated >18 t	HD Euro II - 91/542/EEC Stage II	65 000
Urban Buses Articulated >18 t	HD Euro III - 2000 Standards	65 000
Urban Buses Articulated >18 t	HD Euro IV - 2005 Standards	78 000
Urban Buses Articulated >18 t	HD Euro V - 2008 Standards	87 000

III. Results of emission calculations

The COPERT 4 model with NIIAT emission factors. The assumptions on average annual kilometers traveled remain the same.

Table S6. OC emissions from the adjusted diesel fleet with superemitters (Gg).

	Cars	LCVs	Trucks	Buses	Total
Euro 0	0.07	0.47	2.83	0.20	3.58
Euro 1	0.02	0.11	0.14	0.05	0.31
Euro 2	0.03	0.10	0.49	0.10	0.72
Euro 3	0.02	0.08	0.49	0.12	0.70
Euro 4	0.03	0.13	0.09	0.01	0.26
Euro 5	0.01	0.01	0.03	0.00	0.05
Total	0.18	0.88	4.07	0.48	5.62

Table S7. BC emissions, assuming that all registered trucks and buses use diesel fuel (Gg).

	Trucks	Buses	Total
Euro 0	33.2	3.8	80.2
Euro 1	1.1	0.3	3.6
Euro 2	2.5	0.8	13.6
Euro 3	2.3	0.8	11.4
Euro 4	0.4	0.1	5.8
Euro 5	0.1	0.0	0.2
Total	39.7	5.7	114.8

Table S8. BC emissions from all registered diesel vehicles (Gg).

	Cars	LCVs	Trucks	Buses	Total
Euro 0	0.36	1.85	15.39	0.66	18.26
Euro 1	0.10	0.54	1.06	0.20	1.91
Euro 2	0.18	0.68	2.33	0.32	3.51
Euro 3	0.16	0.66	2.27	0.42	3.52
Euro 4	0.27	1.03	0.42	0.04	1.77
Euro 5	0.01	0.00	0.12	0.00	0.13
Total	1.08	4.77	21.58	1.66	29.09

Table S9. BC emissions from the adjusted diesel fleet without accounting for superemitters (Gg).

	Cars	LCVs	Trucks	Buses	Total
Euro 0	0.20	1.30	6.16	0.46	8.11
Euro 1	0.08	0.41	0.53	0.16	1.18
Euro 2	0.14	0.54	1.40	0.29	2.37
Euro 3	0.14	0.56	1.71	0.42	2.82
Euro 4	0.24	0.98	0.38	0.05	1.65
Euro 5	0.01	0.00	0.12	0.00	0.13
Total	0.80	3.79	10.28	1.39	16.26

Table S10. Uncertainty estimates for BC and OC emissions from on-road vehicles.

	Central	Minimum	Maximum
Share of superemitters	15%	10%	20%
Annual distance traveled, km	Avtostat	NIIAT	Avtostat
Cars	15 000	15 000	15 000
LCVs	55 000	30 000	55 000
Trucks	63 000	45 000	63 000
Buses	65 000	50 000	65 000
PM emissions factor	COPERT	COPERT -20%	COPERT +20%
BC/PM speciation ratio	COPERT	COPERT -10%	COPERT +10%
Emissions, Gg			
BC normal	11.8	7.1	12.3
BC superemitters	8.9	3.4	15.7
BC total	**20.7**	**10.5**	**28.0**
OC normal	5.6	4.3	5.0
OC superemitters	4.9	2.1	8.7
OC total	**10.5**	**6.4**	**13.7**

References

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