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Study on emissions from heating systems in Italy

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The study on emissions from heating systems

- The study has been promoted by Environmental Ministry, Regional Authorities and Industry Associations
- The study has been carried out from 2003 to 2006
- Both statistical and experimental information from the civil heating sector have been gathered and analysed
- The experimental activities in research facilities and in the field have been carried out by SSC (Fuels Experimental Institute – Milan)

Main objectives of the study

- The scope of the study was to carry out a scientific and objective evaluation of the contribution of the civil heating sector to the current level of air pollution
- The assessment has been addressed to the various fuel and to the different heating systems used in Italy
- The quality and the amount of the emissions in atmosphere have been evaluated and the emission factors of the civil heating sector have been updated

Heating systems installed in Italy

	Number	%
Central Systems	4.400.000	19,7
Single House boiler	12.600.000	56,4
Other Systems	5.300.000	23,9
Total	22.300.000	100

Facilities tested in laboratory and in field

Nominal power of the plants tested	Main applications
≤ 75 kW	Very small plants typical single house boiler
75 kW ÷ 200 kW	Mid size plants – Buildings with 10 - 20 flats
≥ 200kW	Large plants – Buildings with more than 50 flats

Facilities tested in laboratory and in field

- The facilities tested represent the typical equipments installed in Italy in the civil heating sector
- The study was not planned to address the performances of the very advanced systems for heating purpose
- The experimental activity in laboratory was carried out adopting the correct parameters for combustion process (air/fuel ratio and preheating temperature)

Facilities tested in laboratory and in field

- Some tests were carried out adopting non optimized parameters to simulate the real operative conditions in field
- The emission levels have been measured both in stationary and transition conditions
- The efficiency of combustion has been also measured
- The experimental activity in field has been carried out in conditions similar to the laboratory's one

Fuels tested in laboratory and field facilities

Fuel	Market share
Natural Gas	72 %
Heating Gas oil	14 %
Water – gas oil emulsion	0,5 %
Biodiesel	1 %
Fuel Oil	2 %
Water – fuel oil emulsion	0,5 %
Fuel oil – biodiesel mix	0,5 %

Properties of Fuel oils tested in laboratory and field

Fuel oils		Laboratory sample n.		Field sample n.			Statistical analysis			
		1	2	1	2	3	average	min	max	σ
Water	% m/m	0,20	0,05	0,05	0,50	<0.05	-	0,05	0,50	-
Total Sediment	% m/m	<0.01	<0.01	<0.01	0,02	<0.01	-	0,02	0,02	-
Viscosity 50°C	mm²/s	95,78	95,93	97,07	97,63	104,7	98,22	95,78	104,70	3,703
Viscosity 50°C	°E	12,65	12,67	12,82	12,89	13,82	12,97	12,65	13,82	0,48
Carbon Residue	% m/m	3,95	4,55	3,76	2,73	5,12	4,022	2,73	5,12	0,898
Ash	% m/m	0,011	0,006	0,008	0,002	0,029	0,011	0,002	0,029	0,010
Nitrogen	% m/m	0,22	0,20	0,20	0,30	0,25	0,23	0,20	0,30	0,042
Sulphur	% m/m	0,24	0,25	0,24	0,23	0,28	0,25	0,23	0,28	0,019
Lower calorific value	Kcal/kg	10.041	10.028	10.022	10.035	9.918	10.008	9.918	10.041	51,26
Lower calorific value	kJ/kg	42.040	41.985	41.960	42.040	41.52	41.910	41.525	42.040	218
Nickel +Vanadium	mg/kg	<15	17,2	<15	<15	48	-	<15	48	-
PCB	mg/kg	<4	<4	<4	<4	<4	-	<4	-	-

Properties of Water in Fuel oils emulsion tested

Water – Fuel oils emulsion		Laboratory sample n.	Field sample n.			Statistical analysis			
		1	1	2	3	average	min	max	σ
Flash point	°C	>100	>100	>100	<100	-	-	-	-
Water	% m/m	13,0	9,5	13,5	16,0	13,0	9,5	16,0	2,677
Total Sediment	% m/m	<0.01	0,01	<0.01	0,01	-	-	0,01	-
Viscosity 50°C	mm²/s	130,20	94,51	133,1	146,8	126,15	94,51	146,8	22,303
Viscosity 50°C	°E	17,16	12,48	17,57	19,38	16,65	12,48	19,38	2,941
Ash	% m/m	0,005	0,025	0,004	0,060	0,024	0,004	0,060	0,026
Sulphur	% m/m	0,20	0,23	0,21	0,24	0,22	0,20	0,24	0,018
Nitrogen	%m/m	0,18	0,15	0,17	0,15	0,16	0,15	0,18	0,015
Lower calorific value	kcal/kg	8638	9.025	8.545	8.305	8.628,2	8.305	9.025	299,40
Lower calorific value	kJ/kg	36165	37.78	35.78	34.77	36.124	34.77	37.78	1.251
Nickel +Vanadium	mg/kg	<15	26,3	<15	19	-	19	26,3	-
PCB	mg/kg	<4	<4	<4	<4	-	0	0	-

Properties of Water in Gas oils emulsion tested

Water – gas oils emulsion		Laboratory sample n.		Field sample n.				Statistical analysis			
		1	2	1	2	3	4	average	min	max	σ
Water K.F.	% m/m	11,75	12,40	11,40	11,40	11,40	10,90	11,54	10,90	12,40	0,500
Density 15 °C	kg/m3	860,4	853,0	859,7	859,7	859,7	862,30	859,13	853,00	862,30	3,169
Viscosity 40°C	mm^2/s	4,602	4,265	3,537	3,537	3,959	4,153	4,009	3,537	4,602	0,421
Flash point	°C	>100	>100	69	69	>100	>100		69	>100	
Pour point	°C	-6		-24	-24	-18	-24	-19,20	-24,00	-6,00	7,823
Sulphur	% m/m	0,028	0,030	0,024	0,024	0,029	0,026	0,027	0,024	0,030	0,003
Lower calorific value	kcal/kg	8.940	8.776	8.770	8.770	8.941	8.823	8.836,67	8.770	8.941	82,84
Lower calorific value	kJ/kg	37.43	36.74	36.71	36.719	37.43	36.941	36.998	36.719	37.435	347

Properties of Biodiesel tested

Biodiesel		Laboratory sample n.		Field sample n.				Statistical analysis			
		1	2	1	2	3	4	mean	min	max	σ
Viscosity 40°C	mm²/s	4,100	4,345	4,321	4,367	4,402	4,400	4,323	4,100	4,402	0,113
Carbon Residue	% m/m	0,17	n.d.	n.d.	0,21	0,26	0,18	-	0,17	0,26	0,040
Sulfated Ash	% m/m	0,001	<0.001	0,01	0,005	0,003	0,001	-	0,001	0,009	0,003
Water K.F.	% m/m	0,043	0,032	0,09	0,096	0,079	0,048	0,065	0,032	0,096	0,027
Total contamination	mg/kg	116	55	172	68	237	12	110	12	237	82,948
Acidity	mg KOH/g	0,41	0,42	0,35	0,35	0,35	0,37	0,375	0,35	0,42	0,032
CFPP	°C	-10	n.d.	n.d.	-7	-7	-5	-	-10	-5	2,062
Pour point	°C	-6	n.d.	n.d.	-15	-10	-6	-	-15	-6	4,272
Lower cal. value	kcal/kg	8.937	8.940	8.95	8.950	8.950	8.970	8.949,5	8.937	8.970	11,554
Lower cal. value	kJ/kg	37.410	37.42	37.5	37.470	37.470	37.560	37.466	37.410	37.560	51
Sulphur	% m/m	0,001	<0.001	0	0,003	0,002	0,009	-	0,001	0,009	0,003
Ester content	% m/m	92,9	94,7	92,3	95,2	95	90,7	93,467	90,7	95,2	1,801
Monoglyceride	% m/m	0,74	0,76	0,51	0,63	0,63	0,35	0,603	0,35	0,76	0,153
Diglyceride	% m/m	0,2	0,12	0,1	0,1	0,09	0,08	0,115	0,08	0,20	0,044
Triglyceride	% m/m	0,12	0,07	0,04	0,01	0,01	0,02	0,045	0,01	0,12	0,043
Free Glycerol	% m/m	<0,01	0,019	0,03	0,005	0,004	<0,01	-	0,004	0,025	0,010

Emission factors PM

	Emission factor PM Total	
Fuel	Laboratory g/Gj	Field g/Gj
Natural Gas	< 0,1	< 0,1 – 0,45
Heating Gas oil	0,1 – 0,29	0,85 – 1,53
Water – gas oil emulsion	0,18 – 0,83	0,1 – 1,09
Biodiesel	0,1 – 0,19	0,1 – 0,14
Fuel Oil	5,79 – 5,88	5,12 – 7,32
Water–fuel oil emulsion	1,62 – 2,84	3,53 – 4,78
Fuel oil – biodiesel mix	2,67 – 3,40	3,47 – 3,99

Emission factors PM 10

	Emission factor PM 10	
Fuel	Laboratory g/Gj	Field g/Gj
Natural Gas	< 0,10	-
Heating Gas oil	0,10 – 0,14	-
Water – gas oil emulsion	0,20 – 0,80	-
Biodiesel	<0,1	-
Fuel Oil	2,90 – 4,83	-
Water – fuel oil emulsion	1,68 – 3,25	-
Fuel oil – biodiesel mix	2,67 – 3,03	-

Emission factors NOx

	Emission factor NOx	
Fuel	Laboratory g/Gj	Field g/Gj
Natural Gas	23 - 97	16 - 72
Heating Gas oil	37 – 51	54 - 69
Water – gas oil emulsion	38 – 47	40 – 52
Biodiesel	30 – 43	35 - 56
Fuel Oil	162 - 167	162 – 234
Water – fuel oil emulsion	136 – 144	178 – 214
Fuel oil – biodiesel mix	144 – 158	225 - 243

Emission factors CO

	Emission factor CO	
Fuel	Laboratory g/Gj	Field g/Gj
Natural Gas	1 – 31	4 - 24
Heating Gas oil	1,6 – 4,9	1,5 – 3,7
Water – gas oil emulsion	1 – 5	0,6 – 17,2
Biodiesel	0,8 – 9,50	0,9 – 67,6
Fuel Oil	3,2 – 3,5	1,8 – 4,3
Water – fuel oil emulsion	2,4 – 10,9	1,5 – 12,1
Fuel oil – biodiesel mix	3,5 – 1,7	1,1 – 1,2

Emission factors VOC

	Emission factor VOC	
Fuel	Laboratory g/Gj	Field g/Gj
Natural Gas	0,1 – 2,17	0,22 – 1,75
Heating Gas oil	0,1 – 0,4	0,1 – 0,17
Water – gas oil emulsion	0,1 – 0,29	0,1 – 0,63
Biodiesel	0,1 – 1,63	0,39 – 3,5
Fuel Oil	0,1 – 0,17	0,23 – 0,26
Water – fuel oil emulsion	0,17 – 0,44	0,12 – 0,23
Fuel oil – biodiesel mix	0,14 – 0,25	0,25 – 0,31

Emission factors updated

	PM (g/GJ)	PM 10 (g/GJ)	NO x (g/GJ)	CO (g/GJ)	CO 2 (Kg/GJ)	SO 2 (g/GJ)	VOC (g/GJ)
Natural Gas							
Laboratory	0,14	0,14	97,40	31,13	60,18	1,39	2,17
Field	0,45	-	72,32	24,43	56,87	1,39	1,75
Gheating gasoil							
Laboratory	0,29	0,14	51,40	4,86	73,02	45,30	0,40
Field	1,53	-	68,93	3,67	75,29	79,15	0,17
Water-gasoil emulsion							
Laboratory	0,83	0,80	46,95	5,02	78,26	15,30	0,29
Field	1,09	-	51,56	17,24	77,29	13,72	0,53
Biodiesel							
Laboratory	0,19	0,14	42,94	9,50	71,55	1,38	1,63
Field	0,14	-	56,41	67,59	73,56	1,58	3,50
Fuel Oil							
Laboratory	5,88	4,83	1.886,53	3,50	72,12	105,82	0,17
Field	7,32	-	232,61	4,28	75,72	115,50	0,26
Water-Fuel oil emulsion							
Laboratory	2,84	3,25	144,01	10,93	76,53	107,13	0,44
Field							
Biodiesel fuel oil mix							
Laboratory	3,40	3,03	158,25	3,51	73,36	96,03	0,25
Field	3,99	-	242,62	1,18	74,38	101,60	0,31

Main Conclusions

- In the recent years the contribution of the civil heating sector to the air pollution has been consistently reduced even if in some local situations is still high
- The combined effect of the technological development of the heating systems and the improvement of the fuels quality are the main reasons of this progress
- The design of the heating system (boiler power vs. building energy demand) remain one of the most important factors to improve energy efficiency and to reduce pollutant emissions

Main Conclusions

- The updated emission factors are among the most relevant results of the study
- The present legislation is extremely severe because based on the previous emission factors
- The PM emission factor used to develop the legislation for fuel oil was 40 g/GJ but the real factor derived from the current quality on the market is 6 g/GJ

Main Conclusions

- To properly assess the present emissions from civil sector and to quantify its real contribution to the global air pollution

  the new emission factors need to be used