AX-Consulting

Green Foundry LIFE project (LIFE17 ENV/FI/173)

Action B2 Total emissions and indoor air quality measurements of pilot foundries

Emissions and indoor air concentrations of different binder systems during full-scale test casts

De2A Results of emission and indoor air measurements of organic and inorganic binder system test casts in Valumehaanika foundry in Estonia

Author: AX-LVI Consulting Ltd
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Client	Valumehaanika AS Teguri 32 Tartu 51013 Estonia
Assignment	Measurement of emissions and indoor air concentrations from the casting mold
Measurement date and place	Tartu, 19.-24th of September 2021
Measurement staff	Pessi Suonpää and Seppo Heinänen
Report writer	Seppo Heinänen

On behalf of
AX-LVI Consulting Ltd
Environmental Engineering Department

Seppo Heinänen
Chief of the Department

Pessi Suonpää
Environmental Engineer

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1 Introduction

Valumehaanika AS (VM) is a small iron foundry locating in Tartu, Estonia. The foundry has been established in 1966 and itis has been recently renovated.

Figure 1. Overview of the foundry. At the back is the induction furnace and on the right the sand mixer.

VM has modern equipment, including a 3 years-old induction furnace with the melting capacity of 750 kg (figure 2) and a continuous mixer line, (figure 3).

Figure 2. Induction furnace


Figure 3. Modern continuous mixer.

The sand system at Valumehaanika is organic phenolic Alphaset binder system. The used silica sand is from Estonia. The moulds and cores are made by hand. Typical casting size varies between 5…100 kg, and the products are used in machines, generators, furnaces and other heating equipment. Total annual production is ca. 200 tons of castings, and work force is ca. 10 employees.

Emission measurements were carried out with different binder systems (one organic phenolic binder and two inorganic binder systems) in order to compare the results between different binders. Same production volumes, products and process conditions were used for each of these three emission measurements. Each binder system was used for castings for the whole day and emission were measured. Same was repeated with other tested binder systems in following days. Measurements were carried out at Valumehaanika on 19.-24.9.2021. The aim of the measurements was to find out the concentration of components, emissions and concentrations in indoor air.

Following binder systems were tested:

1) Alphaset = organic phenolic Alphaset binder
2) Peak = inorganic Cast Clean S 27 binder and Cast Clean K4…K6 hardeners, made by Peak Deutschland GmbH
3) Geopol = inorganic Geopol 618 binder and SA73 hardener, made by SandTeam

2 Measurement results

Emission measurement results are presented in APPENDIX1 and the indoor air concentrations in APPENDIX 2. Trends from the measurements are presented in APPENDICES 3-6. Test parameters are presented in the project deliverable DeB3A Inorganic binder system test casts in Valu-mehaanika Foundry in Estonia”.

3 Conclusions

The weight of the iron castings was 800 kg in each measurement and the sand amount was about 5000 kg. Measurement arrangements were principally same in each three measurement. However, it has to be noticed that there were background concentrations in the foundry hall which effected the results All unit process emissions were mixed in the room air because the foundry processes were in the same hall. The ventilation system was very primitive containing only a general ventilation (roof fans only). The binder system influence in the indoor air quality was affected by the unit processes (shake-out or demolishing activities) carried out in the same hall, and therefore the results were unillustrative and unclear.
Based on the results of the test carried out with iron castings and using inorganic binder system, the total emission measurements demonstrated about 50% less emission concentrations compared to the organic binder. Emission results from both the tested inorganic binders were similar. As a conclusion, emissions in the foundry were clearly reduced when implementing inorganic binders. All measurement results are presented in this report.

3.1. Emissions

3.1.1. Particles

Particulate matter emissions were about two times higher on organic Alphaset binder than on inorganic binders.

3.1.2. Carbon monoxide (CO)

Results show that there was a short-term high concentration of CO when the melt was poured and afterwards the concentrations started to reduce rapidly. Measured CO emissions were almost same with all binder systems.

3.1.3. Volatile Organic Compounds (VOC)

Highest VOC concentration was unexpectedly measured on Geopol inorganic binder and lowest on organic phenolic Alphaset binder. This is mainly due to ethanol and 2-propanol, which come from the coating not from binder systems.

3.1.4. BTEX

Emissions of BTEX compounds were approximately three times higher on Alphaset resin than on inorganic binder systems.

3.1.5. Sulphur dioxide (SO_2) and nitrogen oxides (NO_X)

During the measurements no significant concentrations of sulphur dioxide or nitrogen oxides were detected.

3.1.6. Phenols and cresols

During the measurements no significant concentrations of phenols and cresols were detected. The low phenol concentrations when using organic Alphaset binder system may result of the fact that the hall doors were occasionally left open during the measurement because of the transportation in the foundry hall.

3.1.7. Formaldehyde

Formaldehyde concentration was tree times higher on organic Alphaset binder than on inorganic binders.

3.2. Indoor air

3.2.1. Particles

Organic Alphaset binder particle concentration in indoor air was two times higher than on inorganic binders.

3.2.2. Volatile Organic Compounds (VOC)

VOC concentrations were almost the same with inorganic Geopol binder and with organic Alphaset binder and lowest with inorganic Peak binder. This is mainly due to ethanol and 2-propanol, which come from the coating not from binders.

3.2.3. BTEX

Emissions of BTEX compounds were approximately three times higher on organic Alphaset binder than on inorganic binders. Striking is the significantly higher benzene content on organic Alphaset binder.

3.2.4. Phenols and cresols

During the measurements no significant concentrations of phenols and cresols were detected.

3.2.5. Formaldehyde

Formaldehyde concentration was tree times higher on Alphaset resin than inorganic resins.

3.2.6. Quarts

Table 1. Measured quarts concentrations in indoor air

Binder	Measurement			Measured concentration	Part of limit(8h)-value
	date	start *time*	stop *time*	*mg/m³*	*%*
Alphaset	21.9.2021	11:00	12:49	0,18	358
Peak	22.9.2021	11:14	12:48	0,07	135
Geopol	23.9.2021	12:09	13:39	0,08	152

4 Procedure

4.1 Particles

Particle concentrations from the exhaust air were measured from samples taken with sond and pump in accordance with SFS-EN 13284-1 and SFS 3866 standards. Size of the sond and absorption rate were set so that the speed of the sample rate was as isokinetic with the speed of the exhaust air as possible. Uncertainty of concentration is ±15 %.

4.2 O_2, CO_2, CO, NO_x and SO_2

Sample from the exhaust air for the measurement of O_2, CO_2, CO, NO_x and SO_2 were taken with to the analyzers.

Uncertainty of the concentration is ±15 %.

4.3 Volatile Organic Compounds (VOC)

VOC measurement was made with the adsorption samples. Quantitative analysis from the hydrocarbon compounds was done one by one. Measurement was carried out in accordance with the SFS 3861 standard.

Tenax tube samples were analyzed by an accredited laboratory: Eurofins Environment Testing Finland, Lahti (FINAS T039)
Uncertainty of concentration is ±15 %.

4.4 Phenols

Phenols in the gas phase were collected from the exhaust air with the pump into the XAD-2-Supelco adsorption tubes. The analyses were carried out at an accredited laboratory: Eurofins Product Testing Denmark A/S (ISO 17025 DANAK) by Solvent Desorption/Gas Chromatography method.

4.5 Aldehydes

The aldehyde samples were taken from the exhaust air with the sample pump to the SepPAK-DNPH tubes. The analyses were carried out at an accredited laboratory: Eurofins Environment Testing Finland, Lahti (FINAS T039) by High Performance Liquid Chromatography (HPLC) method. Uncertainty of concentration is ±15 %.

4.6 Flow rate

The flow rate of the exhaust air was measured continuously with the pitot tube and the micromanometer. The result was calibrated with measuring the flow rate randomly from the exhaust air, using multi-point method with the micromanometer and the pitot tube, according to the SFS 5512 standard. The dry and wet temperatures were measured with the instant thermometer. Uncertainty of concentration is ±5 %.

The temperature was measured continuously with the thermoelement and the datalogger. Uncertainty of temperature is approximately ±1 °C.

5 Measurement equipment

The analyzer equipment and used standards and guidance, according to the measurements of the different components that were carried out, are presented in table 2.

Table 2. The measurement equipment, standards and guidance that were followed in the measurements.

Measurement method	Device mark	Measurement	Standard
CO SO2	Testo 300	Chemical cell	SFS 3869 SFS 5412 ISO 12039:2001
NOx	Testo 300	Chemical cell	SFS 3869 SFS 5425 SFS EN 14792:2005
SO2	Testo 300	Chemical cell	SFS 3869 ISO 7935:1992
Flow rate	Micromanometer and pitot-tube	Pressure difference	SFS 3866 SFS 3869 SFS EN 132844:2001
Temperature	Thermoelement	Voltage difference	SFS 3866 SFS 3869 SFS EN 132844:2002
VOC	Adsorption equipment	Adsorption	SFS EN 1948 SFS 3869
Phenols Aldehydes	Adsorption equipment	Adsorption	SFS EN 1948 SFS 3870
Particles	Particle measurem	Gravimetric	SFS EN 13284 SFS 3866 (adjusted)
H2O	Dry/wet temperature	Voltage difference	SFS 3866 SFS 3869 SFS EN 132844:2002

Binder type		Alphaset	Peak	Geopol
Casting quantity (kg)		800	860	800
Sand quantity (kg)		4800	5160	4800
Binder quantity (kg)		77,4	173,4	102,0
Exhaust air flow (Nm^3/s)		2,22	2,22	2,22
Concentration (mg/Nm^3)	Particles	7,23	3,62	3,22
	Total VOC	1,24	1,30	1,39
	BTEX	0,00	0,00	0,00
	Ethanol	0,15	0,15	0,16
	2-Propanol	<0,07	0,08	0,08
	Phenols	<0,04	<0,04	<0,05
	Cresols	0,08	0,08	0,08
	Asetaldehyde	0,03	0,06	0,09
	Formaldehyde	0,00	0,10	0,11
	Carbon monoxide	55,5	62,5	56,9
	NO_x	0,29	1,49	15,23
	SO_2	0,20	2,74	2,69
Emissions (g/h)	Particles	57,8	29,0	25,7
	Total VOC	9,9	10,4	11,1
	BTEX	0,00	0,00	0,00
	Ethanol	1,16	1,22	1,31
	2-Propanol	0,58	0,61	0,66
	Phenols	0,34	0,35	0,38
	Cresols	0,67	0,65	0,63
	Asetaldehyde	0,26	0,47	0,70
	Formaldehyde	0,00	0,77	0,89
	Carbon monoxide	444	500	455
	NOx	2,32	11,88	121,69
	SO2	1,58	21,89	21,51
Emissions per casting quantity (mg/kg)	Particles	72,2	33,7	32,1
	Total VOC	12,4	12,1	13,9
	BTEX	0,0	0,0	0,0
	Ethanol	1,5	1,4	1,6
	2-Propanol	0,7	0,7	0,8
	Phenols	0,4	0,4	0,5
	Cresols	0,8	0,8	0,8
	Asetaldehyde	0,3	0,6	0,9
	Formaldehyde	0,0	0,9	1,1
	Carbon monoxide	555	581	568
	NOx	2,9	13,8	152,1
	SO2	2,0	25,5	26,9
Emissions per sand quantity (mg/kg)	Particles	12,0	5,6	5,4
	Total VOC	2,1	2,0	2,3
	BTEX	0,0	0,0	0,0
	Ethanol	0,2	0,2	0,3
	2-Propanol	0,1	0,1	0,1
	Phenols	0,1	0,1	0,1
	Cresols	0,1	0,1	0,1
	Asetaldehyde	0,1	0,1	0,1
	Formaldehyde	0,0	0,1	0,2
	Carbon monoxide	92,4	96,9	94,7
	NOx	0,5	2,3	25,4
	SO2	0,3	4,2	4,5
Emissions per binder quantity (mg/kg)	Particles	746	167	252
	Total VOC	128	60	109
	BTEX	0	0,0	0,0
	Ethanol	15,0	7,1	13
	2-Propanol	7,5	3,5	6,4
	Phenols	4,3	2,0	3,7
	Cresols	8,7	3,7	6,2
	Asetaldehyde	3,4	2,7	6,9
	Formaldehyde	0,0	4,4	8,8
	Carbon monoxide	5 732	2 883	4 457
	NOx	30,0	68,5	1193,1
	SO2	20,4	126,2	210,9

Binder type		Alphaset	Peak	Geopol
Casting quantity (kg)		800	860	800
Sand quantity (kg)		4800	5160	4800
Binder quantity (kg)		77,4	173,4	102
Concentration (mg/m^3)	Particles	3,95	1,70	2,20
	Total VOC	4,30	3,17	4,43
	BTEX	1,54	0,36	0,38
	Ethanol	0,32	0,45	0,94
	2-Propanol	0,16	0,18	0,75
	Phenols	0,12	<0,08	<0,05
	Cresols	0,28	0,16	0,08
	Asetaldehyde	0,99	0,38	0,23
	Formaldehyde	0,18	0,00	0,00
	Qarts	0,18	0,07	0,08

VOC-concentrations in exhaust air

Binder		Alphaset	Peak	Geopol
Date		21.9.2021	22.9.2021	22.9.2021
Start		11:19:00	11:21:00	12:15:00
End		12:59:00	12:58:00	13:46:00
		Concentration		
VOC-compound	CAS-number	mg/Nm^3	mg/Nm^3	mg/Nm^3
Acetone	67-64-1	0,29	0,31	0,41
Benzofuran	271-89-6	<0,07	<0,08	<0,08
Benzene	71-43-2	0,66	<0,15	<0,08
Butans	106-97-8	0,07	0,46	0,41
Ethylacetate	141-78-6	<0,15	<0,15	<0,16
Ethylbenzene	100-41-4	<0,07	<0,08	<0,08
2-Ethyl-1-heksanol	104-76-7	<0,15	<0,15	<0,16
Ethanol	64-17-5	0,15	0,77	1,64
Ethyl hexyl asetate	103-09-3	<0,15	<0,15	<0,16
Glycyeryl triasetate	102-76-1	<0,15	<0,15	<0,08
3-Caren	498-15-7	<0,07	<0,08	<0,08
Xylene	1330-20-7	0,15	<0,08	<0,08
Methyl acetate	79-20-9	<0,15	<0,15	<0,33
2-Butanoni	78-93-3	<0,07	<0,08	<0,08
Alphapine	7785-70-8	<0,07	<0,08	<0,08
2-Propanol	67-63-0	0,07	0,46	0,82
Styrene	100-42-5	<0,07	<0,08	<0,08
Toluene	108-88-3	0,22	<0,08	<0,08
1,3,5-Trimethylbentsene	108-67-8	0,07	<0,08	<0,08
Other VOCs		0,07	<0,08	<0,08
Sum		**2,91**	**3,68**	**5,08**
Share of the compound		%	%	%
Acetone	67-64-1	10,0	8,3	8,1
Benzofuran	271-89-6	2,5	2,1	1,6
Benzene	71-43-2	22,5	4,2	1,6
Butans	106-97-8	2,5	12,5	8,1
Ethylacetate	141-78-6	5,0	4,2	3,2
Ethylbenzene	100-41-4	2,5	2,1	1,6
2-Ethyl-1-heksanol	104-76-7	5,0	4,2	3,2
Ethanol	64-17-5	5,0	20,8	32,3
Ethyl hexyl asetate	103-09-3	5,0	4,2	3,2
Glycyeryl triasetate	102-76-1	5,0	4,2	1,6
3-Caren	498-15-7	2,5	2,1	1,6
Xylene	1330-20-7	5,0	2,1	1,6
Methyl acetate	79-20-9	5,0	4,2	6,5
2-Butanoni	78-93-3	2,5	2,1	1,6
Alphapine	7785-70-8	2,5	2,1	1,6
2-Propanol	67-63-0	2,5	12,5	16,1
Styrene	100-42-5	2,5	2,1	1,6
Toluene	108-88-3	7,5	2,1	1,6
1,3,5-Trimethylbentsene	108-67-8	2,5	2,1	1,6
Other VOCs		2,5	2,1	1,6

Valumehaanika AS Tartu **VOC-concentrations in indoor air** **APPENDIX 4** 1/1

Binder		Alpahaset	Peak	Geopol
Date		21.9.2021	22.9.2021	22.9.2021
Start		11:06:00	11:14:00	12:09:00
End		12:49:00	12:48:00	13:39:00
		Concentration		
VOC-compound	CAS-number	mg/m^3	mg/m^3	mg/m^3
Acetone	67-64-1	0,45	0,42	0,53
Benzofuran	271-89-6	<0,08	<0,08	<0,09
Benzene	71-43-2	0,76	<0,08	<0,09
Butans	106-97-8	0,23	0,17	0,18
Ethylacetate	141-78-6	<0,15	<0,17	<0,18
Ethylbenzene	100-41-4	<0,08	<0,08	<0,09
2-Ethyl-1-heksanol	104-76-7	<0,15	<0,17	<0,18
Ethanol	64-17-5	0,30	0,42	0,88
Ethyl hexyl asetate	103-09-3	<0,15	<0,17	<0,18
Glycyeryl triasetate	102-76-1	<0,15	<0,17	<0,18
3-Caren	498-15-7	<0,08	<0,08	<0,09
Xylene	1330-20-7	0,23	<0,08	<0,09
Methyl acetate	79-20-9	<0,15	<0,17	<0,18
2-Butanoni	78-93-3	<0,08	<0,08	<0,09
Alphapine	7785-70-8	<0,08	<0,08	<0,09
2-Propanol	67-63-0	0,15	0,17	0,70
Styrene	100-42-5	<0,08	<0,08	<0,09
Toluene	108-88-3	0,38	<0,08	<0,09
1,3,5-Trimethylbentsene	108-67-8	0,15	<0,08	<0,09
Other VOCs		0,15	<0,08	<0,09
Sum		**4,01**	**2,95**	**4,13**
Share of the compound		%	%	%
Acetone	67-64-1	11,3	14,3	12,8
Benzofuran	271-89-6	1,9	2,9	2,1
Benzene	71-43-2	18,9	2,9	2,1
Butans	106-97-8	5,7	5,7	4,3
Ethylacetate	141-78-6	3,8	5,7	4,3
Ethylbenzene	100-41-4	1,9	2,9	2,1
2-Ethyl-1-heksanol	104-76-7	3,8	5,7	4,3
Ethanol	64-17-5	7,5	14,3	21,3
Ethyl hexyl asetate	103-09-3	3,8	5,7	4,3
Glycyeryl triasetate	102-76-1	3,8	5,7	4,3
3-Caren	498-15-7	1,9	2,9	2,1
Xylene	1330-20-7	5,7	2,9	2,1
Methyl acetate	79-20-9	3,8	5,7	4,3
2-Butanoni	78-93-3	1,9	2,9	2,1
Alphapine	7785-70-8	1,9	2,9	2,1
2-Propanol	67-63-0	3,8	5,7	17,0
Styrene	100-42-5	1,9	2,9	2,1
Toluene	108-88-3	9,4	2,9	2,1
1,3,5-Trimethylbentsene	108-67-8	3,8	2,9	2,1
Other VOCs		3,8	2,9	2,1
Sum		**100,0**	**100,0**	**100,0**

Aldehyde concentrations in exhaust air

Binder	Alphaset	Peak	Geopol
Date	21.9.2021	22.9.2021	23.9.2021
Time started	11:19:00	11:21:00	12:15:00
Time finished	12:59:00	12:58:00	13:46:00
Concentration	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*
Acetaldehyde	0,38	1,27	1,19
Bentsaldehyde	0,00	<0,01	0,00
Formaldehyde	0,10	0,19	0,18
Heksanale	0,00	0,00	0,00
2-Butanone	0,03	0,06	0,09
Acetone	0,37	0,59	0,50
Acrolein	0,00	0,10	0,11
Methacrolein	0,00	0,06	0,06
Butyraldehyde	0,00	0,04	0,04
Propionaldehyde	0,00	1,19	0,88
sum	0,9	3,5	3,0

Aldehyde concentrations in indoor air

Binder	Alphaset	Peak	Geopol
Date	21.9.2021	22.9.2021	23.9.2021
Time started	11:06:00	11:14:00	12:09:00
Time finished	12:49:00	12:48:00	13:39:00
Concentration	*mg/m³*	*mg/m³*	*mg/m³*
Acetaldehyde	0,9*	0,8*	0,4*
Bentsaldehyde	0,00	0,00	0,01
Formaldehyde	0,35	0,10	0,06
2-Butanone	0,06	0,04	0,04
Acetone	1,0*	0,4*	0,23
Acrolein	0,06	0,05	0,06
Propionaldehyde	0,18	0,00	0,00
Methacrolein	0,04	0,04	0,02
Butyraldehyde	0,07	0,00	0,02
Propionaldehyde	0,00	0,7*	0,29
Summa	0,00	0,00	0,00
sum	2,7	2,2	1,1
Part of compound	%	%	%
Acetaldehyde	34,5	38,3	35,6
Bentsaldehyde	0,0	0,0	0,5
Formaldehyde	13,2	4,8	5,7
2-Butanone	2,3	1,9	3,6
Acetone	36,8	17,7	20,6
Acrolein	2,3	2,5	5,2
Propionaldehyde	6,8	0,0	0,0
Methacrolein	1,6	1,7	1,5
Butyraldehyde	2,5	0,0	1,6
Propionaldehyde	0,0	33,0	25,8
Summa	0,0	0,0	0,0
sum	100,0	100,0	100,0

*Concentration exceeds maximum reference substance content used

Valu Mehaanika As

Tartu

Metal emissions 21.-23.9.2021

APPENDIX 7

Metal concentration

Binder	Particles	Ag	Al	As	B	Ba	Be	Cd	Co	Cr	Cu	Li	Mn	Mo	Ni	P	Pb	Rb
	mg/Nm³	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*
Alphaset	7,81	0,000	0,056	0,003	0,002	0,008	0,000	0,000	0,000	0,001	0,004	0,000	0,155	0,000	0,003	0,023	0,013	0,000
Alphaset	6,91	0,000	0,113	0,001	0,001	0,003	0,000	0,000	0,000	0,000	0,001	0,000	0,060	0,000	0,001	0,024	0,005	0,000
Average	7,23	0,000	0,085	0,002	0,002	0,005	0,000	0,000	0,000	0,001	0,002	0,000	0,107	0,000	0,002	0,023	0,009	0,000
Peak	3,62	0,000	0,033	0,001	0,001	0,007	0,000	0,000	0,000	0,001	0,001	0,000	0,098	0,000	0,001	0,008	0,008	0,000
Geopol	3,22	0,000	0,021	0,001	0,001	0,005	0,000	0,000	0,000	0,001	0,003	0,000	0,117	0,000	0,001	0,008	0,009	0,000
Inaccuracy (%)		±26	±31	±36	±41	±31	±41	±31	±21	±31	±26	±26	±16	±26	±21	±41	±26	±26

Metal concentration

Binder	Particles	Sb	Se	Sn	Sr	Th	Tl	U	V	Zn	Ca	Fe	K	Mg	Na	S	Si
	mg/Nm³	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*
Alphaset	7,81	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,04	0,11	0,41	0,09	0,32	0,07	0,05	0,34
Alphaset	6,91	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,03	0,10	0,36	0,08	0,28	0,06	0,04	0,30
Average	7,23	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,03	0,11	0,39	0,09	0,30	0,06	0,04	0,32
Peak	3,62	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,02	0,05	0,19	0,04	0,15	0,03	0,02	0,16
Geopol	3,22	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,02	0,05	0,17	0,04	0,13	0,03	0,02	0,14
Inaccuracy (%)		±31	±26	±26	±21	±26	±21	±26	±21	±26	±21	±16	±21	±41	±21	±21	±26

Hourly emissions

Binder	Air flow	Ag	Al	As	B	Ba	Be	Cd	Co	Cr	Cu	Li	Mn	Mo	Ni	P	Pb	Rb
	Nm³/s	*g/h*	*g/h*	*g/h*	*g/h*	*g/h*	*g/h*	*g/h*	*g/h*	*g/h*	*g/h*	*g/h*	*g/h*	*g/h*	*g/h*	*g/h*	*g/h*	*g/h*
Alphaset	2,2	0,0	0,4	0,0	0,0	0,1	0,0	0,0	0,0	0,0	0,0	0,0	1,2	0,0	0,0	0,2	0,1	0,0
Alphaset	2,2	0,0	0,9	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,5	0,0	0,0	0,2	0,0	0,0
Average	2,2	0,0	0,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,9	0,0	0,0	0,2	0,1	0,0
Peak	2,2	0,0	0,3	0,0	0,0	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,8	0,0	0,0	0,1	0,1	0,0
Geopol	2,2	0,0	0,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,9	0,0	0,0	0,1	0,1	0,0
Inaccuracy (%)	±5	±31	±36	±41	±46	±36	±46	±36	±26	±36	±31	±31	±21	±31	±26	±46	±31	±31

Hourly emissions

Binder	Air flow	Sb	Se	Sn	Sr	Th	Tl	U	V	Zn	Ca	Fe	K	Mg	Na	S	Si	Summa
	Nm³/s	*g/h*	*g/h*	*g/h*	*g/h*	*g/h*	*g/h*	*g/h*	*g/h*	*g/h*	*g/h*	*g/h*	*g/h*	*g/h*	*g/h*	*g/h*	*g/h*	*g/h*
Alphaset	2,2	0,0016	0,0009	0,0007	0,004	0,0004	0,0002	0,0002	0,0009	0,29	0,91	3,28	0,73	2,55	0,55	0,36	2,73	13,5
Alphaset	2,2	0,0014	0,0008	0,0006	0,003	0,0003	0,0002	0,0002	0,0008	0,26	0,81	2,90	0,64	2,25	0,48	0,32	2,42	11,8
Average	2,2	0,0015	0,0009	0,0007	0,003	0,0003	0,0002	0,0002	0,0009	0,27	0,86	3,09	0,69	2,40	0,51	0,34	2,57	12,7
Peak	2,2	0,0008	0,0004	0,0003	0,002	0,0002	0,0001	0,0001	0,0004	0,14	0,42	1,52	0,34	1,18	0,25	0,17	1,27	6,6
Geopol	2,2	0,0007	0,0004	0,0003	0,001	0,0001	0,0001	0,0001	0,0004	0,12	0,37	1,35	0,30	1,05	0,22	0,15	1,12	6,0
Inaccuracy (%)		±36	±31	±31	±26	±31	±26	±31	±26	±31	±26	±21	±26	±46	±26	±26	±31	

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Exhaust air O_2-, CO-concentration and temperature 21.9.2021

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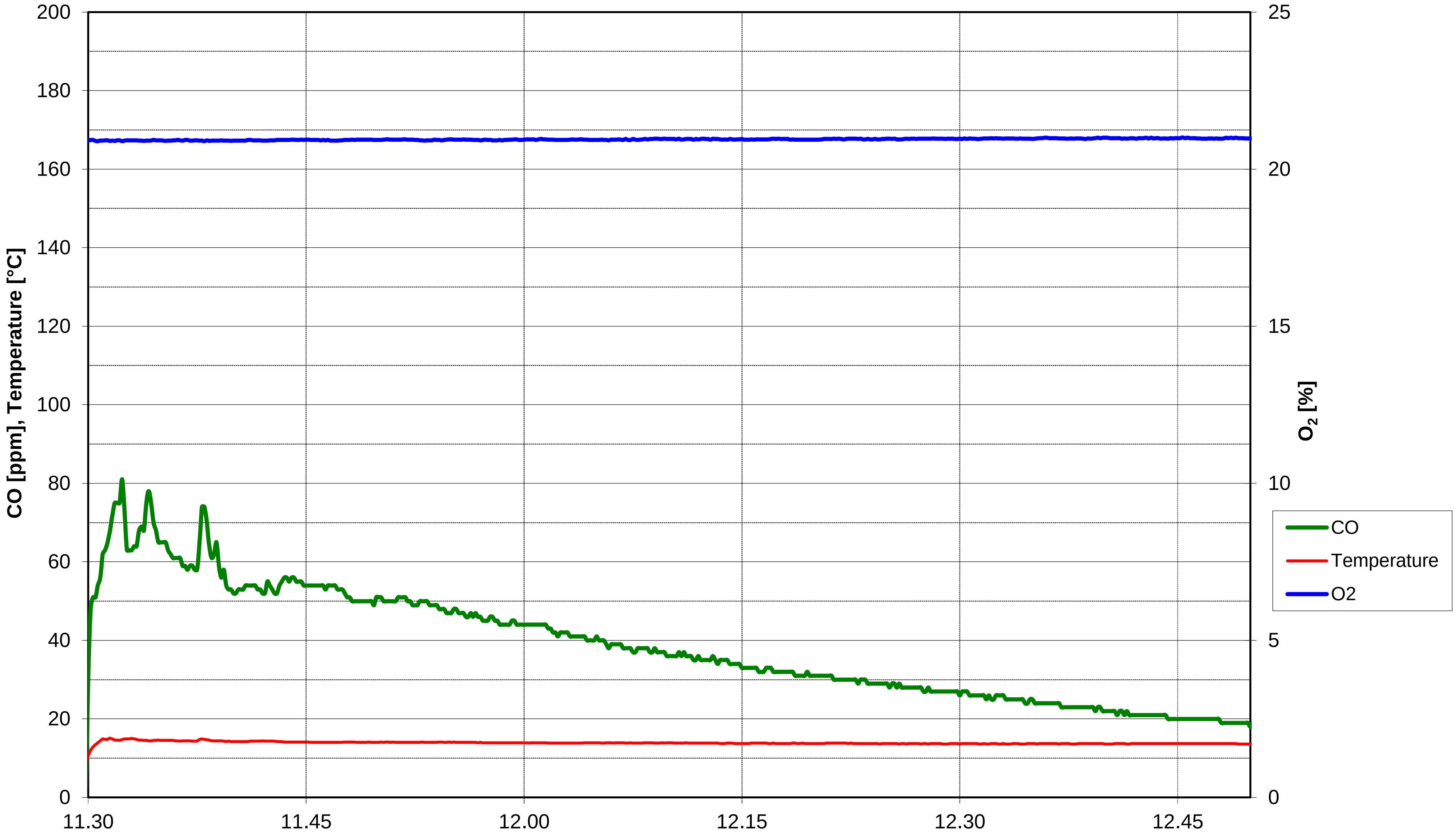

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Exhaust air O2-, CO-concentration and temperature 22.9.2021

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Exhaust air O2-, CO-concentration and temperature 23.9.2021

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