



Industrial Compliance Solutions

ICS Ltd

AIR & EMISSIONS TESTING

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Project / Client Details

Rainbow Mountain Renewable Energy Limited

Site Address

Rainbow Mountain Renewable Energy Limited
216 State Highway 38
Waimangu
New Zealand

Stack/Release Point(s) Tested

Wet Electrostatic Precipitator (WESP)

Target Parameter(s)

Metals

Job Number

100747

Sampling Date(s)

10th July 2024

Report Date / Version:	04/09/24 v1.0
Report By:	Toby Campbell
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Professional Qualification 1	BSc Environmental Management
Professional Qualification 2	MSc Air Pollution Management and Control
Report Approved By:	Brent Kennedy
Business Title	Principal Scientist
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EXECUTIVE SUMMARY (Page 1 of 9)

Stack Emissions Monitoring Objectives

Rainbow Mountain Renewable Energy Limited operates a Anaerobic-Thermal-Reduction (ATR) Pyrolysis at Rainbow Mountain, 216 State Highway 38, Waimangu which is subject to a Resource Consent, under the Resource Management Act 1991 .

Industrial Compliance Solutions were commissioned by Rainbow Mountain Renewable Energy Limited to carry out stack emissions monitoring to determine the release of Metals from the following Plant under Normal operating conditions.

Plant

Wet Electrostatic Precipitator (WESP)

Operator

Resource Consent: RM22-0076-AP
Rainbow Mountain Renewable Energy Limited
216 State Highway 38
Waimangu
New Zealand

Stack Emissions Monitoring Company

Industrial Compliance Solutions Ltd
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EXECUTIVE SUMMARY (Page 2 of 9)

Emissions Summary

Rainbow Mountain Renewable Energy Limited, Rainbow Mountain, 216 State Highway 38, Waimangu
 Wet Electrostatic Precipitator (WESP)
 10th July 2024

Parameter	Units	Result (average of 3 runs)	Uncertainty +/-	Emission Limit Value (ELV)	Outcome (above/below ELV)
Antimony	mg/m ³	0.0009	0.0002	0.055	Below
Arsenic	mg/m ³	0.0049	0.0012	0.005	Below
Barium	mg/m ³	0.0062	0.0016	-	-
Beryllium	mg/m ³	0.0009	0.0002	-	-
Boron	mg/m ³	0.0521	0.0130	-	-
Cadmium	mg/m ³	0.0004	0.0001	0.00875	Below
Chromium	mg/m ³	0.0110	0.0028	0.01	Above
Cobalt	mg/m ³	0.0009	0.0002	0.005	Below
Copper	mg/m ³	0.0103	0.0026	0.065	Below
Lead	mg/m ³	0.0137	0.0034	0.295	Below
Manganese	mg/m ³	0.0469	0.0117	0.055	Below
Nickel	mg/m ³	0.0155	0.0039	0.005	Above
Phosphorus	mg/m ³	1.3331	0.3333	-	-
Selenium	mg/m ³	0.0049	0.0012	-	-
Thallium	mg/m ³	0.00005	0.00001	0.00125	Below
Tin	mg/m ³	0.0119	0.0030	-	-
Vanadium	mg/m ³	0.0049	0.0012	0.005	Below
Zinc	mg/m ³	0.1666	0.0416	-	-
Mercury	mg/m ³	0.0160	0.0040	0.05	Below
Moisture	%	2.9	0.57	-	-
Stack Gas Temperature	°C	24.8	-	-	-
Stack Gas Velocity	m/s	3.8	-	-	-
Gas Volumetric Flow Rate (Actual)	m ³ /hr	7858	-	-	-
Gas Volumetric Flow Rate (STP, Wet)	m ³ /hr	7321	-	-	-
Gas Volumetric Flow Rate (STP, Dry)	m ³ /hr	7107	-	-	-

All results are average values of 3 sample runs, with pollutant concentrations expressed at reference conditions.
 25% uncertainty has been applied to the Metals results due to the nature of the testing.
 Metals: Reference conditions are 273K, 101.3kPa, dry gas.



EXECUTIVE SUMMARY (Page 3 of 9)

Monitoring Times and Results

	Run 1	Run 2	Run 3			
Sampling Date	10/07/2024	10/07/2024	10/07/2024			
Sampling Times	09:08 - 10:08	11:24 - 12:24	13:16 - 14:16			
	Concentration			Mass Emissions		
Parameter	Run 1 mg/m ³	Run 2 mg/m ³	Run 3 mg/m ³	Run 1 g/hr	Run 2 g/hr	Run 3 g/hr
Antimony	0.00113	0.00082	0.00082	0.0069	0.0066	0.01
Arsenic	0.00596	0.00436	0.00436	0.0366	0.0351	0.04
Barium	0.00993	0.00436	0.00436	0.0610	0.0351	0.04
Beryllium	0.00113	0.00082	0.00082	0.0069	0.0066	0.01
Boron	0.08076	0.03780	0.03780	0.4965	0.3045	0.30
Cadmium	0.00026	0.00040	0.00040	0.0016	0.0032	0.00
Chromium	0.01655	0.00824	0.00824	0.1017	0.0664	0.07
Cobalt	0.00113	0.00082	0.00082	0.0069	0.0066	0.01
Copper	0.01258	0.00921	0.00921	0.0773	0.0742	0.07
Lead	0.02132	0.00989	0.00989	0.1310	0.0796	0.08
Manganese	0.03310	0.05379	0.05379	0.2035	0.4333	0.43
Nickel	0.01655	0.01502	0.01502	0.1017	0.1210	0.12
Phosphorus	1.74104	1.12918	1.12918	10.7035	9.0962	9.10
Selenium	0.00596	0.00436	0.00436	0.0366	0.0351	0.04
Thallium	0.00006	0.00004	0.00004	0.0004	0.0004	0.00
Tin	0.01920	0.00824	0.00824	0.1180	0.0664	0.07
Vanadium	0.00596	0.00436	0.00436	0.0366	0.0351	0.04
Zinc	0.17212	0.16380	0.16380	1.0581	1.3195	1.32
Mercury	0.04	0.01	0.003	0.22	0.06	0.02

Process Details

Parameter	Process Details
Process Status	Normal
Capacity and / or Production Rate	10 tonnes per 16 hour cycle
Continuous or Batch Process	Batch
Feedstock (if applicable)	Flock
Abatement System	WESP
Abatement System Running Status	Operational
Fuel (if applicable)	Fuel Oil / Syngas
Plume Appearance	Visible Plume



EXECUTIVE SUMMARY (Page 4 of 9)

Monitoring Methods

Industrial Compliance Solutions Ltd employ USEPA methodologies for stack emissions testing. This section details all of the methods used on site during this monitoring campaign.

The table below summarises the monitoring methods, techniques and technical procedures employed, and details any deviations from the aforementioned hierarchy:

Sampling Methods with Subsequent Analysis

Species	Standard Method	ICS Technical Procedure	IANZ Lab Number	IANZ Accredited Method	Limit of Detection (LOD)	MU of Method (E) +/- %	MU +/- %
Metals	US EPA M29	TMM 2.14	N/A	N/A	~ 0.0001 mg/m ³	20%	25% (E)
H ₂ O	US EPA M4	TMM 2.4	N/A	N/A	0.1%	20%	-

where C = Calculated Measurement Uncertainty, E = Estimated Measurement Uncertainty

On-Site Testing and Analysis

The table below summarises the monitoring methods, techniques and technical procedures employed:

Species	Standard Method	ICS Technical Procedure	IANZ Lab Number	IANZ Accredited Method	Limit of Detection (LOD)	MU of Method (E) +/- %	MU +/- %
Sample and Velocity Traverse	US EPA M1	TMM2.1	N/A	N/A	N/A	10%	10%
Velocity and Volumetric Flow	US EPA M2	TMM2.2	N/A	N/A	0.2 mm H ₂ O	10%	10%

where C = Calculated Measurement Uncertainty, E = Estimated Measurement Uncertainty



EXECUTIVE SUMMARY (Page 5 of 9)

Analytical Methods

The following tables list the analytical methods employed together with the custody and archiving details:

Sampling Methods with Subsequent Analysis

Species	Analytical Technique	Analytical Procedure	IANZ Lab Number	IANZ Accredited Analysis	Laboratory	Sample Archive Location	Archive Period
Metals	ICP-MS	TMM 2.14	N/A	N/A	ICS	Hamilton	3 months
H2O	Gravimetric	TMM 2.4	N/A	N/A	ICS	Hamilton	3 months



EXECUTIVE SUMMARY (Page 6 of 9)

Measurement Uncertainty (MU)

Manual Extractive Testing

There are 4 ways in which to report measurement uncertainty for total particulate matter. These are listed in the hierarchical table below. The table also indicates which method has been used to calculate the MU for the parameters listed in this report.

MU Reported	Yes / No
a) Report a calculated MU	-
b) Report an <u>estimated</u> MU if there are any deviations from the sampling plane validation criteria	-
c) Report an <u>estimated</u> MU if there are any deviations from the specified method	Yes
d) Report the MU specified in the method	-

NOTE: The estimated uncertainty is based upon a calculated MU, coupled with the experience of the Stack Emissions Test house.



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Sampling Location

Sampling Plane Validation Criteria (Ideal Conditions)	Value	Units	Requirement	Compliance	Method
Lowest Differential Pressure	10	Pa	> 5 Pa	Yes	In-house
Lowest Gas Velocity	3.35	m/s	-	-	-
Highest Gas Velocity	4.24	m/s	-	-	-
Ratio of Above	1.26	: 1	< 3 : 1	Yes	In-house
Mean Velocity	3.65	m/s	-	-	-
Angle of flow with regard to duct axis	0	°	< 15°	Yes	In-house
No local negative flow	-	-	-	Yes	In-house
Highly homogeneous flow stream / gas velocity	-	-	-	Yes	In-house
Sampling Plane Validation Criteria US EPA M2	Value	Units	Requirement	Compliance	Method
Duct diameters that measurements site is upstream from flow disturbance	4	Measured Diameters	> 2 Diameters	Yes	US EPA M1
Duct diameters that measurements site is downstream from flow disturbance	4	Measured Diameters	> 8 Diameters	No	US EPA M1

Duct Characteristics

Parameter	Value	Units
Type	Circular	-
Depth	0.86	m
Width	-	m
Area	0.57	m ²
Port Depth	483	mm

Sampling Lines & Sample Points

Parameter	TPM	Oxygen
Sample Port Size	4" Camlock	4" Camlock
Number Used	1	1
Sample Plane Orientation	Horizontal	-
Number Points / Line	12	1
In Stack / Out Stack Filtration	Out Stack	-

NOTE: 1 sampling line was used for sampling as only 1 sampling line was available, however the number of sample points was doubled to meet the requirements of the standard.

Sampling Platform

General Platform Information	Description
Permanent / Temporary Platform	Permanent
Inside / Outside	Outside

Ideal Platform Specifications	Present (Yes / No)
Minimum Platform Area 5 m ²	Yes
Platform has 2 levels of handrails (approximately 0.5 m & 1.0 m high)	Yes
Platform has vertical base boards (approximately 0.25 m high)	Yes
Platform has removable chains / self closing gates at the top of ladders	N/A
Handrail / obstructions do not hamper insertion of sampling equipment	Yes
Depth of Platform = Minimum of 2m or Probe Length + 1m	Yes

Sampling Location / Platform Improvement Recommendations

Two sample lines should be installed on the stack at 45 degrees relevant to the existing port.



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Sampling & Analytical Method Deviations

One Sampling Line

Only 1 sample line was present on the stack.



EXECUTIVE SUMMARY (Page 9 of 9)

Conclusion & Discussion

The results of these tests demonstrate that under normal operating conditions, this Plant is being operated in full compliance with the emission limits specified in its Resource Consent, RM22-0076-AP.

A regular programme of stack emissions testing in accordance with the Plant's Resource Consent, RM22-0076-AP, will be required to demonstrate continued compliance.



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APPENDICES

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APPENDIX 1 - Stack Emissions Monitoring Team

STACK EMISSIONS MONITORING TEAM

Environmental Technician 1

Toby Campbell
Principal Environmental Consultant
Certificate Air Quality Professional (CAQP)
BSc Environmental Management
MSc Air Pollution Management and Control

Environmental Technician 2

Brent Kennedy
Principal Scientist
Certificate Air Quality Professional (CAQP)
BSc Chemistry
MSc Materials and Processing Engineering



APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

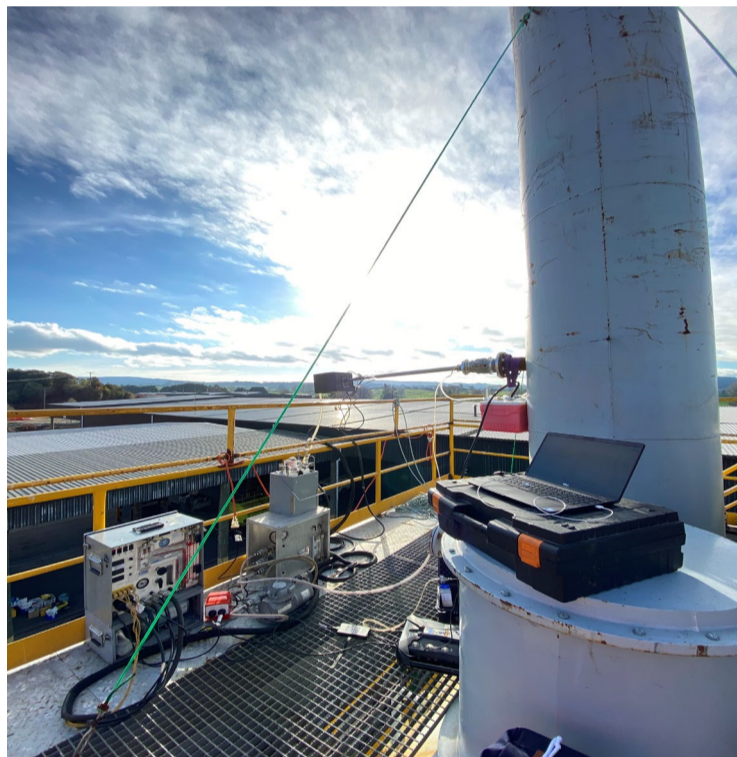
STACK PARAMETERS / SAMPLE LOCATION

	Value	Units
Stack Shape	Circular	-
Stack Depth	0.86	m
Stack Width	-	m
Area	0.57	m ²
Port Depth (including clamp)	483	mm

Gases and Non-Isokinetic Testing

Sampling Point	Distance (% of Depth)	Distance into Stack	Units
N/A	30	0.26	m

Sampling Location



Isokinetic Testing

Sampling Point	Distance into Stack	Probe Marking	Units
1	0.02	0.50	m
2	0.06	0.54	m
3	0.10	0.58	m
4	0.15	0.63	m
5	0.21	0.70	m
6	0.30	0.79	m
7	0.55	1.03	m
8	0.64	1.12	m
9	0.70	1.19	m
10	0.75	1.24	m
11	0.80	1.28	m
12	0.84	1.32	m



APPENDIX 2 - Calibrateable Equipment Checklist & Calibration Gases

CALIBRATEABLE EQUIPMENT CHECKLIST

Extractive Sampling		Instrumental Analyser/s		Miscellaneous	
Equipment	Equipment I.D.	Equipment	Equipment I.D.	Equipment	Equipment I.D.
Control Box DGM	ICS011	-	-	Laboratory Balance	-
Box Thermocouples	Y	-	-	Tapemeasure	Y
Meter In Thermocouple	Y	-	-	Stopwatch	Y
Meter Out Thermocouple	Y	-	-	Protractor	-
Control Box Timer	Y	-	-	Barometer	Y
Umbilical	Y	-	-	Digital Micromanometer	-
Oven Box	ICS009	-	-	Digital Temperature Meter	-
Probe	ICS004	-	-	Stack Thermocouple	ICS005
S-Pitot	ICS006	-	-	-	-
L-Pitot	-	-	-	-	-
Site Balance	Y	-	-	-	-
Last Impinger Arm	Y	-	-	-	-
Calipers	Y	-	-	-	-
Small DGM	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-

NOTE: If the equipment I.D is represented by a dash (-), then this piece of equipment has not been used for this test.



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APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

PRELIMINARY STACK SURVEY

Rainbow Mountain Renewable Energy Limited, Rainbow Mountain, 216 State Highway 38, Waimangu
 Wet Electrostatic Precipitator (WESP)
 10th July 2024

Time of Survey	08:25 - 08:35
Velocity Measurement Device:	S-Type Pitot

Sampling Line A							
Traverse Point	Distance into duct (m)	ΔP_{pt} mmH ₂ O	ΔP_{pt} Pa	Temp °C	Velocity m/s	O ₂ % Vol	Angle of Swirl °
1	0.02	1.0	10	21	3.35	-	0
2	0.06	1.0	10	21	3.35	-	
3	0.10	1.0	10	21	3.35	-	
4	0.15	1.0	10	21	3.35	-	
5	0.21	1.2	12	21	3.67	-	
6	0.30	1.2	12	21	3.67	-	
7	0.55	1.6	16	21	4.24	-	
8	0.64	1.6	16	21	4.24	-	
9	0.70	1.4	14	21	3.96	-	
10	0.75	1.0	10	21	3.35	-	
Mean	-	1.2	12	21	3.65	-	
Sampling Line B							
Traverse Point	Distance into duct (m)	ΔP_{pt} mmH ₂ O	ΔP_{pt} Pa	Temp °C	Velocity m/s	O ₂ % Vol	Angle of Swirl °
1	-	-	-	-	-	-	0
2	-	-	-	-	-	-	
3	-	-	-	-	-	-	
4	-	-	-	-	-	-	
5	-	-	-	-	-	-	
6	-	-	-	-	-	-	
7	-	-	-	-	-	-	
8	-	-	-	-	-	-	
9	-	-	-	-	-	-	
10	-	-	-	-	-	-	
Mean	-	-	-	-	-	-	



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APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

METALS SUMMARY - RUN 1

Rainbow Mountain Renewable Energy Limited, Rainbow Mountain, 216 State Highway 38, Waimangu
Wet Electrostatic Precipitator (WESP)
10th July 2024

Test	Sampling Times	Duration min
Metals	09:08 - 10:08	60

Reference conditions are 273K, 101.3kPa, dry gas.

50% of LOD has been taken where the laboratory result is "<" a quoted value. This data is highlighted in "Green"

Metal	Laboratory Results (µg) Filter/Rinse	Run 1 Filter/Rinse	Laboratory Results (µg) Impingers	Run 1 Impingers	Total Mass (µg)	Concentration mg/m ³	Mass Emission g/hr
Antimony	< 0.9	0.5	< 0.8	0.4	0.85	0.00113	0.0069
Arsenic	< 5	2.5	< 4	2.0	4.50	0.00596	0.0366
Barium	< 5	2.5	5.0	5.0	7.50	0.00993	0.0610
Beryllium	< 0.9	0.5	< 0.8	0.4	0.85	0.00113	0.0069
Boron	< 30	15.0	46.0	46.0	61.00	0.08076	0.4965
Cadmium	0.2	0.2	< 0.04	0.0	0.20	0.00026	0.0016
Chromium	11.0	11.0	< 3	1.5	12.50	0.01655	0.1017
Cobalt	< 0.9	0.5	< 0.8	0.4	0.85	0.00113	0.0069
Copper	8.0	8.0	< 3	1.5	9.50	0.01258	0.0773
Lead	11.2	11.2	4.9	4.9	16.10	0.02132	0.1310
Manganese	21.0	21.0	4.0	4.0	25.00	0.03310	0.2035
Nickel	11.0	11.0	< 3	1.5	12.50	0.01655	0.1017
Phosphorus	< 90	45.0	1270.0	1270.0	1315.00	1.74104	10.7035
Selenium	< 5	2.5	< 4	2.0	4.50	0.00596	0.0366
Thallium	< 0.05	0.0	< 0.04	0.0	0.05	0.00006	0.0004
Tin	< 3	1.5	13.0	13.0	14.50	0.01920	0.1180
Vanadium	< 5	2.5	< 4	2.0	4.50	0.00596	0.0366
Zinc	116.0	116.0	14.0	14.0	130.00	0.17212	1.0581
Mercury	< 0.14	0.07	< 0.8	0.4	26.770	0.035	0.2179
			4.3	4.3			
			22.0	22.0			
					1647	2.180	



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APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

METALS SUMMARY - RUN 2

Rainbow Mountain Renewable Energy Limited, Rainbow Mountain, 216 State Highway 38, Waimangu
Wet Electrostatic Precipitator (WESP)
10th July 2024

Test	Sampling Times	Duration min
Metals	11:24 - 12:24	60

Reference conditions are 273K, 101.3kPa, dry gas.

50% of LOD has been taken where the laboratory result is "<" a quoted value. This data is highlighted in "Green"

Metal	Laboratory Results (µg) Filter/Rinse	Run 2 Filter/Rinse	Laboratory Results (µg) Impingers	Run 2 Impingers	Total Mass (µg)	Concentration mg/m ³	Mass Emission g/hr
Antimony	< 0.9	0.5	< 0.8	0.4	0.85	0.00082	0.0066
Arsenic	< 5	2.5	< 4	2.0	4.50	0.00436	0.0351
Barium	< 5	2.5	< 4	2.0	4.50	0.00436	0.0351
Beryllium	< 0.9	0.5	< 0.8	0.4	0.85	0.00082	0.0066
Boron	< 30	15.0	24.0	24.0	39.00	0.03780	0.3045
Cadmium	0.4	0.4	0.1	0.1	0.41	0.00040	0.0032
Chromium	7.0	7.0	< 3	1.5	8.50	0.00824	0.0664
Cobalt	< 0.9	0.5	< 0.8	0.4	0.85	0.00082	0.0066
Copper	8.0	8.0	< 3	1.5	9.50	0.00921	0.0742
Lead	9.1	9.1	1.1	1.1	10.20	0.00989	0.0796
Manganese	54.0	54.0	< 3	1.5	55.50	0.05379	0.4333
Nickel	14.0	14.0	< 3	1.5	15.50	0.01502	0.1210
Phosphorus	< 90	45.0	1120.0	1120.0	1165.00	1.12918	9.0962
Selenium	< 5	2.5	< 4	2.0	4.50	0.00436	0.0351
Thallium	< 0.05	0.0	< 0.04	0.0	0.05	0.00004	0.0004
Tin	< 3	1.5	7.0	7.0	8.50	0.00824	0.0664
Vanadium	< 5	2.5	< 4	2.0	4.50	0.00436	0.0351
Zinc	152.0	152.0	17.0	17.0	169.00	0.16380	1.3195
Mercury	< 0.14	0.1	< 0.8	0.4	7.370	0.010	0.0600
			< 0.8	0.4			
			6.5	6.5			
					1509	1.998	



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APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

METALS SUMMARY - RUN 3

Rainbow Mountain Renewable Energy Limited, Rainbow Mountain, 216 State Highway 38, Waimangu
Wet Electrostatic Precipitator (WESP)
10th July 2024

Test	Sampling Times	Duration min
Metals	13:16 - 14:16	60

Reference conditions are 273K, 101.3kPa, dry gas.

50% of LOD has been taken where the laboratory result is "<" a quoted value. This data is highlighted in "Green"

Metal	Laboratory Results (µg) Filter/Rinse	Run 3 Filter/Rinse	Laboratory Results (µg) Impingers	Run 3 Impingers	Total Mass (µg)	Concentration mg/m ³	Mass Emission g/hr
Antimony	< 0.9	0.5	< 0.8	0.4	0.85	0.00082	0.0066
Arsenic	< 5	2.5	< 4	2.0	4.50	0.00436	0.0351
Barium	< 5	2.5	< 4	2.0	4.50	0.00436	0.0351
Beryllium	< 0.9	0.5	< 0.8	0.4	0.85	0.00082	0.0066
Boron	< 30	15.0	24.0	24.0	39.00	0.03780	0.3045
Cadmium	0.4	0.4	0.1	0.1	0.41	0.00040	0.0032
Chromium	7.0	7.0	< 3	1.5	8.50	0.00824	0.0664
Cobalt	< 0.9	0.5	< 0.8	0.4	0.85	0.00082	0.0066
Copper	8.0	8.0	< 3	1.5	9.50	0.00921	0.0742
Lead	9.1	9.1	1.1	1.1	10.20	0.00989	0.0796
Manganese	54.0	54.0	< 3	1.5	55.50	0.05379	0.4333
Nickel	14.0	14.0	< 3	1.5	15.50	0.01502	0.1210
Phosphorus	< 90	45.0	1120.0	1120.0	1165.00	1.12918	9.0962
Selenium	< 5	2.5	< 4	2.0	4.50	0.00436	0.0351
Thallium	< 0.05	0.0	< 0.04	0.0	0.05	0.00004	0.0004
Tin	< 3	1.5	7.0	7.0	8.50	0.00824	0.0664
Vanadium	< 5	2.5	< 4	2.0	4.50	0.00436	0.0351
Zinc	152.0	152.0	17.0	17.0	169.00	0.16380	1.3195
Mercury	< 0.14	0.1	< 0.8	0.4	2.140	0.003	0.0174
			< 0.8	0.4			
			1.3	1.3			
					1504	1.991	



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APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

METALS SUMMARY - BLANK

Rainbow Mountain Renewable Energy Limited, Rainbow Mountain, 216 State Highway 38, Waimangu
Wet Electrostatic Precipitator (WESP)
10th July 2024

Test	Sampling Times	Duration min
Metals	N/A	N/A

Reference conditions are 273K, 101.3kPa, dry gas.

50% of LOD has been taken where the laboratory result is "<" a quoted value. This data is highlighted in "Green"

Metal	Laboratory Results (µg) Filter/Rinse	Blank Filter/Rinse	Laboratory Results (µg) Filter/Rinse	Blank Impingers	Total Mass (µg)
Antimony	< 0.9	0.5	< 1.1	0.6	0.450
Arsenic	< 5	2.5	< 6	3.0	2.500
Barium	< 5	2.5	< 6	3.0	2.500
Beryllium	< 0.9	0.5	< 1.1	0.6	0.450
Boron	< 30	15.0	< 40	20.0	15.000
Cadmium	< 0.05	0.0	< 0.06	0.0	0.025
Chromium	< 3	1.5	< 4	2.0	1.500
Cobalt	< 0.9	0.5	< 1.1	0.6	0.450
Copper	< 3	1.5	< 4	2.0	1.500
Lead	< 0.9	0.5	< 1.1	0.6	0.450
Manganese	< 3	1.5	< 4	2.0	1.500
Nickel	< 3	1.5	< 4	2.0	1.500
Phosphorus	< 90	45.0	1300.0	1300.0	1345.000
Selenium	< 5	2.5	< 6	3.0	2.500
Thallium	< 0.05	0.0	< 0.06	0.0	0.025
Tin	< 3	1.5	8.0	8.0	9.500
Vanadium	< 5	2.5	< 6	3.0	2.500
Zinc	< 5	2.5	< 6	3.0	2.500
Mercury	< 0.14	0.1	< 1.6	0.8	1.3
			< 0.8	0.4	
			< 0.08	0.0	



ISOKINETIC SAMPLING EQUATIONS 1

Metals

Test	1	2	3	Units
Absolute pressure of stack gas, P_s				
Barometric pressure, P _b	781.5	781.5	757.5	mm Hg
Stack static pressure, P _{static}	0.2	0.2	0.2	mm H ₂ O
$P_s = P_b + \frac{(P_{static})}{13.6}$	781.5	781.5	757.5	mm Hg
Volume of water vapour collected, V_{wstd}				
Impinger volume collected	5.8	20.1	25.7	ml
Silica gel weight increase	4.0	4.9	4.2	g
Total volume of liquid collected, V _{lc}	9.8	25.0	29.9	ml
$V_{wstd} = (0.001246)(V_{lc})$	0.0122	0.0310	0.0371	m ³
Volume of gas metered dry, V_{mstd}				
Volume of gas sample through gas meter, V _m	0.7476	1.0609	0.9311	m ³
Gas meter correction factor, Y _d	1.015	1.015	1.015	-
Average dry gas meter temperature, T _m	9.5	20.8	20.8	°C
Average pressure drop across orifice, ΔH	16.8	30.8	24.7	mm H ₂ O
$V_{mstd} = \frac{(0.3592)(V_m)(P_b + (\Delta H/13.6))(Y_d)}{T_m + 273}$	0.7553	1.0317	0.8773	m ³
Volume of gas metered wet, V_{mstw}				
$V_{mstw} = V_{mstd} + V_{wstd}$	0.7674	1.0627	0.9144	m ³
Volume of gas metered at O₂ Ref. Cond., V_{mstd@X%O2}				
% oxygen measured in gas stream, act%O ₂	18.0	17.6	17.0	%
% oxygen reference condition (21.0 denotes no O ₂ correction)	21.0	21.0	21.0	%
O ₂ Reference Factor O ₂ Ref = $\frac{21.0 - act\%O_2}{21.0 - ref\%O_2}$	No O ₂ Ref	No O ₂ Ref	No O ₂ Ref	
$V_{mstd@X\%oxygen} = (V_{mstd}) (O_2 \text{ Ref})$	No O ₂ Ref	No O ₂ Ref	No O ₂ Ref	m ³
Moisture content, B_{wo}				
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$	0.016	0.029	0.041	m ³
	1.58	2.92	4.05	%
Molecular weight of dry gas stream, M_d				
CO ₂	2.3	2.9	3.1	%
O ₂	18.0	17.6	17.0	%
Total	20.3	20.5	20.2	%
N ₂ (100 -Total)	79.7	79.5	79.8	%
$M_d = 0.44(\%CO_2) + 0.32(\%O_2) + 0.28(\%N_2)$	29.09	29.16	29.18	g/gmol
Molecular weight of stack gas (wet), M_s				
$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	28.91	28.84	28.73	g/gmol



ISOKINETIC SAMPLING EQUATIONS 2

Metals

Test	1	2	3	Units
Velocity of stack gas, V_s				
Pitot tube velocity constant, K_p	34.97	34.97	34.97	-
Velocity pressure coefficient, C_p	0.84	0.84	0.84	-
Average stack gas temperature, T_s	20	25	29	°C
$V_s = \frac{(K_p)(C_p)(\sqrt{\Delta P})(\sqrt{T_s + 273})}{\sqrt{(M_s)(P_s)}}$	3.16	4.27	3.98	m/s
V_s corrected for angle of swirl	3.16	4.27	3.98	m/s
Actual flow of stack gas, Q_a				
Area of stack, A_s	0.57	0.57	0.57	m ²
$Q_a = (60)(A_s)(V_s)$	108.7	147.0	137.2	m ³ /min
	6523.6	8820.6	8229.4	m ³ /hr
Dry total flow of stack gas, Q_{std}				
Conversion factor (K/mm.Hg)	0.3592	0.3592	0.3592	-
$Q_{std} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})}{(T_s) + 273}$	102.5	134.3	118.6	m ³ /min
	6148	8056	7118	m ³ /hr
Dry total flow of stack gas, at O₂ Ref. Cond., $Q_{std@X\%O_2}$				
% oxygen measured in gas stream, act%O ₂	18.0	17.6	17.0	%
% oxygen reference condition (21.0 denotes no O ₂ correction)	21.0	21.0	21.0	%
O ₂ Reference Factor O ₂ Ref = $\frac{21.0 - \text{act}\%O_2}{21.0 - \text{ref}\%O_2}$	No O ₂ Ref	No O ₂ Ref	No O ₂ Ref	
$Q_{std@X\%O_2} = (Q_{std}) (O_2 \text{ Ref})$	No O ₂ Ref	No O ₂ Ref	No O ₂ Ref	m ³ /min
Wet total flow of stack gas, Q_{stw}				
Conversion factor (K/mm.Hg)	0.3592	0.3592	0.3592	-
$Q_{stw} = \frac{(Q_a)P_s(0.3592)}{(T_s) + 273}$	104.1	138.3	123.6	m ³ /min
	6247	8298	7419	m ³ /hr
Percent isokinetic, %I				
Nozzle diameter, D_n	9.28	9.28	9.28	mm
Nozzle area, A_n	67.64	67.65	67.65	mm ²
Total sampling time, θ	60	60	60	min
$\%I = \frac{(4.6398E6)(T_s+273)(V_{mstd})}{(P_s)(V_s)(A_n)(\theta)(1-B_{wo})}$	104.3	108.7	104.6	%
Acceptable isokinetic range 90% to 110%"	Yes	Yes	Yes	-



ISOKINETIC SAMPLING EQUATIONS 3

Metals

Test	1	2	3	Units
Particulate Concentration, C				
Mass of particulate collected on filter, M_f	0.8500	7.5000	61.0000	g
Mass of particulate collected in probe, M_p	4.5000	0.8500	0.2000	g
Mass of total particulate collected, M_n	5.3500	8.3500	61.2000	g
$C_{wet} = \frac{M_n}{V_{mstw}}$	6971.15	7857.21	66928.43	mg/m ³
$C_{dry} = \frac{M_n}{V_{mstd}}$	7083.31	8093.30	69756.82	mg/m ³
$C_{dry@X\%O_2} = \frac{M_n}{V_{mstd@X\%oxygen}}$	No O2 Ref	No O2 Ref	No O2 Ref	mg/m ³
Particulate Emission Rates, E				
$E = [(C_{wet})(Q_{stw})(60)] / 1000$	43546.5	65196.3	496530.4	g/hr
	43.547	65.196	496.530	kg/h
Weighing, Conditioning & Filtration Temperatures				
Pre-conditioning temperature	105	105	105	°C
Maximum filtration temperature	105	105	105	°C
Post-conditioning temperature	105	105	105	°C



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APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

METALS QUALITY ASSURANCE CHECKLIST

Leak Test Results	Value Run 1	Value Run 2	Value Run 3	Units
Mean Sampling Rate	12.6	17.9	15.8	litre/min
Pre-sampling Leak Rate	0.15	0.12	0.09	litre/min
Post-sampling Leak Rate	0.18	0.14	0.10	litre/min
Acceptable Leak Rate	0.25	0.36	0.32	litre/min
Leak Tests Acceptable	Yes	Yes	Yes	-

Overall Blank Value	Value Run 1	Units
Overall Blank Value	0.0015	mg/m ³
Daily Emission Limit Value	-	mg/m ³
Acceptable Blank Value	-	mg/m ³
Overall Blank Acceptable	-	-

Isokinetic Criterion Compliance	Value Run 1	Value Run 2	Value Run 3	Units
Isokinetic Variation	104.3	108.7	104.6	%
Acceptable Isokineticity	Yes	Yes	Yes	-

Acceptable isokinetic range 90% to 110%"

Total Particulate Matter Filters	Value Run 1	Value Run 2	Value Run 3	Units
Filter Material	QF	QF	QF	-
Filter Size	82	82	82	mm

GF = Glass Fibre

QF = Quartz Fibre



APPENDIX 4 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - METALS

	Value	Units
Limit value	-	mg/m ³
Measured concentration	2.2	mg/m ³
Reference oxygen	N/A	% by volume

Measured Quantities	Symbol	Value	Units
Sampled Volume	V _m	0.7553	m ³
Sampled Gas Temperature	T _m	282	K
Sampled Gas Pressure	p _m	104.2	KPa
Sampled Gas Humidity	H _m	0.0	% by volume
Oxygen Content	O _{2,m}	N/A	% by volume
Mass of Particulate	m	1.6	mg
Leak	L	1.42	%
Uncollected Mass	UCM	0.00	mg

NOTE: Sampled Gas Temperature, Pressure and Humidity are at the Dry Gas Meter.

Standard Uncertainty	Symbol	Value	Units	Uncertainty as a %	Uncertainty Required	Uncertainty Met?
Sampled Volume	uV _m	0.0151	m ³	2.0	≤ 2%	Yes
Sampled Gas Temperature	uT _m	3	K	1.0	≤ 1%	Yes
Sampled Gas Pressure	up _m	1.0420	KPa	1.0	≤ 1%	Yes
Sampled Gas Humidity	uH _m	0.0000	% by volume	0.0	≤ 1%	Yes
Oxygen Content	uO _{2,m}	N/A	% by volume	N/A	≤ 10%	N/A
Mass of Particulate	um	0.0001	mg	N/A	≤ 5% of ELV	N/A
Leak	-	-	-	1.4	≤ 2%	Yes
Uncollected Mass	-	-	-	N/A	≤ 10% of ELV	No

Parameter	Symbol	Value	Units	Uncertainty in Result	Units	Uncertainty as a %	Units
Volume (STP)	V	0.7509	m ³	0.05	mg/m ³	2.46	%
Mass of Particulate	m	1.6	mg	0.00	mg/m ³	0.01	%
Factor for O2 Correction	fc	N/A	-	0.09	mg/m ³	4.16	%
Leak	L	0.02	mg/m ³	0.02	mg/m ³	0.82	%
Uncollected mass	UCM	0.00	mg	0.00	mg/m ³	0.05	%
Combined uncertainty				0.11	mg/m ³	4.91	%

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	0.21	mg/m³	9.81	%
R2 - Uncertainty expressed at a 95% confidence level (where k = 2)	0.08	mg/m³	5.13	%
R3 - Uncertainty expressed at a 95% confidence level (where k = 2)	0.08	mg/m³	5.21	%

(k is a coverage factor which gives a 95% confidence in the quoted figures)

NOTE: Because there are one or more method deviations from US EPA M29, a calculated MU can not be quoted for the concentration or mass emission of total particulate matter. Instead, this figure may be used to make a best estimate of what the MU might be.



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