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Unlimited pollutants emitted by traffic in the Czech Republic

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Abstract Traffic is a dynamic sector that increases in most of monitored indicators in worldwide scale factor. Negative impacts on environment and human health are growing in proportion to it, especially in big towns. Air polluting substances, to which the emission limits are not applied, are the major problem. These are emissions contributing to long-time greenhouse effect: carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and substances with toxic effects on human health - lead (Pb), sulphur dioxide (SO_2). Other contaminants produced by traffic are polyaromatic hydrocarbons (PAH), dioxins, benzene-toluene-xylene (BTX) and 1,3 butadiene. The highest increase is recorded for emissions of greenhouse gases (CO_2 and N_2O). That is more in accordance with international emission stocking of greenhouse gases. Organic pollutants emitted by traffic show similar increasing trend. These are dangerous due to their toxic, genotoxic and mutagenic effects. Emissions of CH_4 still decrease respectively, because the new cars must fulfil the higher EURO limits. Emissions of SO_2 and Pb from traffic are imponderable in practice. The paper presents emission inventories of unlimited pollutants in traffic, their development and prediction in Czech Republic.

Key words: *carbon dioxide, methane, nitrous oxide, sulphur dioxide, lead, polyaromatic hydrocarbons, polychlorinated biphenyls, polychlorinated dibenzodioxins, polychlorinated dibenzofurans, transport, emissions, emission factors, air pollution.*

Introduction

The traffic – related emissions participate very significantly on the total air pollution. Besides long-term monitored pollutants such as nitrogen oxides (NO_X), carbon monoxide (CO), carbon dioxide (CO_2) or sulphur dioxide (SO_2), lately the attention is also paid to human exposure to persistent organic pollutants (POPs) such as e.g. polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs). The air pollution and noise is the most serious problem, especially due to their effect on human health, particularly in municipalities with densely motor vehicle traffic. Exhaust gases from motor vehicles contain hundreds of chemical substances in different concentrations and with a wide spectrum of potential health effects and related risks to human health.

The share of traffic on unlimited pollutants emissions strongly increases, namely CO_2, methane (CH_4), nitrous oxide (N_2O) and PAHs. Road traffic volumes and performances has permanently increased during the 90-ties, mainly as a result of increase the volumes of car and road freight transport and on the other hand, decrease of public buses and railway transport.

Methods

While the emission factors (Ef) of limited pollutants like CO, NO_X, hydrocarbons (C_xH_y), particulars (PM) are obligatorily measured (regular technical inspections), the measurement of greenhouse gases is not set by any legislative standard. That is why, the measurement of these emissions is not measured regularly, or mainly on experimental basis. The results however have a big dispersion and it makes the situations difficult.

For the calculation and balance of CO_2, N_2O, and CH_4 emissions we use own methodology and emission factors database that has been developed by our research institute for Czech Ministry of Transport. The Emission factor (Ef) is given by the mass amount per unit of consumed energy ($g.MJ^{-1}$), distance ($g.km^{-1}$), consumed fuel ($g.kg^{-1}$) or the engine power ($g.kWh^{-1}$). The emission factors of selected pollutants are part of the traffic – related emission factors database, its source are the results of Czech and foreign measurements. These results are continuously statistically evaluated. The used emission factors for the emission inventory are shown in Table 1. We came out from the averages for each vehicle categories at the emissions calculation.

Regarding the fact that POPs do not belong among limited components of the traffic exhaust gases determination of emission factors of these pollutants is very limited. The situation is also complicated by the fact that values measured so far have relatively large dispersion. The calculation and the audit of the amount of POPs emissions from transport started from the following works: Ntziachristos and Samaras (2000), Krobl (2001) and Adamec et al. (2003).

Emission factor (Ef) of a pollutant is always presented in the mass per the unit of energy (g.MJ-1), the length of transport (g.km-1), the mass of consumed fuel (g.kgfuel-1) or power of the engine (g.kWh-1). Ef of limited pollutants such as

e.g. CO, NOx, hydrocarbons (CxHy), particular matters (PM) are compulsorily measured (periodical technical inspections) but the measurement of POPs emissions from transport is not so far controlled by any legislative directive. That is why POPs emissions from vehicles are not usually measured and these measurements are especially connected with the experimental field. For this purpose, the authors made the database of Ef of selected POPs produced by transport (Dufek and Adamec, 2002a, 2002b). For the increase of number of reliable data, the authors performed the measurement campaign, with the collaboration of Czech Motor Vehicle Research Institute, where the PAHs and dioxins were measured in Czech passenger cars. Results from national and foreign measurements, which are the sources, are continuously completed (updated) and evaluated statistically. The following Table 1 presents used emissions factors of selected POPs produced by transport, which were used for the elaboration of the emission inventory. Calculations of total emissions used average values for each category of means of transport.

Emission factors of PCDDs, PCDFs and PCBs are very low, in $pg.km^{-1}$, hence there is the probable origin of this minimum amount also by burning fuels, which do not contain halogenated scavengers. This assumption is also supported by the fact that the database includes emission factors of diesel vehicles as well, where halogenated ingredients were not applied. Nevertheless a suspicion that polyhalogenated hydrocarbons from exhaust emissions can contribute to a total human exposure to this kind of xenobiotics raised from results of analyses of breast milk samples collected at places with extremely high traffic density (Adamec et al. 2005, Bencko et al. 2004).

Results and discussion

The results of the unlimited emissions calculation are summarised in Tables No. 2 – 10.

Table 1 Emission factors of selected unlimited pollutants produced by the transport

Vehicle category	Emission factors						
	CO_2 $g.kg^{-1}$ fuel	CH_4 $g.kg^{-1}$ fuel	N_2O $g.kg^{-1}$ fuel	PAHs $mg.kg^{-1}$ fuel	PCDDs $pg.kg^{-1}$ fuel	PCDFs $pg.kg^{-1}$ fuel	PCBs $pg.kg^{-1}$ fuel
Motorcycles	3183	5,27	0,059	4,58	359	738	126,5
Conventional passenger gasoline vehicles	3183	1,04	0,861	3,75	148	306	126,5
EURO-meeting passenger gasoline vehicles	3177	0,314	3,878	2,26	0	0	126,5
Passenger diesel	3193	0,083	0,165	20,8	8,2	16,3	0
Passenger LPG	3030	1,02	0	5,08	0	0	0
Gasoline light duty vehicles	3183	0,718	0,047	3,75	16	30	126,5
Diesel light duty vehicles	3192	0,055	0,188	20,8	11,9	11,9	0
Diesel heavy duty vehicles	3138	0,243	0,122	1,60	11,9	11,9	0

Table 2 CO_2 emissions by mode of transport [thousand tonnes]

Transport mode	Year												
	1993	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
IPT	4 425	5 080	5 679	5 894	5 640	6 230	7 215	7 632	7 927	8 932	9 266	9 791	9 812
RPT	1 064	1 042	1 151	1 097	1 424	1 392	1 121	1 227	1 336	1 545	1 637	1 868	1 996
RFT	1 535	2 619	3 347	3 873	3 396	3 673	2 937	3 270	3 484	4 071	4 421	5 132	5 442
RWT	636	761	810	672	697	619	326	304	295	289	285	270	264
WWT	89	96	131	66	76	79	16	25	12	12	19	15	18
Air	933	1 062	1 006	1 035	1 123	1 366	637	683	653	838	1 072	1 115	1 118
Total	8 682	10 660	12 124	12 637	12 356	13 359	12 252	13 141	13 707	15 687	16 700	18 191	18 650

Table 3 CH_4 emissions by mode of transport [t]

Transport mode	Year												
	1993	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
IPT	1 394	1 524	1 627	1 603	1 408	1 398	1 237	1206	1098	1105	1002	933	840
RPT	83	83	92	87	114	119	166	193	200	221	232	272	279
RFT	139	245	300	354	301	359	296	333	332	369	386	448	453
RWT	49	59	63	52	54	48	20	19	19	18	18	17	17
WWT	7	7	10	5	6	6	1	2	1	1	1	1	1
Air	127	130	111	107	116	134	122	130	125	160	205	213	214
Total	1 800	2 048	2 203	2 208	1 999	2 064	1 842	1 883	1 775	1 874	1 844	1 884	1 804

Table 4 N_2O emissions by mode of transport [t]

Transport	Year												
mode	1993	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
IPT	930	1 058	1 222	1 291	1 253	1 435	1 067	1 184	1 354	1 620	1 775	1 876	1 929
RPT	41	40	43	37	50	44	50	59	61	70	77	92	94
RFT	60	100	130	140	123	159	129	155	164	207	251	312	330
RWT	25	30	32	26	27	22	19	17	17	17	16	15	15
WWT	3	4	5	3	3	3	1	1	1	1	1	1	1
Air	79	81	70	67	72	103	86	92	88	113	144	150	151
Total	1 138	1 340	1 502	1 564	1 528	1 766	1 352	1 508	1 685	2 028	2 264	2 446	2 520

Table 5 SO_2 emissions by mode of transport [t]

Transport	Year												
mode	1993	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
IPT	1 391	1 595	1 783	1 842	1 762	1 937	804	878	926	1071	1 151	320	322
RPT	339	327	360	318	418	396	217	249	261	309	347	60	65
RFT	488	820	1 049	1 162	1 006	1 062	590	681	709	843	953	164	177
RWT	203	242	258	214	222	197	73	68	66	64	64	9	8
WWT	28	31	42	21	24	25	4	6	3	3	4	1	1
Air	350	356	470	470	508	617	39	42	40	51	65	67	68
Total	2 799	3 371	3 962	4 028	3 940	4 234	1 727	1 930	2 005	2 341	2 584	621	641

Table 6 Pb emissions by mode of transport [t]

Transport	Year												
mode	1993	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
IPT	161	132	127	112	98	96	58	5,70	5,78	4,20	2,09	1,03	1,00
RFT	10	13	13	13	10	11	7	2,24	1,71	1,39	0,00	0,00	0,00
Air	15	14	5	6	6	2	2	1,04	0,73	0,49	0,00	0,00	0,00
Total	185	160	145	132	114	109	67	11,92	8,22	5,52	2,10	1,03	1,00

** Since 1997 gasoline vans are placed within the goods vehicles*

Table 7 Total PAHs emissions in the Czech Republic [t]

Transport	Year													
mode	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006*
IPT	6,13	6,64	7,11	8,25	8,54	8,59	9,22	9,45	10,48	10,99	13,03	14,41	16,90	25,86
RPT	0,33	0,17	0,19	0,20	0,18	0,27	0,27	0,58	0,63	0,66	0,76	0,82	0,95	1,01
RFT	2,22	3,00	4,00	5,21	5,81	5,16	5,57	6,04	6,68	6,92	8,17	9,04	10,59	2,74
RWT	0,20	0,16	0,23	0,25	0,21	0,19	0,15	0,10	0,09	0,09	0,09	0,09	0,09	0,08
WWT	0,03	0,02	0,03	0,04	0,02	0,02	0,01	0,01	0,01	0,00	0,00	0,01	0,01	0,01
Total	8,91	10,10	11,70	14,12	14,93	14,46	15,22	16,19	17,89	18,66	22,05	24,37	28,54	29,70

** from 2006 the passenger cars and light duty vehicles are grouped in IPT category*

Table 8 Total PCDDs emissions in the Czech Republic [mg]

Transport	Year													
mode	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006*
IPT	195,1	214,9	209,6	219,9	211,2	178,1	163,3	116,3	105,6	81,9	77,7	66,1	54,5	39,2
RPT	3,4	3,7	4,5	4,8	4,5	5,8	5,5	4,4	4,8	4,8	5,6	6,1	7,0	7,5
RFT	17,9	29,0	32,9	38,1	45,8	37,0	37,0	12,0	13,1	13,1	15,3	16,7	19,3	20,5
RWT	2,4	2,0	2,9	3,1	2,5	2,6	2,3	1,2	1,2	1,1	1,1	1,1	1,1	1,0
WWT	0,3	0,3	0,4	0,5	0,2	0,3	0,3	0,1	0,1	0,0	0,0	0,1	0,1	0,1
Total	219,1	249,9	250,3	266,4	264,2	223,8	208,4	134,0	124,8	100,9	99,7	90,1	82,0	68,3

** from 2006 the passenger cars and light duty vehicles are grouped in IPT category*

Table 9 Total PCDFs emissions in the Czech Republic [mg]

Transport	Year													
mode	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006*
IPT	403,2	444,4	433,3	454,6	436,6	368,2	338,0	240,2	218,1	169,0	160,3	136,2	112,1	80,4
RPT	4,9	4,2	5,1	5,3	4,9	6,3	6,1	4,4	4,8	4,8	5,6	6,1	7,0	7,5
RFT	32,8	54,7	61,3	69,9	84,5	67,6	80,0	12,0	13,1	13,1	15,3	16,7	19,3	20,6
RWT	2,4	2,0	2,9	3,1	2,5	2,6	2,3	1,2	1,2	1,1	1,1	1,1	1,1	1,0
WWT	0,3	0,3	0,4	0,5	0,2	0,3	0,3	0,1	0,1	0,0	0,0	0,1	0,1	0,1
Total	443,6	505,6	503,0	533,4	528,7	445,0	426,7	257,9	237,3	188,0	182,3	160,2	139,6	109,5

** from 2006 the passenger cars and light duty vehicles are grouped in IPT category*

Table 10 Total PCBs emissions in the Czech Republic [mg] – gasoline vehicles

Transport	Year													
mode	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006*
IPT	169,0	190,1	192,4	212,0	218,8	204,7	224,4	226,5	222,4	218,2	237,7	235,5	231,3	253,7
RPT	0,3	0,4	0,4	0,4	0,3	0,4	0,4	0,4	0,5	0,6	0,7	0,8	0,9	0
RFT	10,0	17,5	19,1	21,2	26,0	20,3	24,7	26,1	26,9	31,3	28,4	28,2	27,5	0
RWT	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0
WWT	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0
Total	179,4	208,1	212	233,7	245,2	225,5	249,6	253,1	249,9	250,2	266,9	264,6	259,8	253,7

** from 2006 the passenger cars and light duty vehicles are grouped in IPT category*

The emissions of N_2O show the biggest growth because the newer cars have higher measured factors than the older types. That is why the growth of these emissions is predicted also in next years. The production of CO_2 emissions grew in 2002 as well, but not so markedly like N_2O. The gasoline and diesel consumption is increasing but the growth itself got slow in 2002, which is positive. In contrast to N_2O, the new cars emit the less amount of CO_2 than older ones due to lower fuel consumption. The methane emission has a decreasing trend, after a slight increase during 1990 – 1997 years. The methane emissions approximately copy the trend of all hydrocarbons like a consequence of improvement of combustion cycle at new cars.

Conclusion

The decrease of emissions depends on the efficiency of reduction measures like for instance modification of vehicle fleet, use of catalytic converters, lower fuel consumption etc. The development of emissions index shows that it thrives to decrease only emissions limited by EURO standards. Non-limited emissions like greenhouse gases, has been increasing in the Czech Republic (except CH_4). This shows that the setting of new emission standards would not be the only one measure and it should be added on non technical measures like: promotion of more environmentally friendly transport modes (electrified railways, cycling ...), new taxes policies, internalisation of external costs, etc. Our main health interest in a current project dealing with solid aerosols in traffic emissions is oriented due to our previous experience on immunity aspects in this context.

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