AX-Consulting

REPORT

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

Action B2 Total emission measurements at pilot foundries

De.B2C Results of total emission measurements in organic binder system Karhula Foundry in Finland

“The publication reflects only the Author´s view and that the Agency/commission is not responsible for any use of that may be made of the information contains.”

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Client	Karhula Foundry Pajatie 91 48600 Kotka Finland
Assignment	Emmission measurement at Karhula Foundry
Measurement date and place	Kotka, April 24-25th 2019
Measurement staff	Perttu Kriikku, Pauli Pellikka and Valtteri Shemeikka,
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On behalf of
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Environmental Engineering Department

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1 Introduction

The goal of the Green Foundry Project is to demonstrate the new clean technology molding systems in practice. The new inorganic molding system is based on the use of aluminum phosphate or silicate basis, which emits reduced amount of harmful components indoors, to the environment or via foundry sand. The techniques and methods demonstrated in the project are to improve the EU-wide uptake of more environmentally friendly casting processes. The demonstrations will be carried out on a transnational level to increase the dissemination and awareness of the project.

Karhula Foundry Oy is ferrous foundry that produces demanding cast components for process industry, mining, marine, energy and general engineering. The production began at Karhula in 1880's. The melting capacity consists of 8 tons arc furnace and 8 tons, 1,5 ton and 0,5 ton induction furnaces. Karhula Foundry has an 8 tons AOD (Argon Oxygen Decarburization) converter for metal treatment. Karhula Foundry produces high alloyed steels such as duplex, martensite, ferritic and austenitic stainless steel, super-austenitic steel, heat, wear and corrosion resistant steels and low alloyed steel. Karhula Foundry produces also ductile iron, ADI iron (Austempered Ductile Iron) and special alloyed iron. Typical products are pumps and valves, coilers, gear wheels, segments castings. The binder system for moulds is Alphaset. The cores are made by using Alphaset, Betaset or Cold-Box binder systems. All these methods are based on phenolic resin binders.

The sand used for moulds and cores is high quality silica sand. Some chromite sand is used for the surface part of moulds, when an excellent heat resistance is needed.

The painting of the moulds and cores is made by zircon-based coatings.
The weight range of the castings is between 1 kg to 30 tons.

Karhula Foundry has two mechanical moulding lines for small and medium size castings and a hand moulding for the bigger moulds.

The pouring of the metal into moulds is made from pre-heated ladles. Cooled moulds are shaken out by vibration. The feeders are removed by cutter, arc-air or powder cutting methods. The surfaces of the castings are refined by steel shot blasting. Karhula Foundry has 10 furnaces and 2 quenching pools for different heat treatments.

Annual production capacity is 3500 tons of steel castings, but the production in recent years has been 2000..3000 tons. The foundry has about 80 employees.

1.1 Primary processes of the Karhula Foundry Ltd.

Mold cores are primarily made of extremely pure quartz sand (SiO_2). Chromite sand (Cr_2O_3) is used in smaller quantities in mold cores when higher heat tolerance is required. Sand is dried, cooled and dust is removed before mixing the sand and adhesive in a sand mixer. Most of the sand is recycled from the casting process.

Casting molds and some of the mold cores are primarily produced by Alphaset ® -method, where Quartz or Chromite sand is mixed with phenol resin and ester hardener in a closed mixer. The sand-adhesive mixture is pressed either manually or mechanically on a casting model and dried. After the model is removed a Zircon-based surface agent is applied to the mold surface in order to improve heat tolerance of the casting molds. After casting and cooling the molds are removed in a closed, under pressured vibrator/shake-out containers that have separate dust exhaust system and sand collection system, where the used sand is crushed, screened and pneumatically moved to storage silos for recycle.

Casting molds are also produced by Cold-Box method, where sand is mixed with phenol resin, MDI-isocyanate and iron powder in a closed mixer. The sand-adhesive mixture is blown into a casting mold box with pressurized air. Heated DMEA (Dimethyl diamine) gas is then blown through the tightly formed mold in order to cause the phenol resin and MDI-isocyanate to react and form solid urethane resin that binds the sand granules. Casting mold boxes are dried, and a Zircon-based surface agent is applied before casting. Odorous amine fumes that form within the closed Cold-Box process are washed with Sulfuric acid solution in an amine scrubber that operates by reverse-flow principal.

Melting is done in load-operated electric arc furnace (8 tons) and mid-frequency induction furnaces (0,5 tons, 1,5 tons and 8 tons). The melt contains primarily scrap iron and ferro mixtures as 85-90 % of the melt load is recycled material. The melt can also be processed in AOD (Argon-Oxygen-Decarburization) converter (8 tons), where cheaper raw-materials containing more carbon can be used. Each of the furnaces and the converter are equipped with fume- and dust extraction hoods, that collect to the smelter filter unit.

Melted steel or cast iron is casted to molds by fireproof crucibles that are pre-heated by Methane-Oxygen burners. After the cast some of the adhesives of the molds and casting molds are vaporized to the indoor air and the fumes collected by the general ventilation of the foundry building. Indoor air quality of the foundry is measured regularly by mandatory occupational hygiene measurements. Indoor air quality is also monitored by automatic Carbon Monoxide (CO) and natural gas detectors.

The cast articles are cleaned in a closed shot blasting machines that are equipped with filters. Cast residuals are removed either by closed abrasive cutoff machines, or in closed cutoff cells equipped with filter units by powder- and Arc-Air methods that produce large amounts of metallic fumes and dust.

1.2 Foundry Emissions

The term emission refers to transmission of material and energy from a source to the environment. The foundry´s emission sources consist of several pipes and exhaust vents from the processes as well as ventilation hatches and extraction outlets, mostly located on the roof of the building. Emissions are monitored regularly by mandatory measurements. Permitted emission levels are defined by the current Finnish environmental legislation and the environmental permit of the foundry.

In the environmental permit of Karhula foundry (2008) there are only limit values for particles. Limit value for particles from melting shop and fettling shop after treatment is 10 mg/m^3 (n). The limit value for particles from core demolishing, sand reclamation and centrifugal blast cleaning after treatment is at maximum of 20 mg/m^3 (n).

2 Measurement Results

Measurement results are presented in APPENDICES 1-15.

Based on the emission measurement results carried out on 24-25th of April 2019, the concentrations did not exceed the limit values set for particles. Particles from melting shop, vibrator, core making, cooling line/pouring line and sand reclamation were under the limit values. Highest particle concentration was measured in the sand reclamation 14,1 mg/Nm^3.

There are no limit value for VOC emissions and concentrations varied between 0,7-16,3 mg/Nm^3 in different measurement points. The highest VOC concentration was measured in cooling/pouring line (16,3 mg/Nm^3).

3 Production During the Measurements

The measurements were carried out during two normal production days. The production amounts according to the information provided by the melting shop operators are presented in Table 1.

Table 1. Production amounts during the measurements
.

		Melted	Casted	
Date	*Time (casting)*	*kg*	*kg*	*note*
Apr.24th	10:00-10:15	1900	1200	
	12:40-12:55	1900	1900	
	16:10-16:25	1680	1460	
	19:10-19:15	602	292	
Apr.25th	11:00	1800	1800	
	11:00-11:15		30	Chamber Test
	14:00-14:20	9900	6800	
	14:45-14:55	1800	1800	

4 Measurement Staff

The measurements were executed by Mr. Perttu Kriikku (B.Sc. Chemical Engineering), Mr. Pauli Pellikka (B.Sc. Chemical Engineering) and Mr. Valtteri Shemeikka (B.Sc. Bioproduct and Process Engineering) from AX-LVI Consulting Ltd.

Senior Expert Mr. Markku Tapola from AX-LVI Consulting Ltd. was supervising the chamber test.

Mr. Pekka Kemppainen represented the client concerning measurement arrangements at Karhula Foundry.

5 Procedure

5.1 Foundry Emissions

5.1.1 Odour

The odour samples were taken in sample bags from the exhaust air during normal process operation. The sampling points of the emission flows were chosen to represent the average odour of the production area or process in question. The odour samples were taken in accordance with the EN 13725:2003 standard[2].

The strength of the odour was determined by an odour panel and dynamic olfactometric analyses according to standard EN 13725:2003. In the method, the odour concentrations ou_E/m^3 (ou=odour unit) were measured by the dilution of the odour sample to the odour threshold, where the numerical value of the odour concentration is equal to the dilution factor that is necessary to reach the odour threshold. The odour panel was comprised of 4 persons from AX-LVI Consulting Ltd. The suitability of personnel who participated in the odour panel had been determined according to standard practice using n-butanol. The odour emissions of the foundry were calculated based on the determined odour concentrations and airflow of the area or process in question.

5.1.2 TVOC

TVOC concentrations (methane equivalent concentration, ppm) were measured continuously with flame ionization detector analyzer (FID). The FID analyzer was calibrated during the measurements with zero and span gases. The FID measurements were carried out in accordance with the USA Environmental Protection Agency (EPA) Method 25.

The analysers' results were double-checked, and the concentration response was calculated for the devices by taking samples from measured gases simultaneously into adsorption tubes via a condenser and analysing different hydrocarbon compounds from the condensate as well as adsorption tube by gas chromatography. The samples were used to derive multiplying factors to make the methane equivalent response (ppm) of the analysers reflect the true VOC concentration (mg/Nm^3). Standards SFS 3869 and SFS 3861 were applied in adsorption tube measurement.

At the same time, a silica sample tube was taken from the exhaust air from which the Total Volatile Organic Carbon (TVOC) concentrations were analyzed by an accredited laboratory. In the analysis, the sample oxidated at a temperature of at least 600 °C and the CO_2 - gas discharge during oxidation was detected. The sampling was carried out in accordance with the SFS 3869 standard.

5.1.3 Hydrocarbons

Hydrocarbons were measured from a sample taken with an activated charcoal sample tube from the exhaust air with a pump. The hydrocarbon compounds were detected with GC-MS-analysis in an accredited laboratory. The measurements were carried out in accordance with the SFS 3869 standard.

5.1.4 Carbon Monoxide (CO)

CO concentrations were measured continuously with an electrochemical measurement cell. The measurements were carried out in accordance with the SFS 3869 standard.

5.1.5 Sulphur Dioxide (SO_2)

SO_2 concentrations were measured continuously with an electrochemical measurement cell. The measurements were carried out in accordance with the SFS 3869 standard.

5.1.6 Aldehydes

The concentrations of aldehydes were measured from a sample taken with a Sep-Pak sample tube from the exhaust air with a sample pump. The measurements were carried out in accordance with the SFS 3869 standard. The analyses were carried out at an accredited laboratory by liquid chromatograph method.

5.1.7 Phenols and cresols

The concentrations of phenols and cresols were measured from a sample taken with an SepPak-adsorptiontubes with a sample pump. The analyses were carried out at an accredited laboratory by liquid chromatograph method. The measurements were carried out in accordance with the SFS 3869 standard.

5.1.8 Dust

The dust concentrations were measured from samples. Analyses were carried out by gravimetric method in AX lab.

5.1.9 Flow rate

The flow rates of the exhaust air were measured with a pitot tube and a micromanometer according to the ISO 10780 standard. The humidity was calculated with dry/wet temperature measurements.

6 Measurement Equipment

Sample pumps and probes
Micromanometer: A021-11
Pitot probes: L081-11, LVI-1000
Thermoanemometer: TA440
Absolute pressure meter: A025-4
Condition meter: T&D TR-76Ui-H (temperature, CO_2, relative humidity)
Pressure difference transmitter: HK-Instruments DPT250-R8-AZ-D

7 Uncertainty of the Measurements

Uncertainty of the measurements are presented with the results.

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Finland

Summary of results

Measuring points		Sand reclamation	Vibrator	Core making, before amine gas scrubber	Core making, after amine gas scrubber	Cooling line, pouring	Melting shop	**Total sum**
Date		24.4.2019	24.4.2019	24.4.2019	24.4.2019	24.4.2019	25.4.2019	
Flow rate	*Nm³/h*	48 577	35 759	8 747	8 747	23 337	54 782	
Particles								
Concentration	*mg/Nm³*	14,1	0,09	1,00		0,74	3,9	
Hourly emission	*kg/h*	0,68	0,0032	0,01		0,02	0,21	0,93
TVOC								
Concentration	*mg/Nm³*	2,4	1,3	0,7	0,7	16,3	0,2	
Hourly emission	*kg/h*	0,12	0,0	0,0	0,01	0,4	0,01	0,6
Formaldehyde								
Concentration	*mg/Nm³*	0,22	0,26	0,24	0,25	0,31	0,17	
Hourly emission	*kg/h*	0,01	0,01	0,00	0,00	0,01	0,01	0,04
Other aldehydes								
Concentration	*mg/Nm³*	<0,32	<0,41	<0,33	<0,87	<0,55	<0,19	
Hourly emission	*kg/h*	<0,015	<0,01	<0,00	<0,01	<0,01	<0,01	0,06
Phenol								
Concentration	*mg/Nm³*	0,02	<0,01	0,03	0,05	0,12		
Hourly emission	*kg/h*	0,001	<0,0002	0,0002	0,0004	0,003		0,005
Creosols								
Concentration	*mg/Nm³*	<0,02	<0,03	<0,02	<0,01	0,2		
Hourly emission	*kg/h*	<0,001	<0,001	<0,0001	<0,0001	0,005		0,01
SO_2								
Concentration	*mg/Nm³*	0,000	0,000	0,000	0,000	<0,35	0,32	
Hourly emission	*kg/h*	0,00	0,00	0,00	0	0,008	0,02	0,03

**CO and SO_2 emissions
defined by chemical cell analyzer**

Measuring points		Sand reclamation	Vibrator	Core making, before amine gas burner	Cooling line, pouring	Melting shop
Date		24.4.2019	24.4.2019	24.4.2019	24.4.2019	25.4.2019
Time started		8:20	10:05	12:00	15:18	8:53
Time finished		10:05	11:05	14:00	18:15	14:00
Concentration						
Carbon monoxide (CO)	*mg/Nm³*	1,2	2,7	2,0	18,3	25,5
Sulphur dioxide (SO_2)	*mg/Nm³*	0,0	0,0	0,0	0,4	0,3
Flow rate	*Nm³/h*	48 763	35 881	8 834	23 455	54 988
Hourly emission						
Carbon monoxide (CO)	*kg/h*	0,1	0,1	0,0	0,4	1,4
Sulphur dioxide (SO_2)	*kg/h*	0,00	0,00	0,00	0,01	0,02

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Measured particle concentrations and emissions

Appendix 3

Measuring point	Day	Starting	Ending	Concentration	Flow rate	Emission	
				mg/Nm³	*Nm³/s*	*mg/s*	*g/h*
Sand reclamation	24.4	8:26	9:21	3,36			
	24.4	9:23	10:50	20,8			
	average			14,1	13,49	190	684
Vipration	24.4	9:44	10:33	0,07			
	24.4	10:34	11:06	0,12			
	average			0,09	9,93	0,9	3,2
Core making before amine scrubber	24.4	11:59	14:00	1,00	2,43	2,4	8,7
Cooling line, pouring	24.4	16:15	17:11	1,18			
	24.4	17:48	18:16	0,35			
	average			0,74	6,48	4,8	17,2
Melting shop	25.4	9:04	11:21	3,91	15,22	59,5	214,3

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Phenol and cresols compounds defined from adsorption samples

Measuring points	Sand reclamation	Vibrator	Core making, before amine	Core making bfter amine	Cooling line, pouring	Melting shop
Time started	8:58:00	9:49:00	12:15:00	13:35:00	16:18:00	9:01:00
Time finished	10:07:00	11:03:00	14:00:00	14:39:00	18:18:00	14:00:00
Concentration	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*
Phenol	0,02	<0,01	0,03	0,05	0,12	na
o-Cresole	<0,01	<0,01	<0,01	<0,00	0,14	na
p-Cresole	<0,02	<0,02	<0,01	<0,01	0,06	na
Cresols total	<0,02	<0,03	<0,02	<0,01	0,20	na
sum	**0,04**	**<0,04**	**0,04**	**0,06**	**0,32**	**0**
Part of compound	*%*	*%*	*%*	*%*	*%*	*%*
Phenol	42,3	16,7	64,3	78,3	37,1	na
o-Cresole	19,2	27,8	11,9	7,2	42,9	na
p-Cresole	38,5	55,6	23,8	14,5	20,0	na
sum	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**	**0,0**

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Aldehyde compounds defined from adsorption samples

Measuring points	Sand reclamation	Vibrator	Before amine gas scrubber	Atrer amine gas scubber	Cooling line, Pouring	Melting shop
Time started	8:50:00	9:49:00	12:15:00	13:35:00	16:18:00	9:01:00
Time finished	10:41:00	11:03:00	14:00:00	14:39:00	18:18:00	14:00:00
Concentration	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*
Acetaldehyde	<0,08	<0,08	<0,08	<0,44	<0,32	<0,09
Bentsaldehyde	<0,01	<0,02	<0,01	<0,02	<0,01	<0,00
Butanale	0,15	0,16	0,14	0,27	0,10	0,07
Dekanale	<0,01	<0,02	<0,01	<0,02	<0,01	<0,00
Formaldehyde	0,22	0,26	0,24	0,25	0,31	0,17
Heksanale	<0,01	<0,02	<0,01	<0,02	<0,01	<0,00
Heptanale	<0,01	<0,02	<0,01	<0,02	<0,01	<0,00
Nonale	<0,01	<0,02	<0,01	<0,02	<0,01	<0,00
Oktanale	<0,01	<0,02	<0,01	<0,02	<0,01	<0,00
Pentanale	<0,01	<0,02	<0,01	<0,02	<0,01	<0,00
Propanale	<0,01	<0,02	<0,01	<0,02	0,05	<0,00
sum	**0,5**	**0,7**	**0,6**	**1,1**	**0,9**	**0,4**
Sum-formaldehyde	0,32	0,41	0,33	0,87	0,55	0,19
Part of compound	*%*	*%*	*%*	*%*	*%*	*%*
Acetaldehyde	14,3	12,3	13,9	38,7	37,0	24,6
Bentsaldehyde	2,2	3,1	2,5	1,8	1,5	1,1
Butanale	27,5	24,6	24,1	24,3	11,1	19,0
Dekanale	2,2	3,1	2,5	1,8	1,5	1,1
Formaldehyde	40,7	38,5	41,8	22,5	36,3	47,5
Heksanale	2,2	3,1	2,5	1,8	1,5	1,1
Heptanale	2,2	3,1	2,5	1,8	1,5	1,1
Nonale	2,2	3,1	2,5	1,8	1,5	1,2
Oktanale	2,2	3,1	2,5	1,8	1,5	1,1
Pentanale	2,2	3,1	2,5	1,8	1,5	1,1
Propanale	2,2	3,1	2,5	1,8	5,3	1,1
sum	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**

Odor emissions 24.-25.4.2019

Measuring point	Odor consentration	air flow	Odor emission
	ou_E/m^3	*m^3/s*	*ou_E/s*
Vipration	28	9,9	278
Amine scrubber	40	2,43	97
Core makeing	38	6,48	246

Karhula Foundry Ltd
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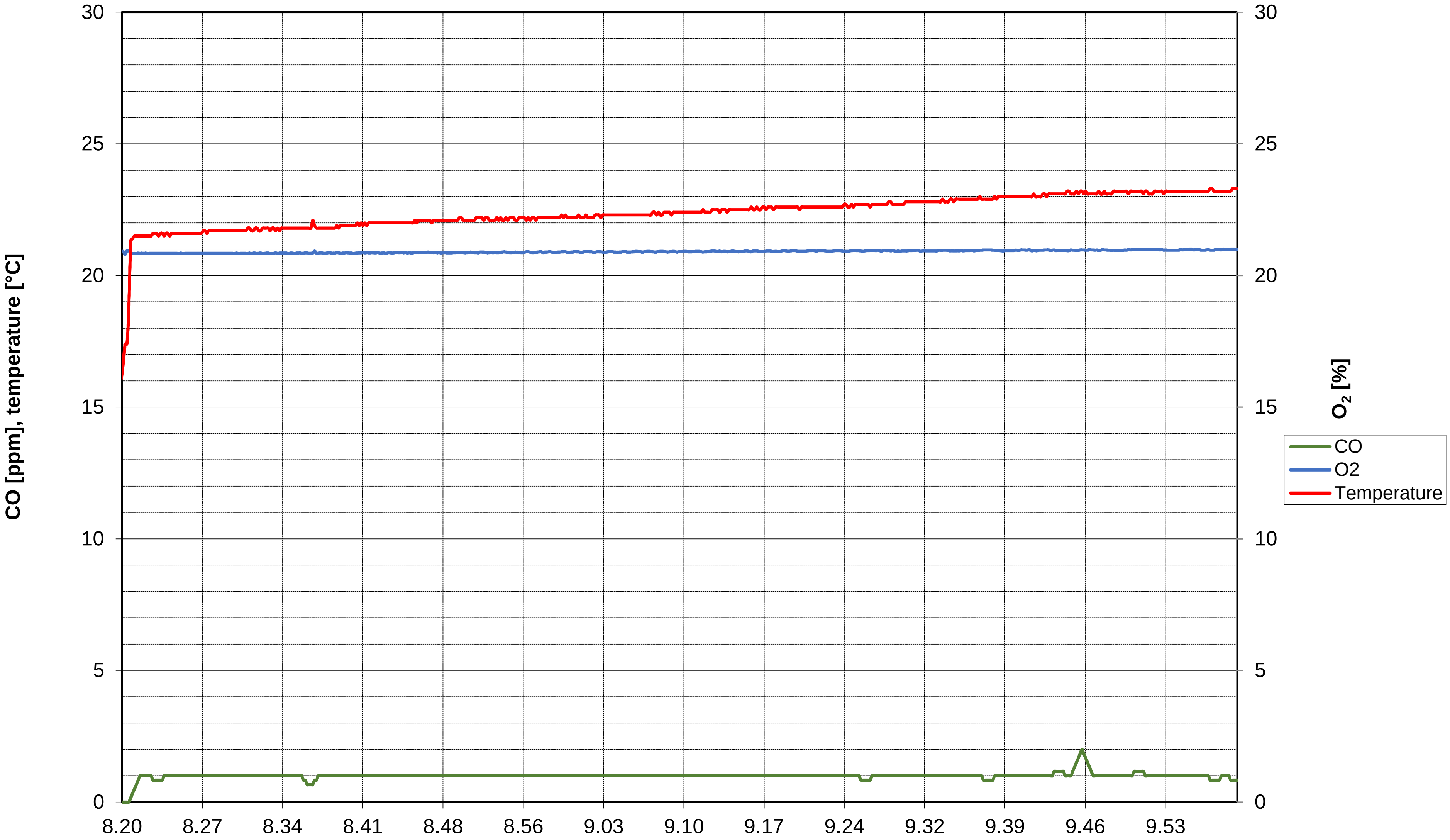
Sand reclamation O_2- and CO- concentration and temperature 24.4.2019

APPENDIX 7 1/1



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Karhula Foundry Ltd **Cooling line and pouring O_2- and CO- concentration and temperature 24.4.2019** **APPENDIX 8** 1/1
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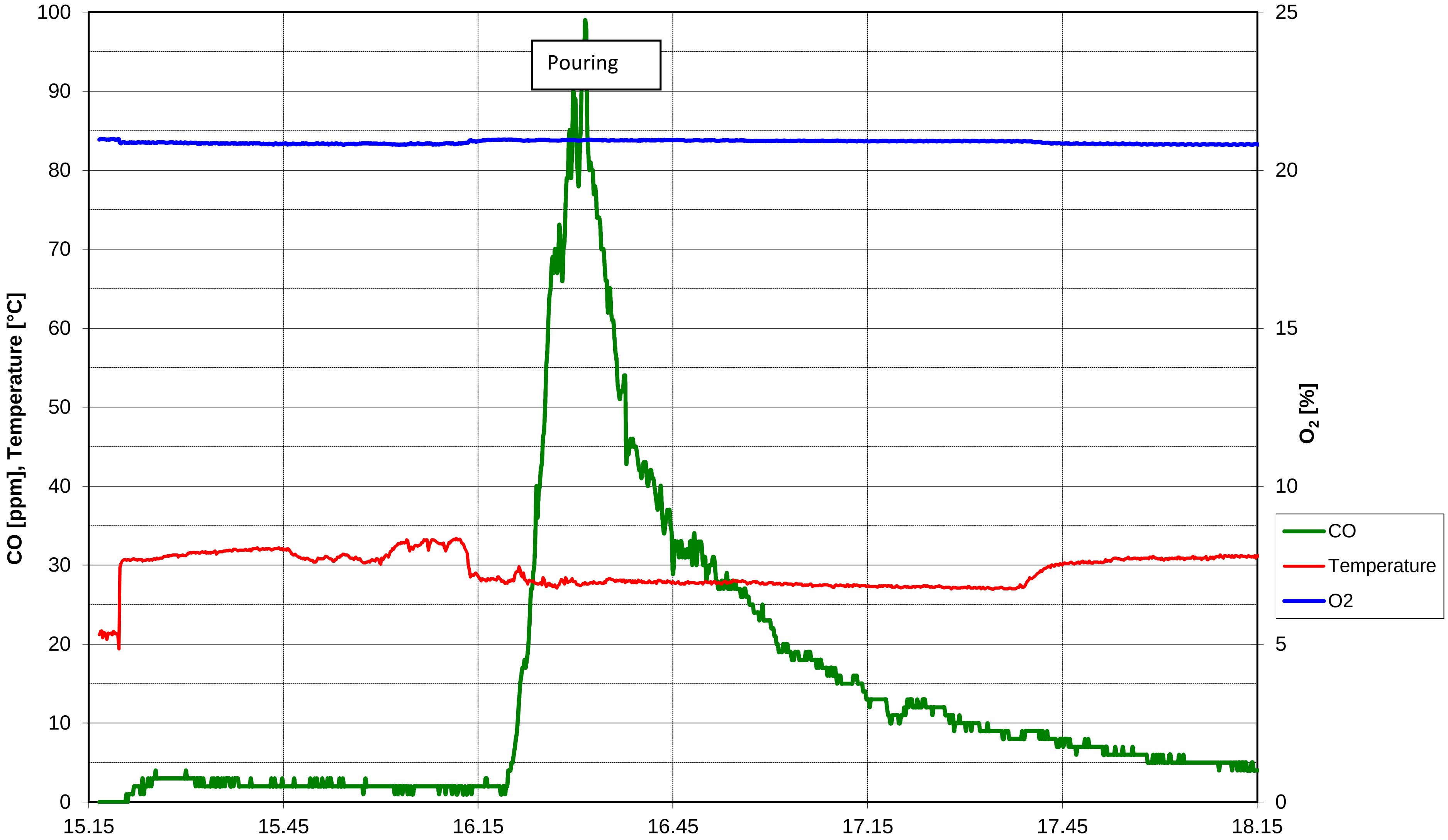

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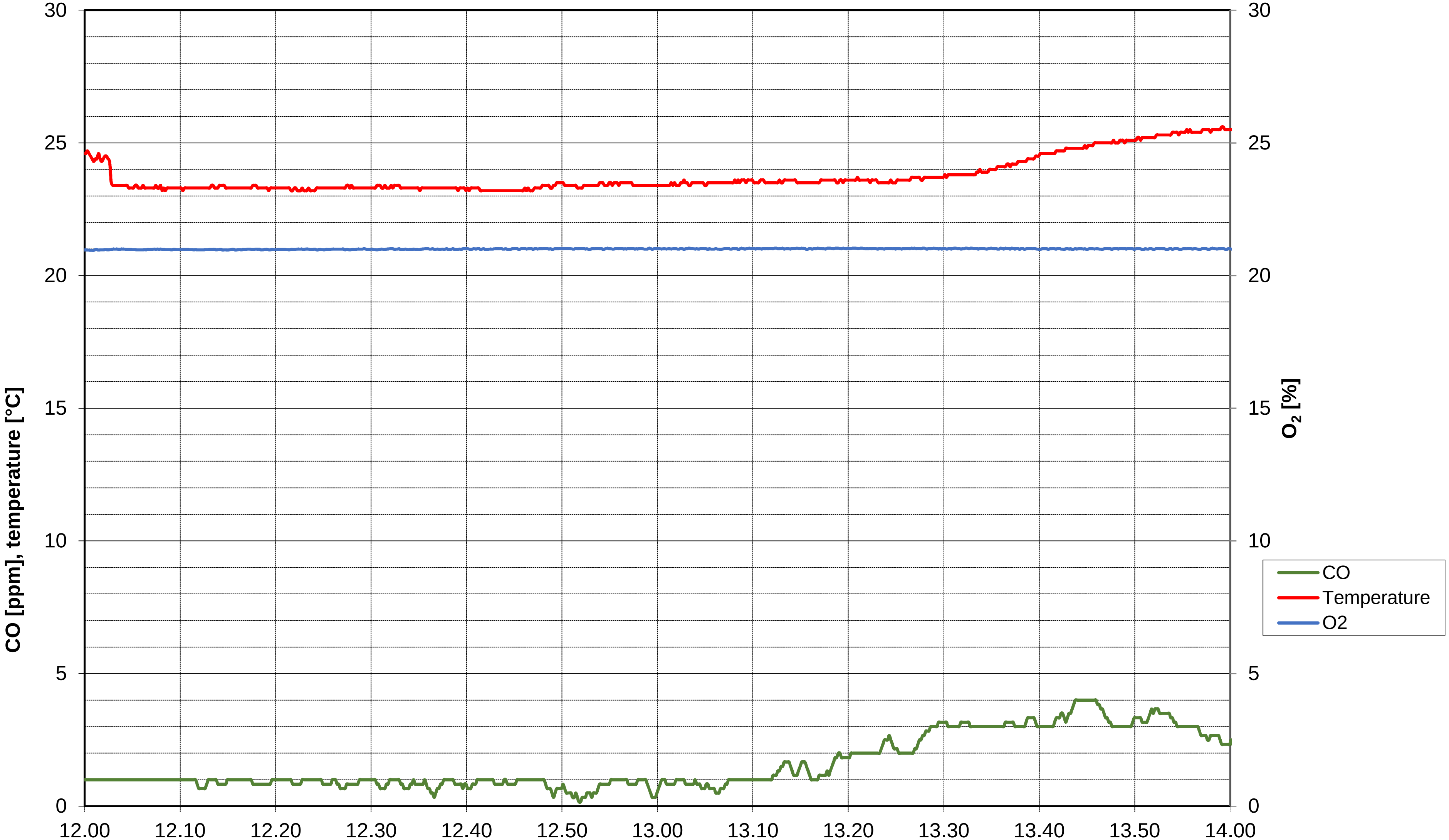
Amine srubber O_2- and CO-concentration and temperature 24.4.2019

APPENDIX 9 1/1



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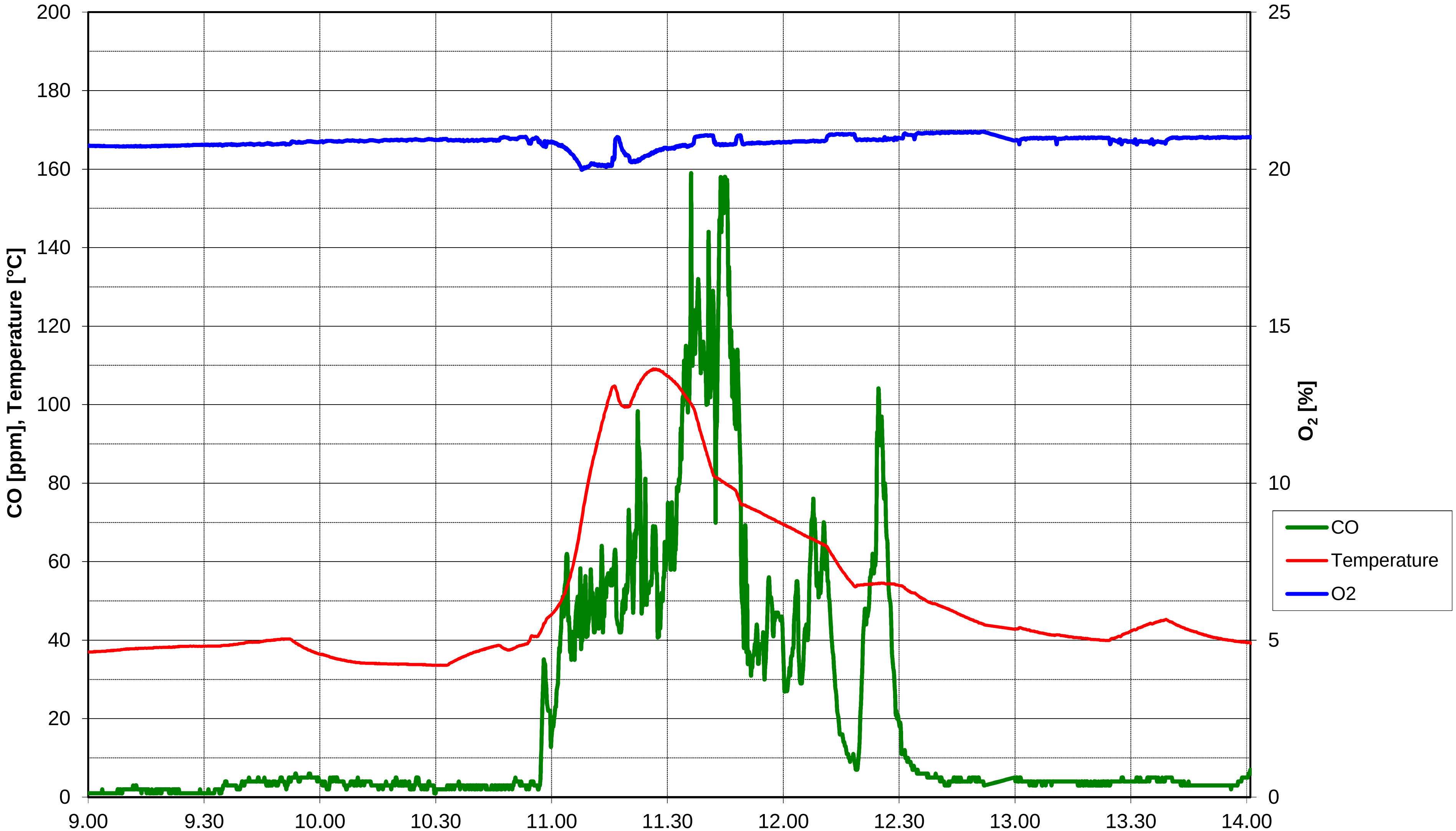
Melting shop O_2-, CO-concentration and temperature 25.4.2019

APPENDIX 10 1/1



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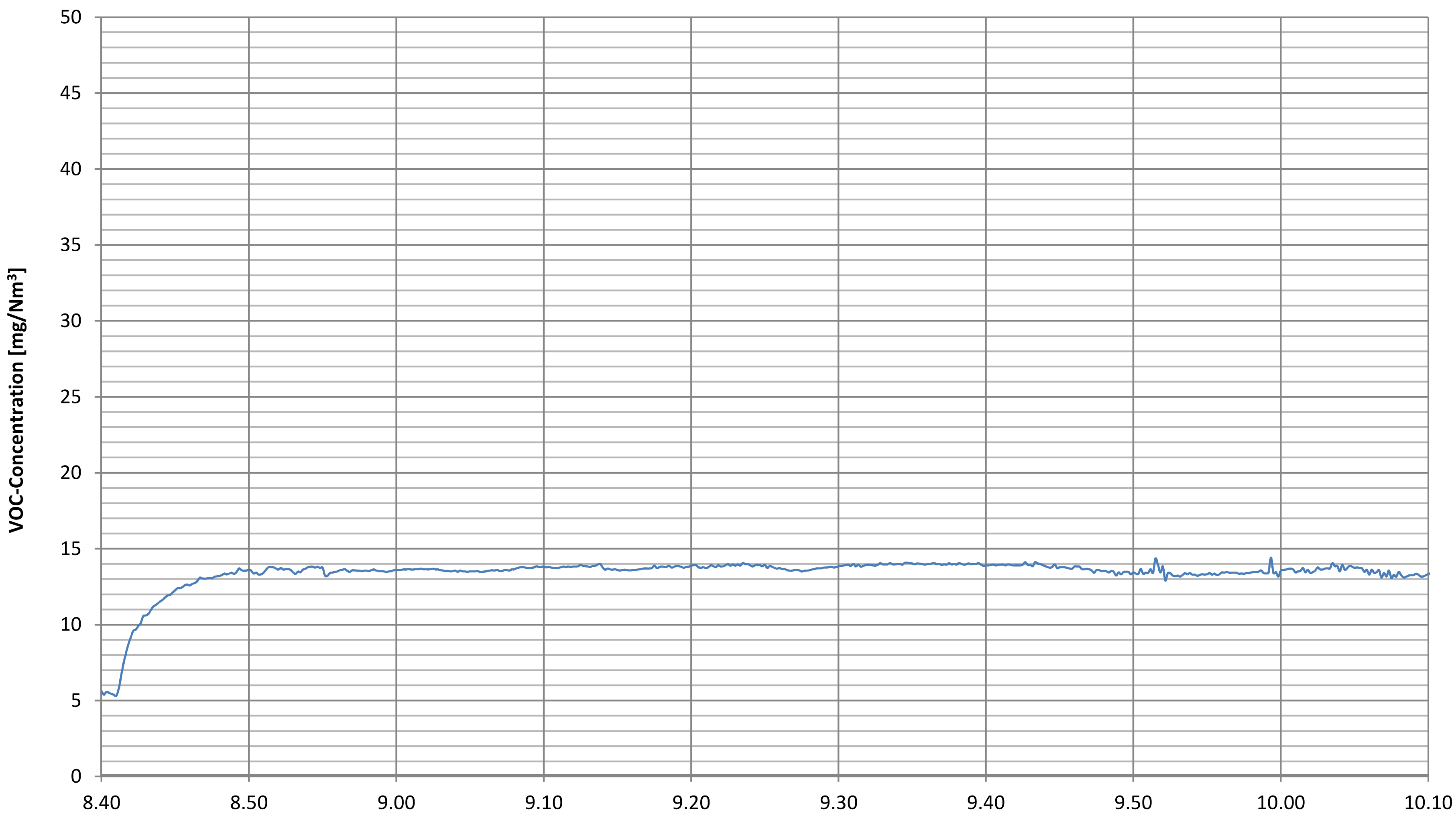
Sand reclamation VOC-concentration 24.4.2019

APPENDIX 11 1/1



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Vipration VOC-concentration 24.4.2019

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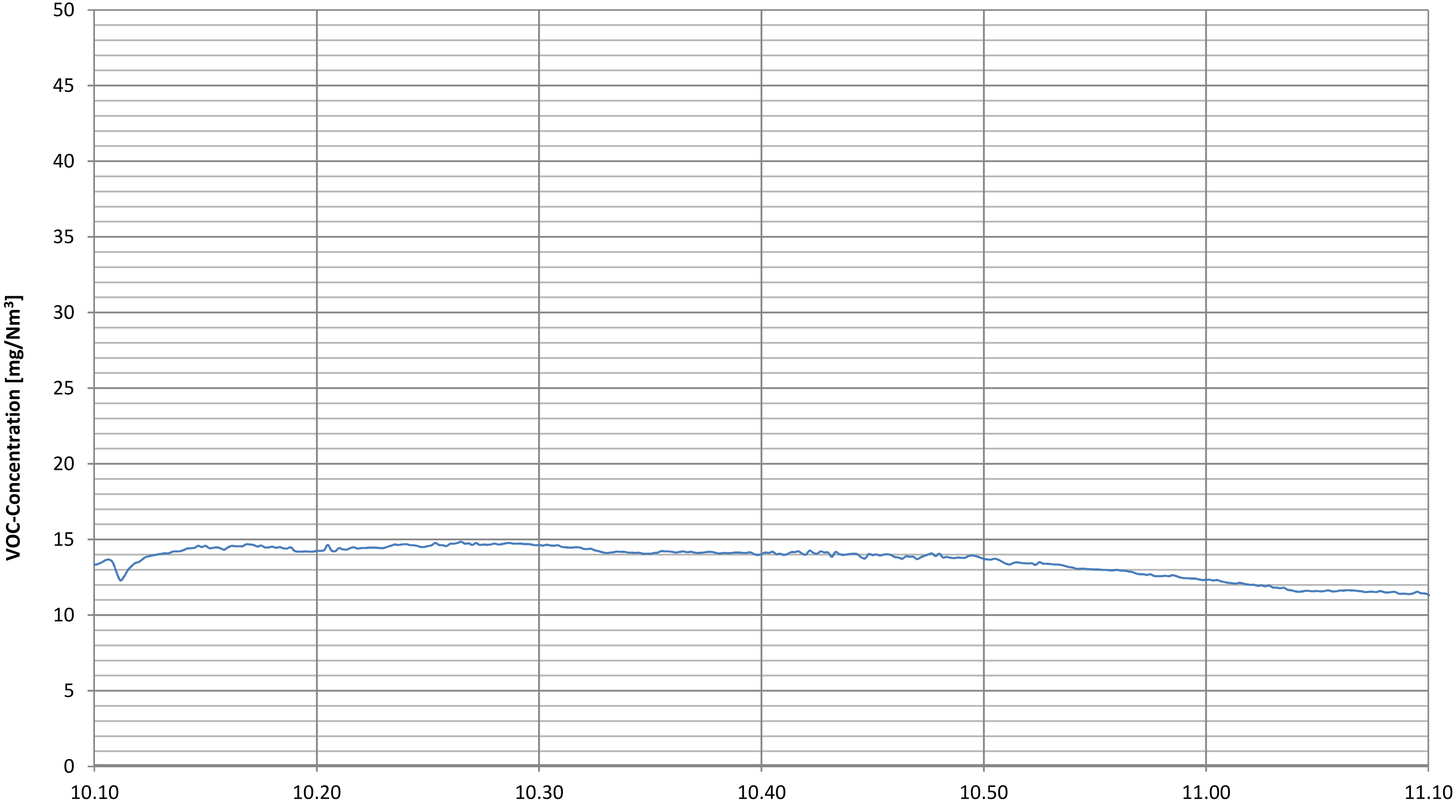

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Karhula Foundry Ltd
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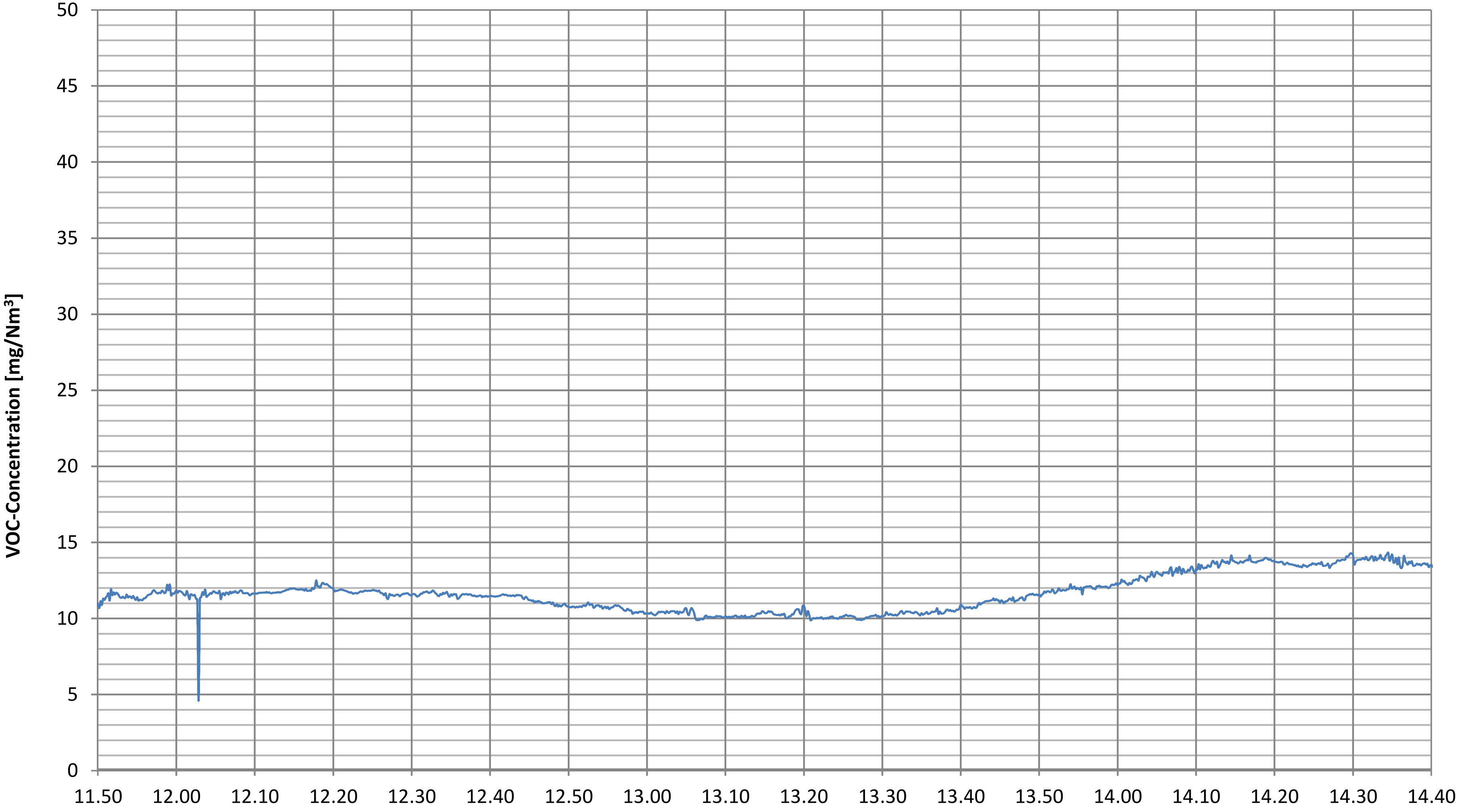
Amine scrubber VOC-concentration 24.4.2019



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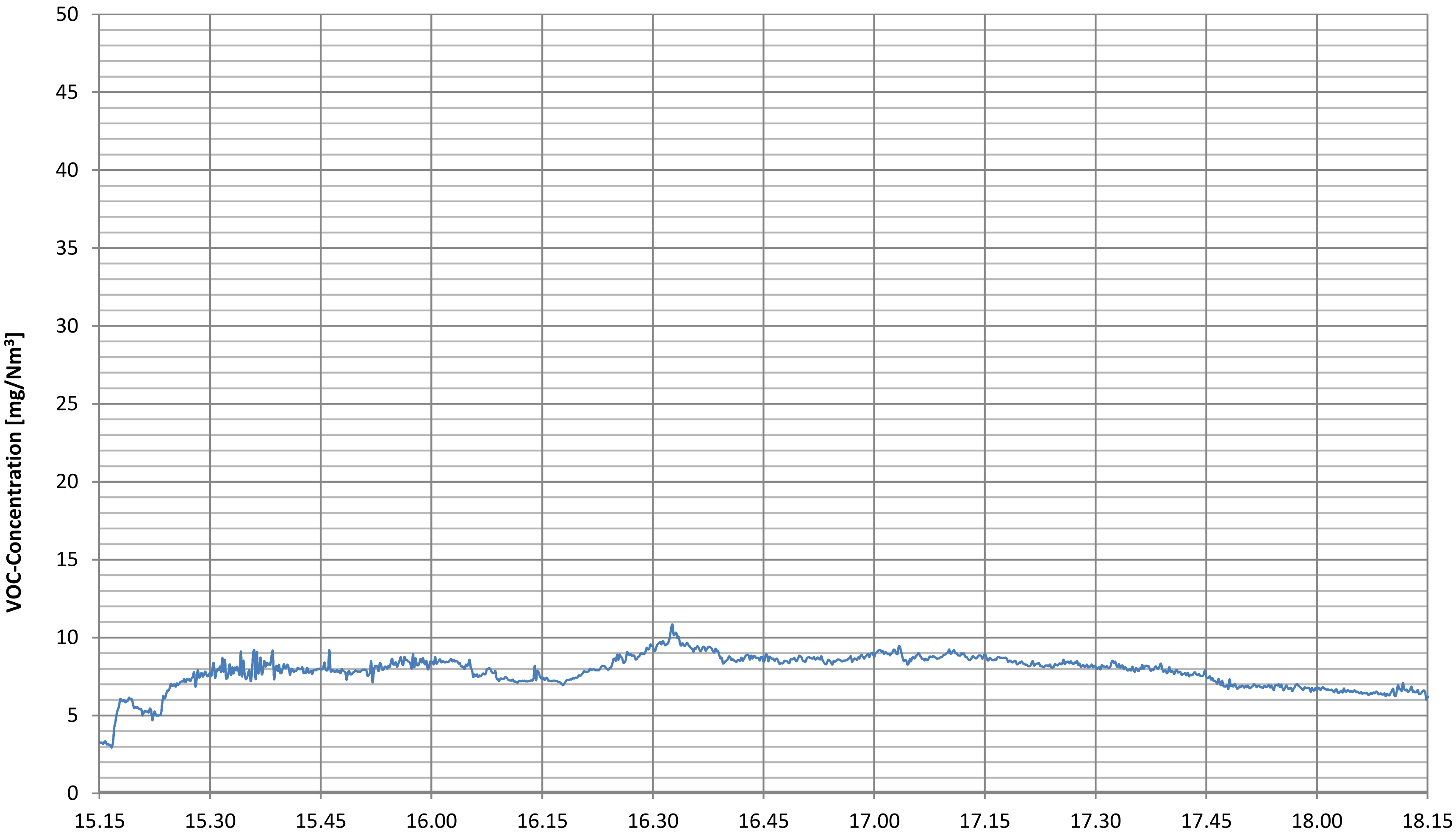
Core making VOC-concentration 24.4.2019

APPENDIX 14 1/1



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Melting shop VOC-concentration 25.4.2019

APPENDIX 15 1/1