AQ-SPEC
Air Quality Sensor Performance Evaluation Center

Laboratory Evaluation Report for

IKEA Vindstyrka

Report ID: L20260201.0

Published on:
February 24, 2026

Published by:
South Coast Air Quality Management District
21865 Copley Drive
Diamond Bar, CA 91765

Citation:
South Coast Air Quality Management District. (2026). Air Quality Sensor Performance Evaluation Center (AQ-SPEC) Laboratory Evaluation Report for IKEA Vindstyrka. Available at http://www.aqmd.gov/aq-spec

Revision History

Version	Date	Note
0	02/24/2026	Original issued report

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The laboratory evaluation was conducted in an AQ-SPEC environmental chamber with simulated pollutant and interferent concentrations that were generated from nebulizer solutions, dust dispensers, and/or gas dilution calibrators. Generated environments may not be able to fully replicate the conditions that may be experienced under ambient settings. The sensor assembly, installation, and use can also impact the reliability of the products evaluated by the AQ-SPEC program.

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Report Role	Name	Date Completed
Tested by	Noel Ruiz	09/19/2025
Analysis by	Michelle Kuang, Ph.D.	12/31/2025
QC Review by	Wilton Mui, Ph.D.	02/14/2026
Approved by	Wilton Mui, Ph.D.	02/21/2026
Revision by	-----	-----

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Section 1: Background

Three **IKEA Vindstyrka** sensors (units IDs: 4, 5, 6) were evaluated in an AQ-SPEC environmental chamber under controlled temperatures, humidities, and volatile organic compound (VOC) concentrations.

Note: *The IKEA sensors tested do not allow datalogging/data retrieval. A custom datalogging script was created in Python, which ran on a laptop to poll the data from the IKEA sensors at 1-minute interval. The IKEA Vindstyrka sensors only report VOC Index, thus no error metrics and sensor detection limits can be calculated.*

IKEA Vindstyrka

Thermo 55i

Section 2: Manufacturer Specs (VOC)

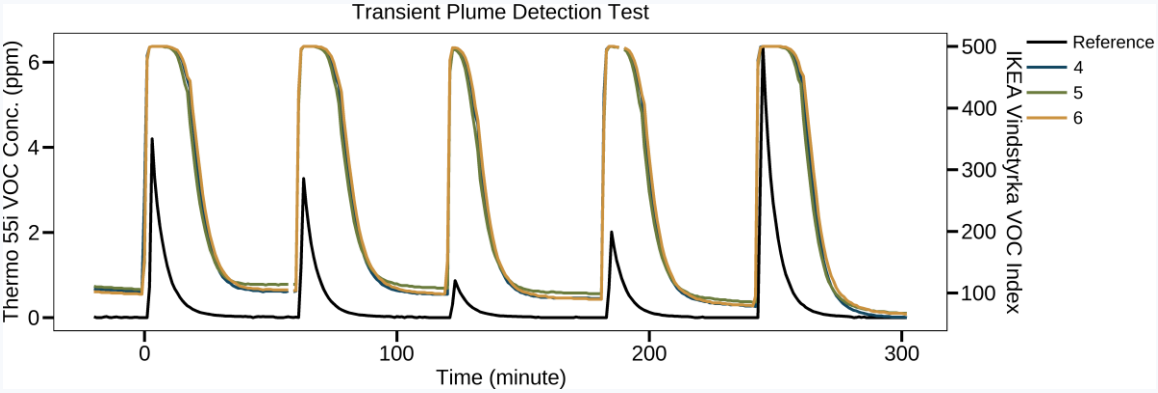
Parameter	Sensor: IKEA Vindstyrka (raw sensor is Sensirion SEN54)	Reference Instrument*: Thermo 55i
Pollutant	Total VOC (hereinafter referred to as "VOC")	CH_4 and non-methane hydrocarbons
Cost	$60	~$25,000
Weight	0.3 pounds	50 pounds
Dimensions (LxWxD)	3.5 x 2 x 2.25 inches	23 x 16.75 x 8.62 inches
Power	5 VDC	115 - 240 VAC
Battery	No	No
Data transmission	None	Ethernet, serial, analog output
Internal memory	No	Yes (>20,000 total records)
Operating temperature range	14 to 122 degrees F	59 to 95 degrees F
Operating RH range	0 to 90%	N/A
Product website	https://www.ikea.com/us/en/p/vindstyrka-air-quality-sensor-smart-30498239/	https://www.thermofisher.com/order/catalog/product/55I
Operating principle	Metal Oxide	Flame Ionization Detection
Time resolution	N/A (see note above)	70 seconds
Concentration range	0 – 500 VOC Index	0 – 50 ppm

*There is also an Agilent 6890N GC-FID that is used as a supplemental VOC reference instrument; additional results with the GC-FID can be found at the end of the report.

Section 3: VOC

Section 3.1: Transient Plume Detection

IKEA Vindstyrka vs Thermo 55i Reference



Interpretation:

- The IKEA Vindstyrka sensors responded to 100% of the VOC peaks.
- The IKEA Vindstyrka sensors detected the peaks at nearly the same time as the Thermo 55i reference; the apparent difference is due to different sampling times of the sensors vs. the Thermo 55i reference instrument.
- The height of the peaks from the IKEA Vinstyrka sensors were the same regardless of the VOC concentrations as measured by the Thermo 55i reference instrument.

Section 3: VOC

Section 3.2: Initial Concentration Ramp

Section 3.2.1: Data Recovery

Basic QA/QC procedures such as removal of duplicate records was performed. Nulls, negatives, out of instrument bounds as specified by the manufacturer, and values flagged as invalid by the sensor were considered invalid. Data recovery was calculated as the percent of valid readings through the entire evaluation.

Parameter	Unit 4	Unit 5	Unit 6
VOC, low conc. ramp	NA	NA	NA
VOC, high conc. ramp	NA	NA	NA

Note: *The IKEA sensors do not allow datalogging / data retrieval. Therefore, the data recovery metric is not calculable.*

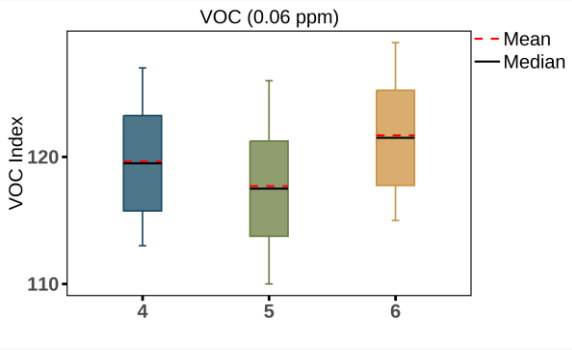
Section 3.2.2: Intra-Model Variability

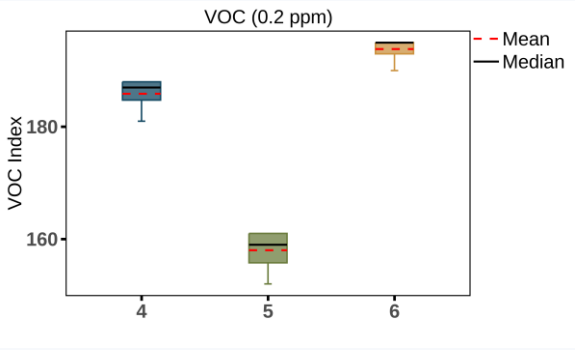
Absolute intra-model variability was calculated as the standard deviation of the mean values of the sensors. Relative intra-model variability was calculated as the absolute intra-model variability divided by the sensor grand mean. Calculations were performed using 20 measurements from each steady-state period.

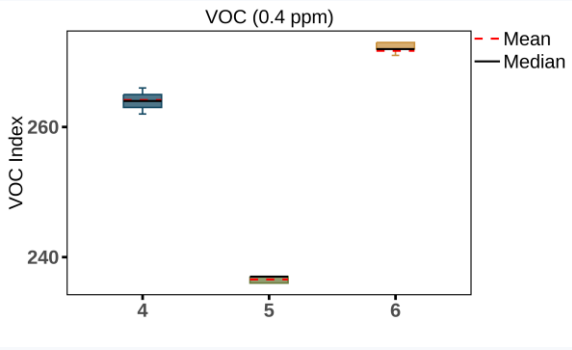
Test VOC Concentration (ppm)	Absolute intra-model variability (VOC Index)	Relative intra-model variability (%)
0.06	2.00	1.67
0.20	18.83	10.50
0.40	18.50	7.19
1.60	2.68	0.59
2.00	6.83	1.60
4.00	2.00	0.43
6.00	0.70	0.16
8.00	1.41	0.37

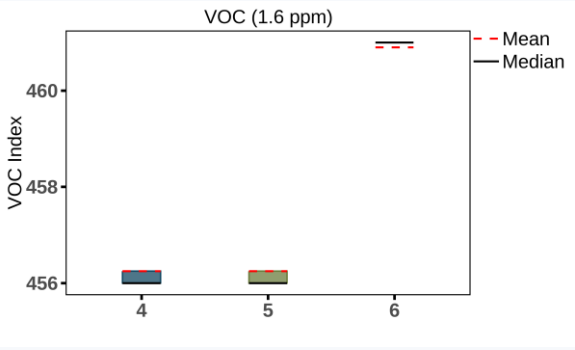
Section 3: VOC

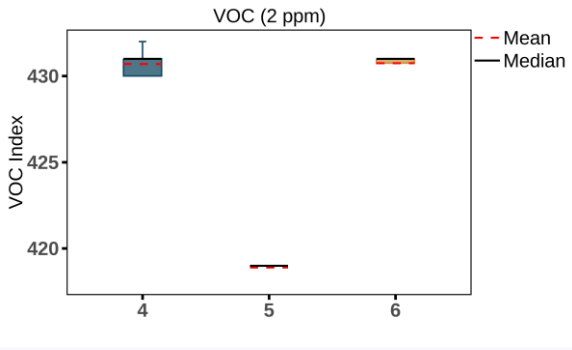
Section 3.2.2: Intra-Model Variability – Box Plots

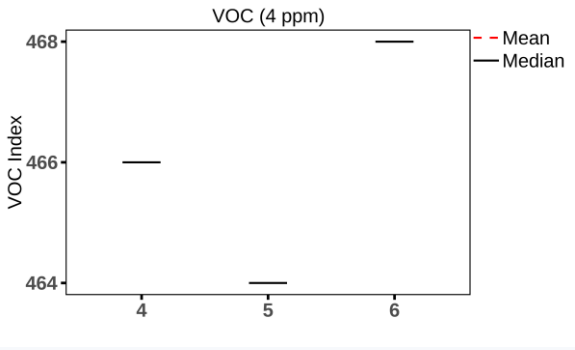


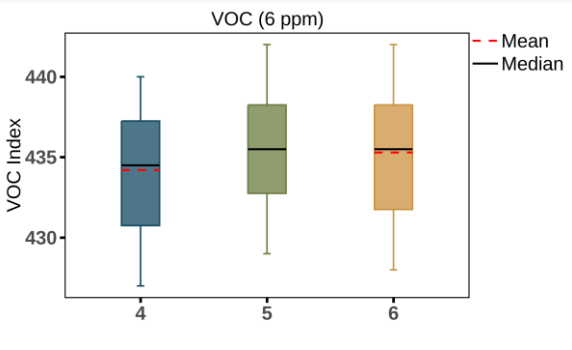


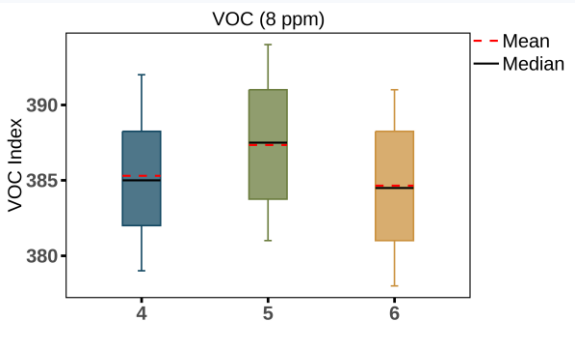












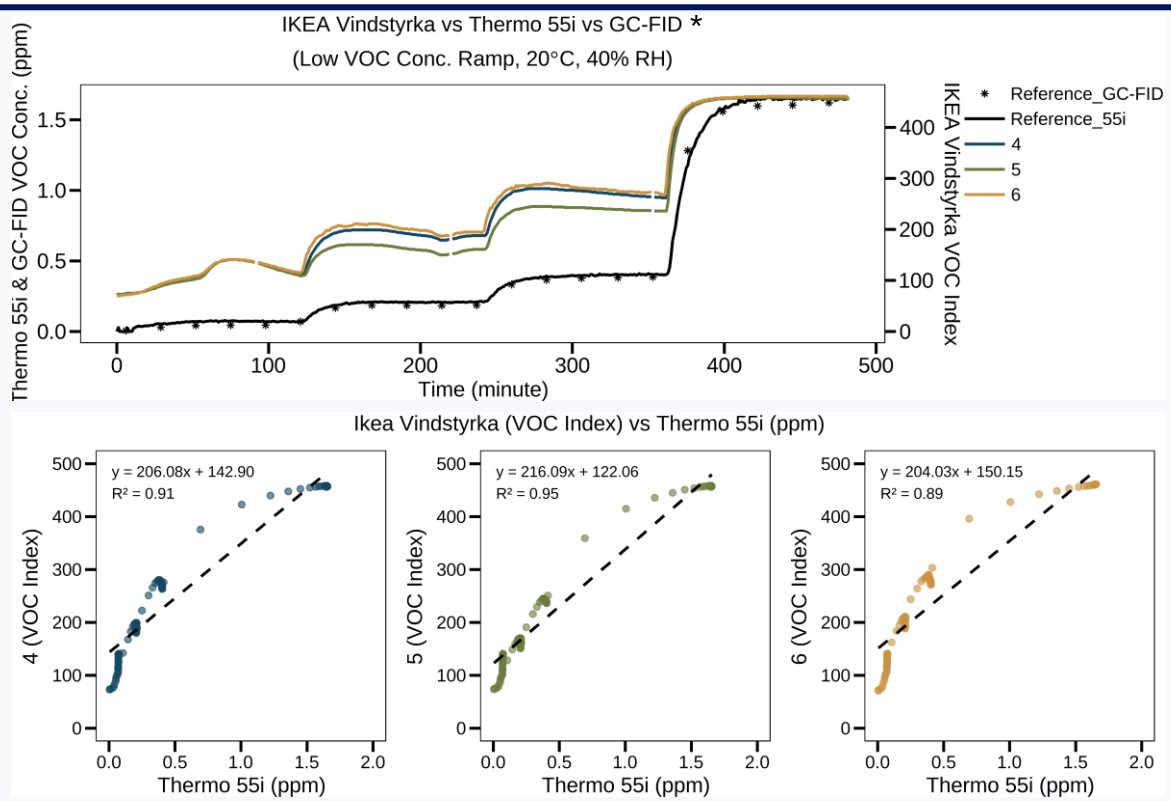
Section 3: VOC

Section 3.2.3: Linearity (R^2) – Low Conc. Ramp

Basic QA/QC procedures were used to validate the collected data (i.e., obvious outliers, negative values, readings flagged by the sensor, and invalid data points were eliminated from the data-set.

A summary of the mean R^2 between the sensor and reference instruments across all units tested.

Parameter	Time Resolution	IKEA Vindstyrka (mean ± SD)
VOC, low conc. ramp	5-minute	0.92 ± 0.03



Interpretation:

- The IKEA Vindstyrka sensors showed strong to very strong correlation with the corresponding Thermo 55i reference instrument ($0.89 < R^2 < 0.96$), at 5-minute averaging, for a VOC mixture containing equal concentrations of 1,3 butadiene, benzene, ethane and tetrachloroethylene, from 0.06 to 1.6 ppm (low concentration ramp), at 20°C and 40% RH.

*There is also an Agilent 6890N GC-FID that is used as a supplemental VOC reference instrument; additional results with the GC-FID can be found at the end of the report.

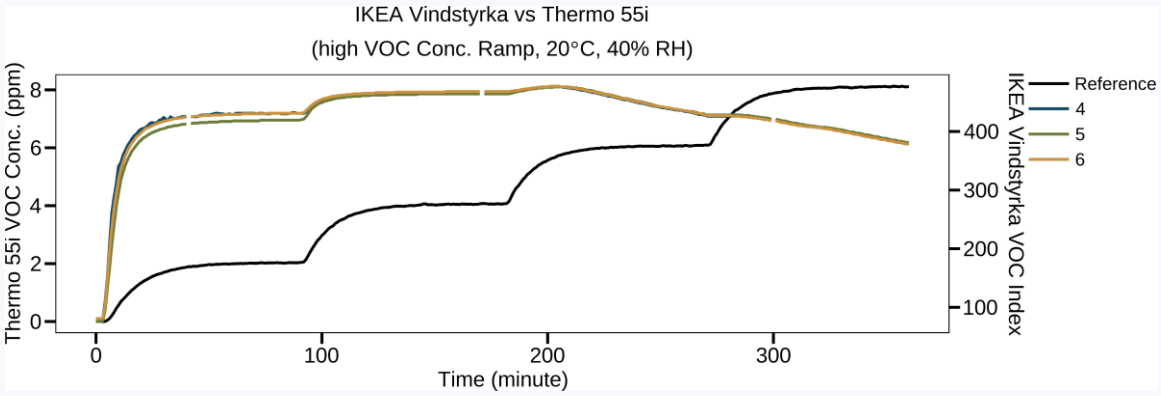
Section 3: VOC

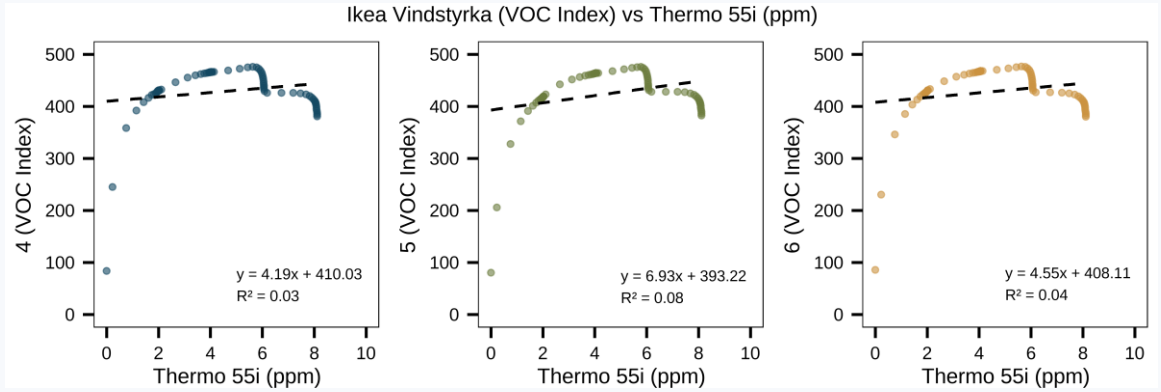
Section 3.2.3: Linearity (R^2) – High Conc. Ramp

Basic QA/QC procedures were used to validate the collected data (i.e., obvious outliers, negative values, readings flagged by the sensor, and invalid data points were eliminated from the data-set.

A summary of the mean R^2 between the sensor and reference instruments across all units tested.

Parameter	Time Resolution	IKEA Vindstyrka (mean ± SD)
VOC, high conc. ramp	5-minute	0.05 ± 0.03





Interpretation:

- The IKEA Vindstyrka sensors showed no correlation with the corresponding Thermo 55i reference instrument ($0.03 < R^2 < 0.09$) at 5-minute averaging, for a VOC mixture containing equal concentrations of 1,3 butadiene, benzene, ethane and tetrachloroethylene, from 2 to 8 ppm (high concentration ramp), at 20°C, 40% RH.
- After approximately 200 minutes at concentrations ≥ 4 ppm, the IKEA Vindstyrka sensors displayed a gradual decrease in VOC Index at a rate of about 1 VOC index unit per minute.

Section 3: VOC

Section 3.3: Effect of Temperature and Humidity

Section 3.3.1: Normal and Extreme Conditions

Section 3.3.1.1: Data Recovery

Basic QA/QC procedures such as removal of duplicate records was performed. Nulls, negatives, out of instrument bounds as specified by the manufacturer, and values flagged as invalid by the sensor were considered invalid. Data recovery was calculated as the percent of valid readings through the entire evaluation.

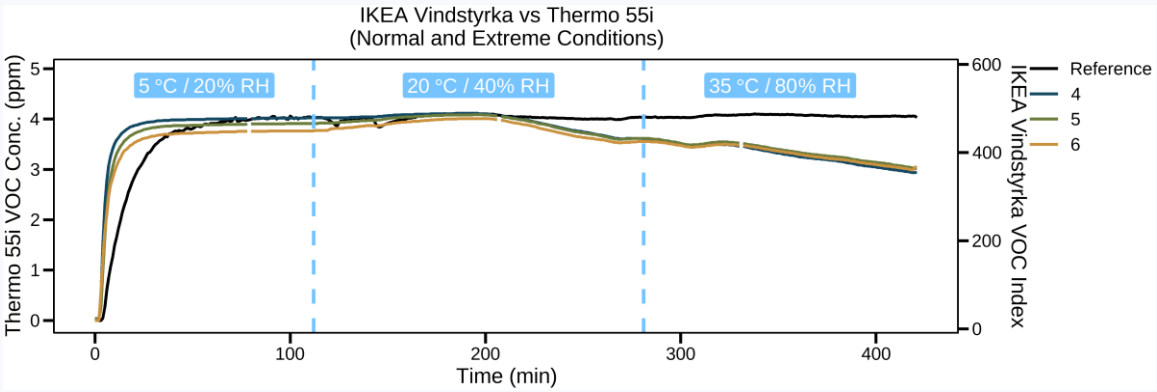
Parameter	Unit 4	Unit 5	Unit 6
VOC	NA	NA	NA

Note: *The IKEA sensors do not allow datalogging / data retrieval. Therefore, the data recovery metric is not calculable.*

Section 3.3.1.2: Intra-Model Variability

Absolute intra-model variability was calculated as the standard deviation of the mean values of the sensors. Relative intra-model variability was calculated as the absolute intra-model variability divided by the sensor grand mean. Calculations were performed using 20 measurements from each steady-state period.

Condition	T (°C)	RH (%)	Absolute intra-model variability (VOC Index)	Relative intra-model variability (%)
Cold/dry	5	20	14.66	3.16
Baseline	20	40	6.06	1.38
Hot/humid	35	80	5.45	1.49



Interpretation:

- As seen in earlier results, after approximately 200 minutes at concentrations ≥ 4 ppm, the IKEA Vindstyrka sensors displayed a gradual decrease in VOC Index at a rate of about 1 VOC index unit per minute.
- It is unclear from this test what was the impact of extreme T/RH was on the VOC index report by the IKEA Vindstryka sensors.

Section 3: VOC

Section 3.3.2: RH interference

Section 3.3.2.1: Data Recovery

Basic QA/QC procedures such as removal of duplicate records was performed. Nulls, negatives, out of instrument bounds as specified by the manufacturer, and values flagged as invalid by the sensor were considered invalid. Data recovery was calculated as the percent of valid readings through the entire evaluation.

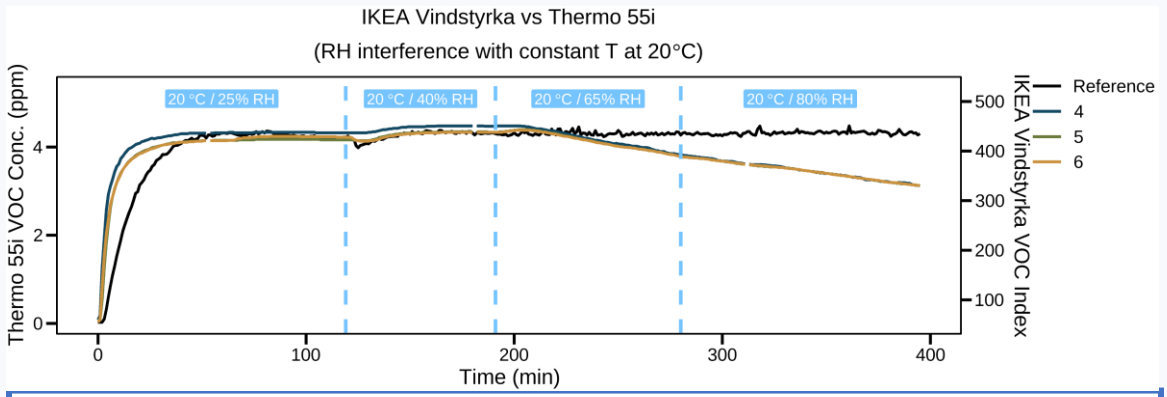
Parameter	Unit 4	Unit 5	Unit 6
VOC	NA	NA	NA

Note: *The IKEA sensors do not allow datalogging / data retrieval. Therefore, the data recovery metric is not calculable.*

Section 3.3.2.2: Intra-Model Variability

Absolute intra-model variability was calculated as the standard deviation of the mean values of the sensors. Relative intra-model variability was calculated as the absolute intra-model variability divided by the sensor grand mean. Calculations were performed using 20 measurements from each steady-state period.

RH (%) (T constant at 20° C)	Absolute intra-model variability (VOC Index)	Relative intra-model variability (%)
25	7.01	1.63
40	7.12	1.61
65	1.66	0.42
80	0.42	0.12



Interpretation:

- As seen in earlier results, after approximately 200 minutes at concentrations ≥ 4 ppm, the IKEA Vindstyrka sensors displayed a gradual decrease in VOC Index at a rate of about 1 VOC index unit per minute.
- It is unclear from this test what was the impact of RH was on the VOC index report by the IKEA Vindstryka sensors.

Section 3: VOC

Section 3.3.3: T interference at constant RH

Section 3.3.3.1: Data Recovery

Basic QA/QC procedures such as removal of duplicate records was performed. Nulls, negatives, out of instrument bounds as specified by the manufacturer, and values flagged as invalid by the sensor were considered invalid. Data recovery was calculated as the percent of valid readings through the entire evaluation.

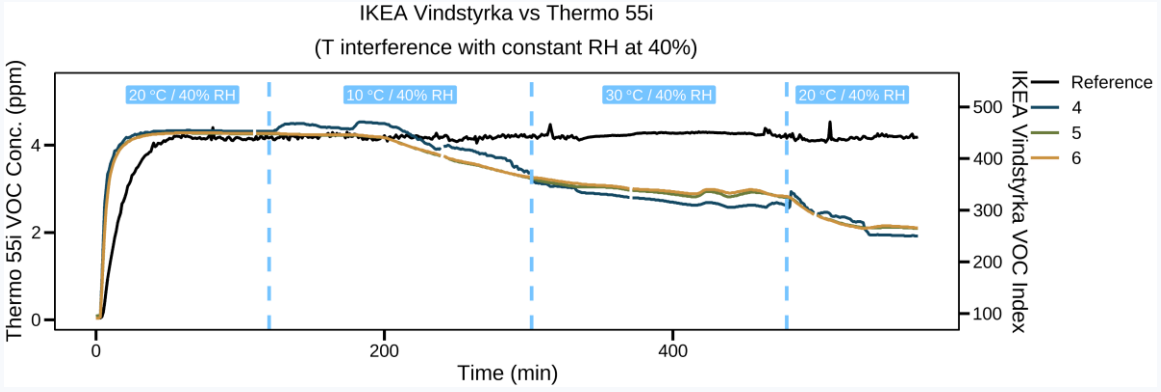
Parameter	Unit 4	Unit 5	Unit 6
VOC	NA	NA	NA

Note: *The IKEA sensors do not allow datalogging / data retrieval. Therefore, the data recovery metric is not calculable.*

Section 3.3.3.2: Intra-Model Variability

Absolute intra-model variability was calculated as the standard deviation of the mean values of the sensors. Relative intra-model variability was calculated as the absolute intra-model variability divided by the sensor grand mean. Calculations were performed using 20 measurements from each steady-state period.

T (°C) (RH constant at 40%)	Absolute intra-model variability (VOC Index)	Relative intra-model variability (%)
20	2.65	0.59
10	5.24	1.49
30	11.06	3.42
20	9.52	3.64



Interpretation:

- As seen in earlier results, after approximately 200 minutes at concentrations ≥ 4 ppm, the IKEA Vindstyrka sensors displayed a gradual decrease in VOC Index at a rate of about 1 VOC index unit per minute.
- It is unclear from this test what was the impact of T at constant RH was on the VOC index report by the IKEA Vindstryka sensors.

Section 3: VOC

Section 3.3.4: T interference at constant absolute humidity (AH)

Section 3.3.4.1: Data Recovery

Basic QA/QC procedures such as removal of duplicate records was performed. Nulls, negatives, out of instrument bounds as specified by the manufacturer, and values flagged as invalid by the sensor were considered invalid. Data recovery was calculated as the percent of valid readings through the entire evaluation.

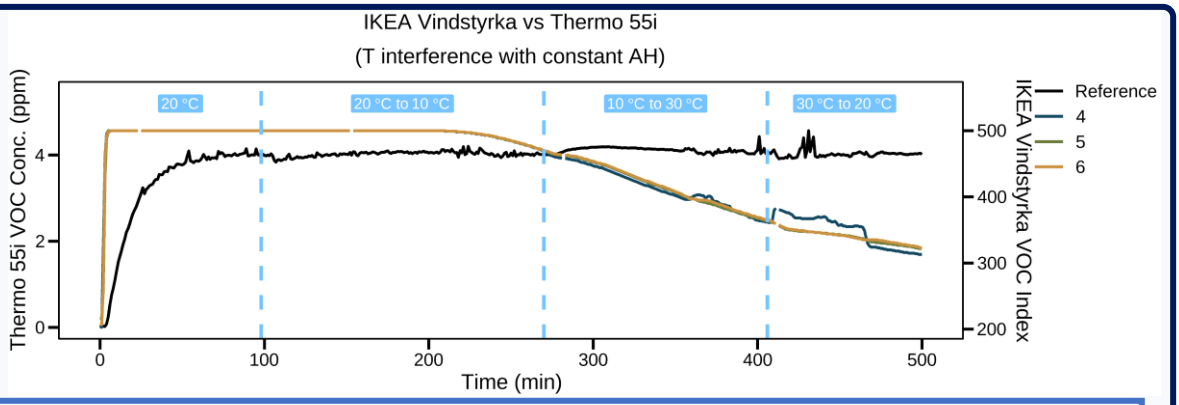
Parameter	Unit 4	Unit 5	Unit 6
VOC	NA	NA	NA

Note: *The IKEA sensors do not allow datalogging / data retrieval. Therefore, the data recovery metric is not calculable.*

Section 3.3.4.2: Intra-Model Variability

Absolute intra-model variability was calculated as the standard deviation of the mean values of the sensors. Relative intra-model variability was calculated as the absolute intra-model variability divided by the sensor grand mean. Calculations were performed using 20 measurements from each steady-state period.

T (°C) (AH constant at 0.007 kg/m³)	Absolute intra-model variability (IVOC Index)	Relative intra-model variability (%)
20	0.00	0.00
10	0.33	0.07
30	1.61	0.44
20	6.04	1.87



Interpretation:

- As seen in earlier results, after approximately 200 minutes at concentrations ≥ 4 ppm, the IKEA Vindstyrka sensors displayed a gradual decrease in VOC Index at a rate of about 1 VOC index unit per minute.
- It is unclear from this test what was the impact of T at constant AH was on the VOC index report by the IKEA Vindstryka sensors.

Section 3: VOC

Section 3.4: Effect of Gaseous Interferents

Section 3.4.1: Ozone Interference

Section 3.4.1.1: Data Recovery

Basic QA/QC procedures such as removal of duplicate records was performed. Nulls, negatives, out of instrument bounds as specified by the manufacturer, and values flagged as invalid by the sensor were considered invalid. Data recovery was calculated as the percent of valid readings through the entire evaluation.

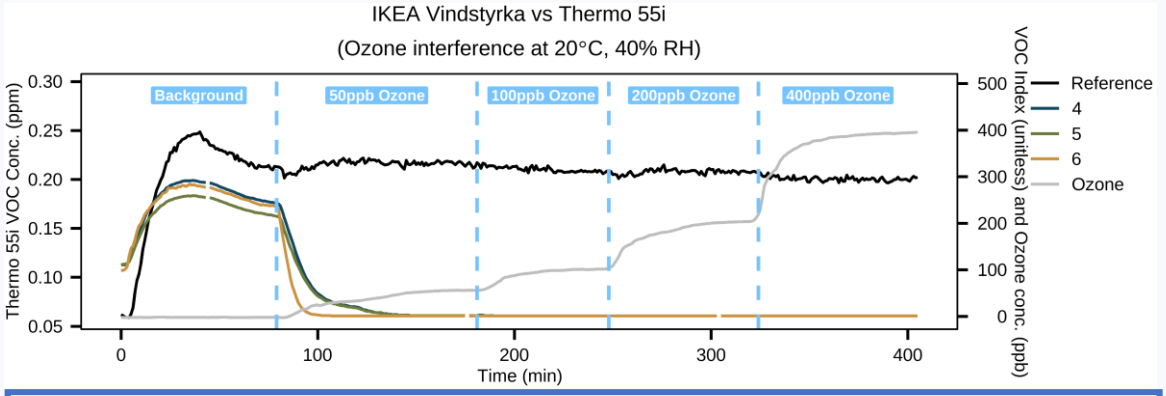
Parameter	Unit 4	Unit 5	Unit 6
VOC	NA	NA	NA

Note: *The IKEA sensors do not allow datalogging / data retrieval. Therefore, the data recovery metric is not calculable.*

Section 3.4.1.2: Intra-Model Variability

Absolute intra-model variability was calculated as the standard deviation of the mean values of the sensors. Relative intra-model variability was calculated as the absolute intra-model variability divided by the sensor grand mean. Calculations were performed using 20 measurements from each steady-state period.

O_3 (ppb) (At constant 0.2 ppm of VOC)	Absolute intra-model variability (VOC Index)	Relative intra-model variability (%)
background	14.60	6.07
50	0.58	34.64
100	0.00	0.00
200	0.00	0.00
400	0.00	0.00



Interpretation:

- The VOC index readings measured by the IKEA Vindstyrka sensors were very sensitive to O_3 any concentrations; the sensors' VOC readings decreased to ~ 0 when O_3 was introduced.

Section 3: VOC

Section 3.4.2: CO Interference

Section 3.4.2.1: Data Recovery

Basic QA/QC procedures such as removal of duplicate records was performed. Nulls, negatives, out of instrument bounds as specified by the manufacturer, and values flagged as invalid by the sensor were considered invalid. Data recovery was calculated as the percent of valid readings through the entire evaluation.

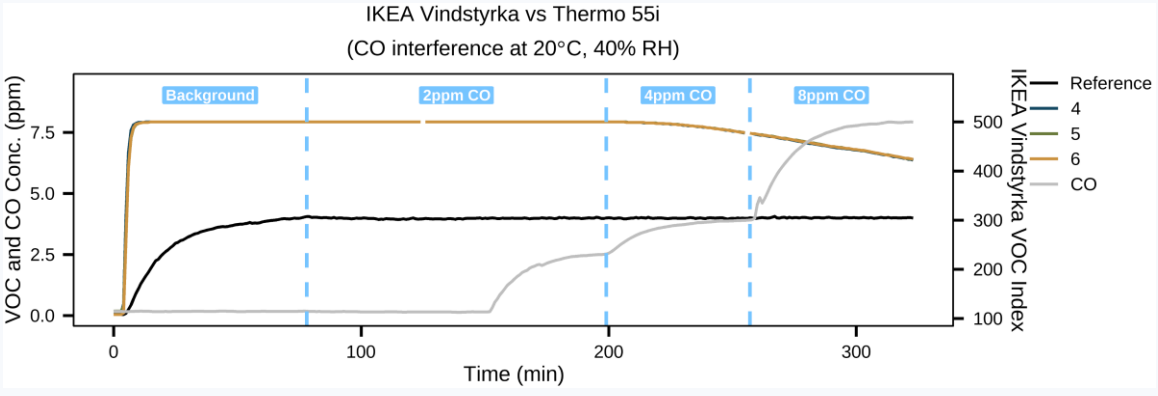
Parameter	Unit 4	Unit 5	Unit 6
VOC	NA	NA	NA

Note: *The IKEA sensors do not allow datalogging / data retrieval. Therefore, the data recovery metric is not calculable.*

Section 3.4.2.2: Intra-Model Variability

Absolute intra-model variability was calculated as the standard deviation of the mean values of the sensors. Relative intra-model variability was calculated as the absolute intra-model variability divided by the sensor grand mean. Calculations were performed using 20 measurements from each steady-state period.

CO (ppm) (At constant 4 ppm of VOC)	Absolute intra-model variability (VOC Index)	Relative intra-model variability (%)
background	0.00	0.00
2	0.00	0.00
4	0.24	0.05
8	0.8	0.13



Interpretation:

- As seen in earlier results, after approximately 200 minutes at concentrations ≥ 4 ppm, the IKEA Vindstyrka sensors displayed a gradual decrease in VOC Index at a rate of about 1 VOC index unit per minute.
- It is unclear from this test what was the impact of CO was on the VOC index report by the IKEA Vindstryka sensors.

Section 3: VOC

Section 3.4.3: CO_2 Interference

Section 3.4.3.1: Data Recovery

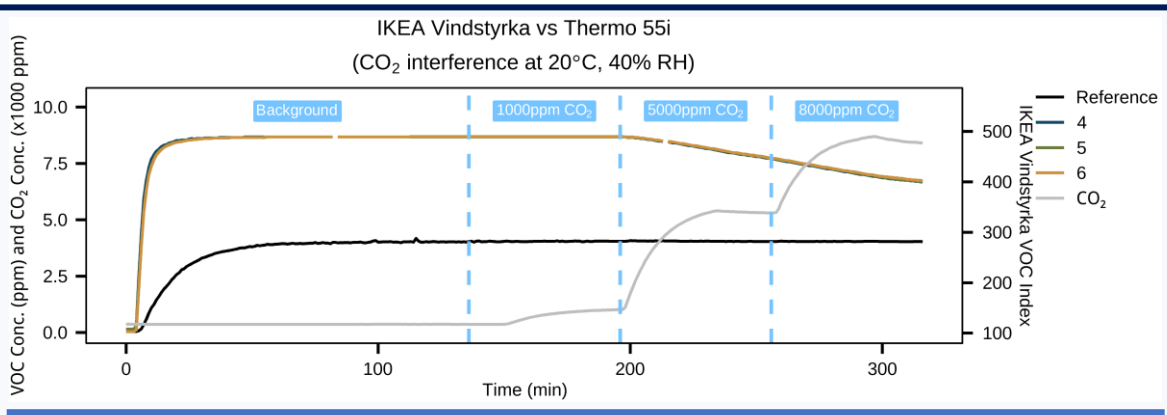
Basic QA/QC procedures such as removal of duplicate records was performed. Nulls, negatives, out of instrument bounds as specified by the manufacturer, and values flagged as invalid by the sensor were considered invalid. Data recovery was calculated as the percent of valid readings through the entire evaluation.

Parameter	Unit 4	Unit 5	Unit 6
VOC	NA	NA	NA

Note: *The IKEA sensors do not allow datalogging / data retrieval. Therefore, the data recovery metric is not calculable.*

Section 3.4.3.2: Intra-Model Variability

CO_2 (ppm) (At constant 4 ppm of VOC)	Absolute intra-model variability (VOC Index)	Relative intra-model variability (%)
background	0.58	0.12
1000	0.58	0.12
5000	0.83	0.18
8000	1.36	0.34



Interpretation:

- As seen in earlier results, after approximately 200 minutes at concentrations ≥ 4 ppm, the IKEA Vindstyrka sensors displayed a gradual decrease in VOC Index at a rate of about 1 VOC index unit per minute.
- It is unclear from this test what was the impact of CO_2 was on the VOC index report by the IKEA Vindstryka sensors.

Section 3: VOC

Section 3.5: Outdoor Simulation

Section 3.5.1: Data Recovery

Basic QA/QC procedures such as removal of duplicate records was performed. Nulls, negatives, out of instrument bounds as specified by the manufacturer, and values flagged as invalid by the sensor were considered invalid. Data recovery was calculated as the percent of valid readings through the entire evaluation.

Parameter	Unit 4	Unit 5	Unit 6
VOC	NA	NA	NA

Note: *The IKEA sensors do not allow datalogging / data retrieval. Therefore, the data recovery metric is not calculable.*

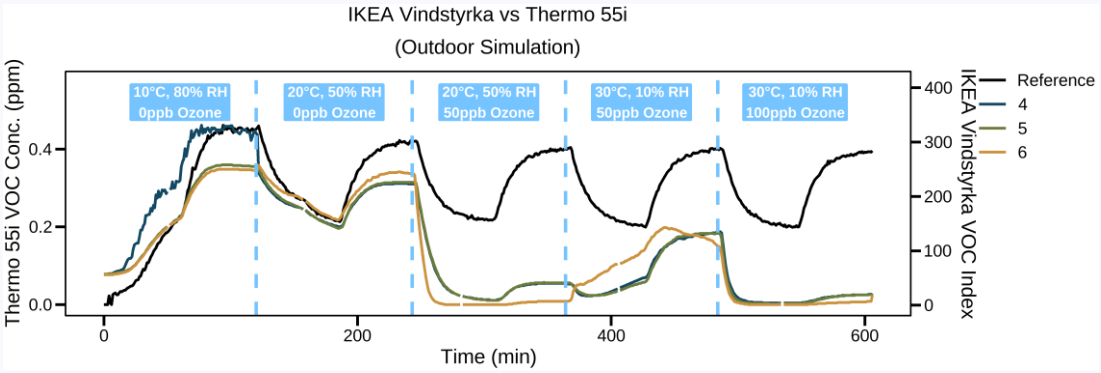
Section 3.5.2: Intra-Model Variability

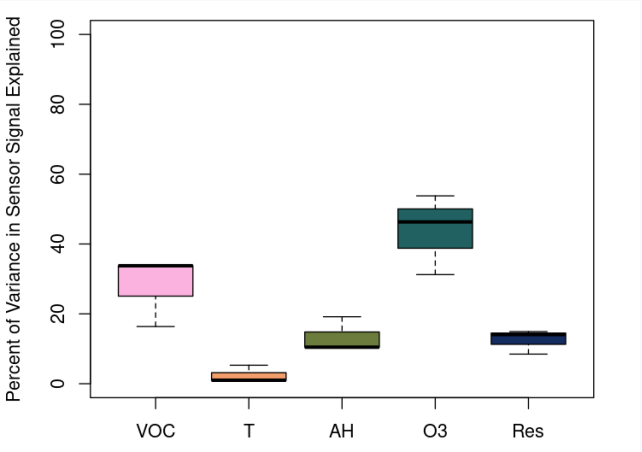
Absolute intra-model variability was calculated as the standard deviation of the mean values of the sensors. Relative intra-model variability was calculated as the absolute intra-model variability divided by the sensor grand mean. Calculations were performed using 20 measurements from each steady-state period.

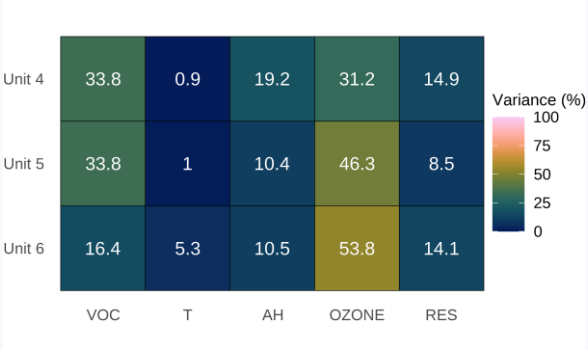
Step	VOC (ppm)	T (°C)	RH (%)	O_3 (ppb)	Absolute intra-model variability (VOC Index)	Relative intra-model variability (%)
1	0.2	10	80	0	40.42	24.21
2	0.4	10	80	0	38.20	13.91
3	0.2	20	50	0	8.43	5.32
4	0.4	20	50	0	10.98	4.76
5	0.2	20	50	50	6.17	75.98
6	0.4	20	50	50	19.35	65.96
7	0.2	30	10	50	26.74	52.86
8	0.4	30	10	50	5.52	4.31
9	0.2	30	10	100	1.50	59.04
10	0.4	30	10	100	7.39	51.03

Section 3: VOC

Section 3.5.3: ANOVA Statistical Test







Interpretation:

- **Ozone** explained ~ 31-54% of the IKEA Vindstyrka sensors' VOC readings, followed by **VOC** (~ 16-34%), followed by **AH** (~ 10-19%), while **Temperature** explained a small percentage (~0-5%) of the variance.

Notes:

- "VOC" is the Thermo 55i reference VOC monitor reading
- "AH" is the absolute humidity and is used instead of RH in ANOVA due to multicollinearity between RH and T
- "RES" is the residual, or variance that is not explained by the other variables

Section 3: VOC

Section 3.6: Final Concentration Ramp

Section 3.6.1: Data Recovery

Basic QA/QC procedures such as removal of duplicate records was performed. Nulls, negatives, out of instrument bounds as specified by the manufacturer, and values flagged as invalid by the sensor were considered invalid. Data recovery was calculated as the percent of valid readings through the entire evaluation.

Parameter	Unit 4	Unit 5	Unit 6
VOC, low conc. ramp	NA	NA	NA
VOC, high conc. ramp	NA	NA	NA

Note: *The IKEA sensors do not allow datalogging / data retrieval. Therefore, the data recovery metric is not calculable.*

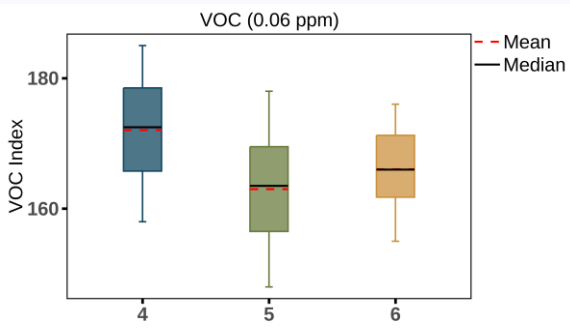
Section 3.6.2: Intra-Model Variability

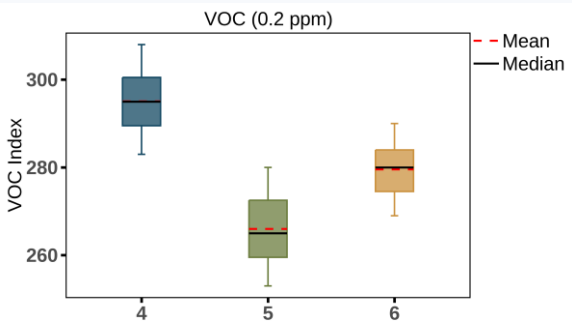
Absolute intra-model variability was calculated as the standard deviation of the mean values of the sensors. Relative intra-model variability was calculated as the absolute intra-model variability divided by the sensor grand mean. Calculations were performed using 20 measurements from each steady-state period.

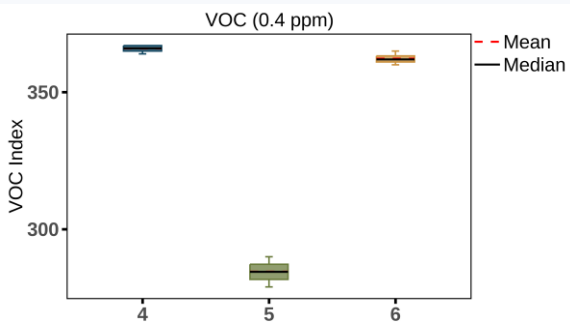
Test VOC Concentration (ppm)	Absolute intra-model variability (VOC Index)	Relative intra-model variability (%)
0.06	4.60	2.76
0.2	14.54	5.19
0.4	45.94	13.61
1.6	10.96	2.34
2	1.15	0.23
4	0.58	0.12
6	2.92	0.64
8	4.43	1.11

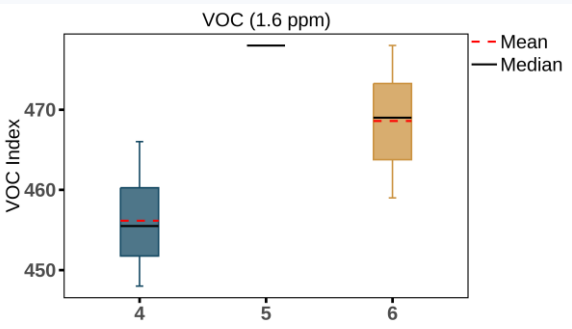
Section 3: VOC

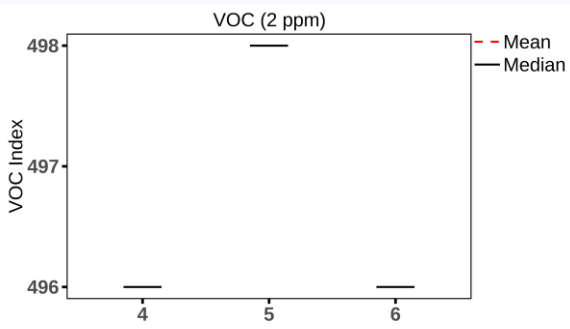
Section 3.6.2: Intra-Model Variability – Box Plots

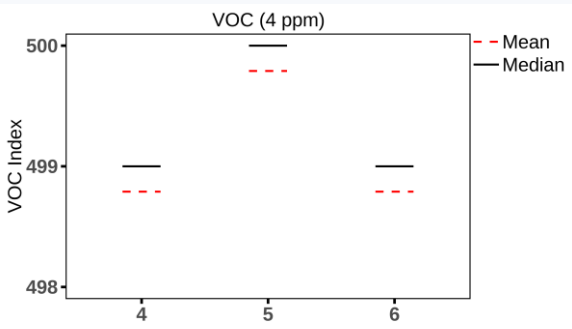


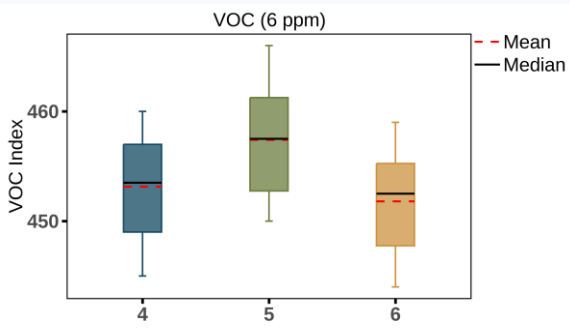


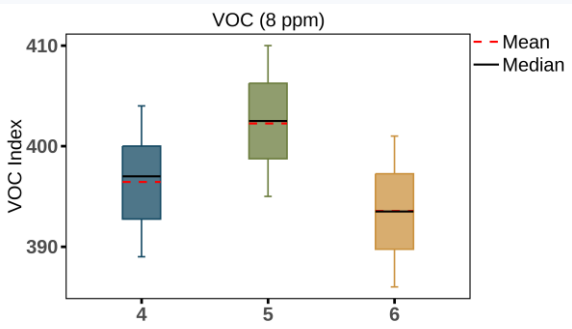












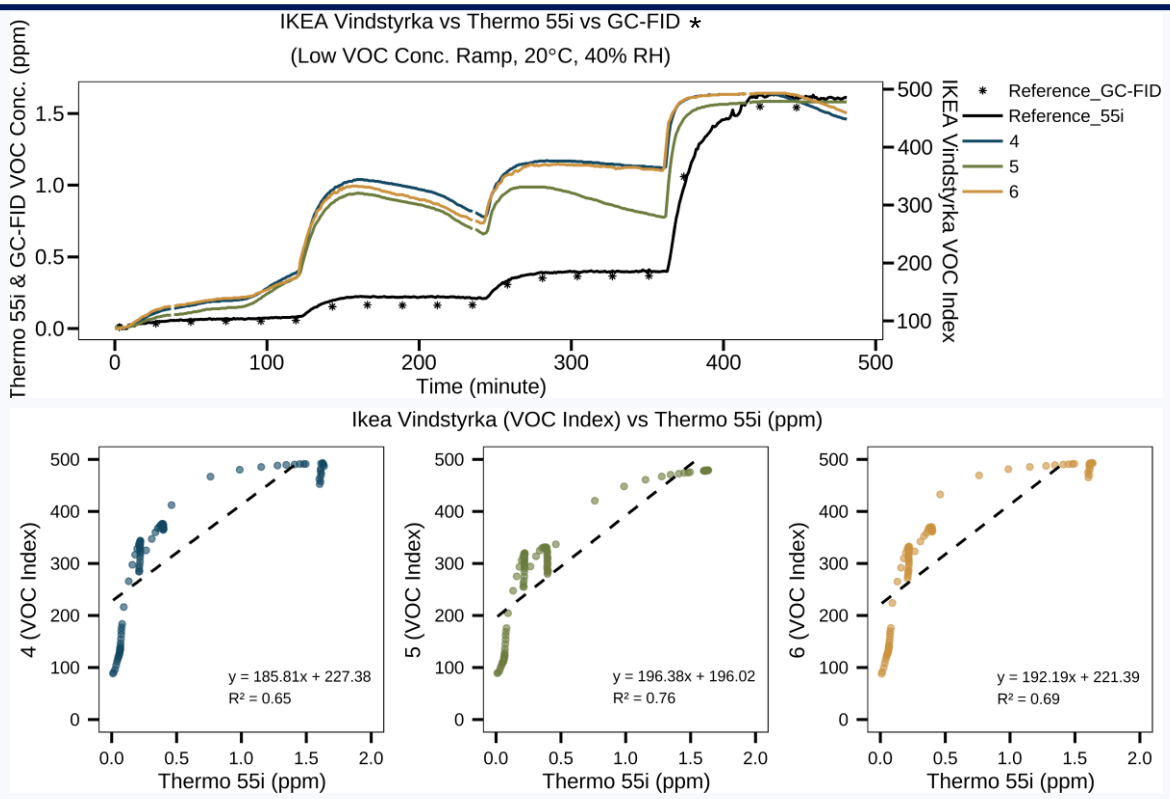
Section 3: VOC

Section 3.6.3: Linearity (R^2) – Low Conc. Ramp

Basic QA/QC procedures were used to validate the collected data (i.e., obvious outliers, negative values, readings flagged by the sensor, and invalid data points were eliminated from the data-set.

A summary of the mean R^2 between the sensor and reference instruments across all units tested.

Parameter	Time Resolution	IKEA Vindstyrka (mean ± SD)
VOC, low conc. ramp	5-minute	0.70 ± 0.06



Interpretation:

- The IKEA Vindstyrka sensors showed moderate to strong correlation with the corresponding Thermo 55i reference instrument ($0.65 < R^2 < 0.77$), for a VOC mixture containing equal concentrations of 1,3 butadiene, benzene, ethane and tetrachloroethylene, from 0.06 to 1.6 ppm (low concentration ramp), at 20°C and 40% RH.

*There is also an Agilent 6890N GC-FID that is used as a supplemental VOC reference instrument; additional results with the GC-FID can be found at the end of the report.

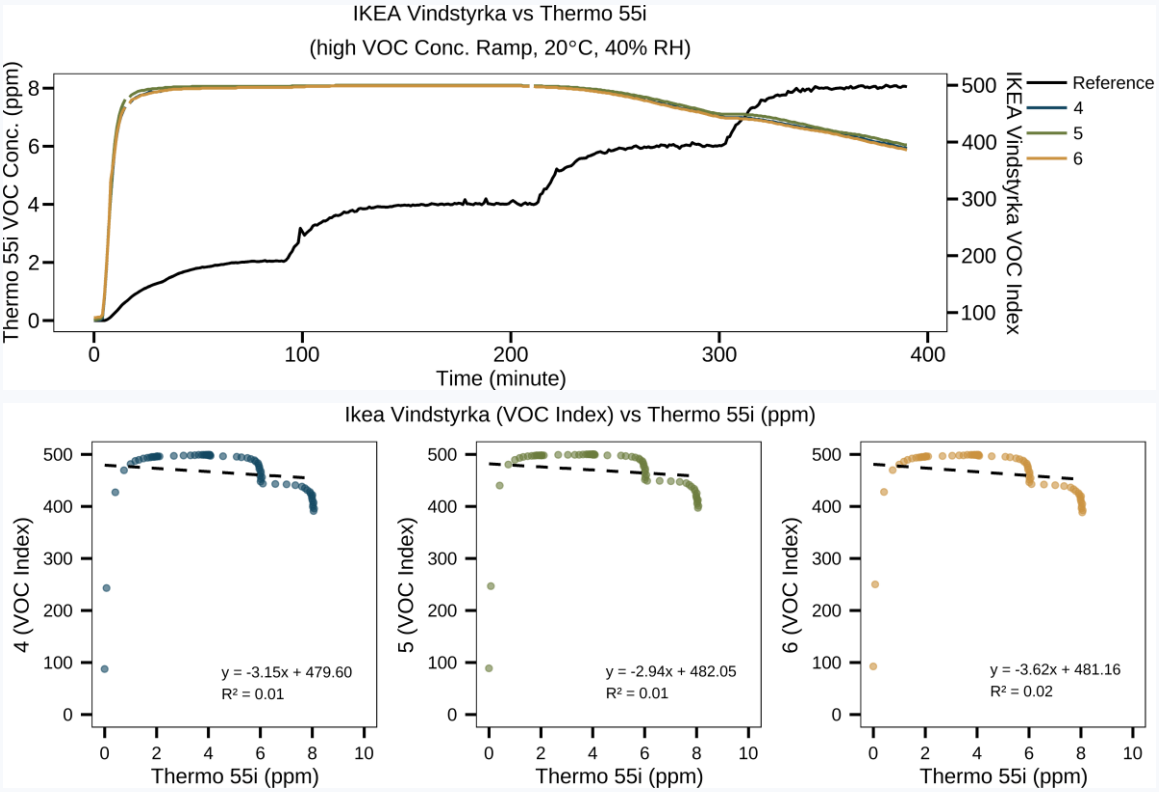
Section 3: VOC

Section 3.6.3: Linearity (R^2) – High Conc. Ramp

Basic QA/QC procedures were used to validate the collected data (i.e., obvious outliers, negative values, readings flagged by the sensor, and invalid data points were eliminated from the data-set.

A summary of the mean R^2 between the sensor and reference instruments across all units tested.

Parameter	Time Resolution	IKEA Vindstyrka (mean ± SD)
VOC, high conc. ramp	5-minute	0.02 ± 0.00



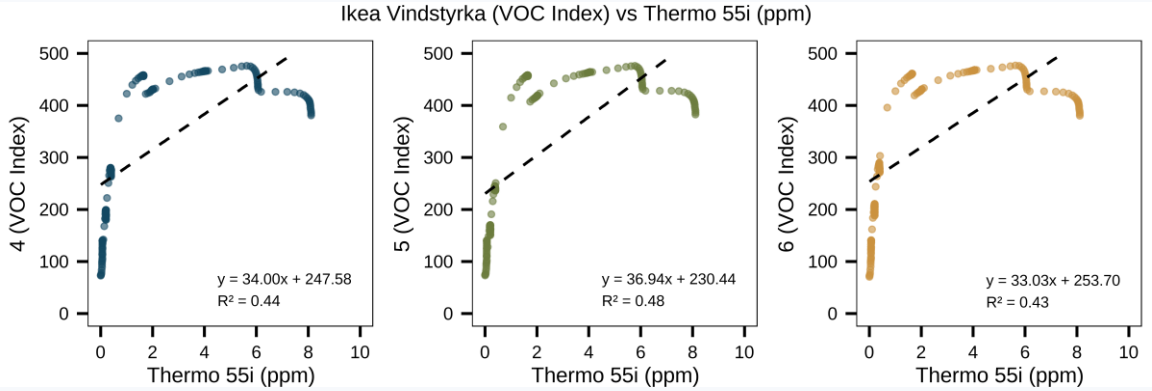
Interpretation:

- The IKEA Vindstyrka sensors showed no correlations with the corresponding Thermo 55i reference instrument ($0.01 < R^2 < 0.02$) at 5-minute averaging, for a VOC mixture containing equal concentrations of 1,3 butadiene, benzene, ethane and tetrachloroethylene, from 2 to 8 ppm (high concentration ramp), at 20°C, 40% RH.
- After approximately 200 minutes at concentrations ≥ 4 ppm, the IKEA Vindstyrka sensors displayed a gradual decrease in VOC Index at a rate of about 1 VOC index unit per minute.

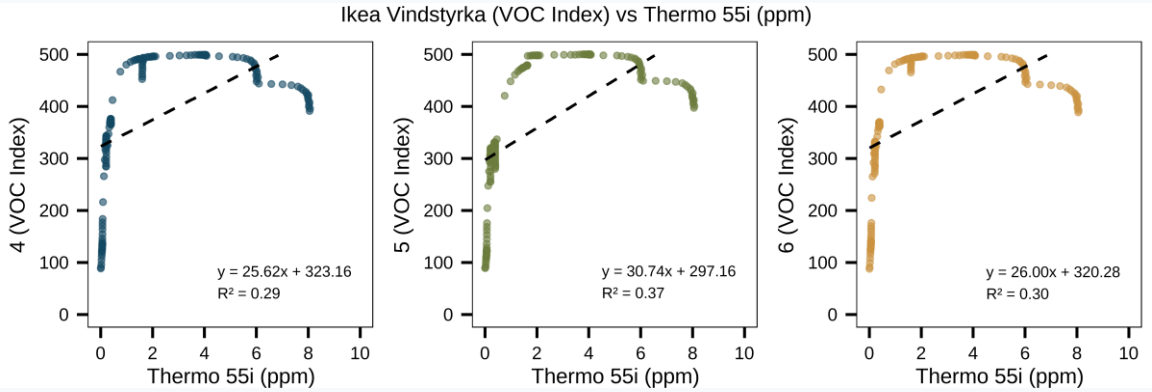
Section 3: VOC

Section 3.6.4: Short-Term Sensor Response Change

Initial Concentration Ramp



Final Concentration Ramp



Interpretation:

- Short-term sensor response change is characterized as the change in reference-sensor regression between the initial and final concentration ramping experiments
- Combining data from both low and high concentration ramps of the VOC blend, the slope of the final concentration ramp was lower, suggesting that the IKEA Vindstyrka sensors on average became less sensitive to unit changes in VOC concentrations compared to the initial concentration ramp.

Section 4: Summary Metrics

		Initial VOC Concentration Ramp							
		0.06 ppm VOC	0.2 ppm VOC	0.4 ppm VOC	1.6 ppm VOC	2 ppm VOC	4 ppm VOC	6 ppm VOC	8 ppm VOC
IKEA Vindstyrka	Average (Index)	119.68	179.25	257.49	457.80	426.78	466.00	435.07	385.77
	SD (Index)	4.60	2.40	1.08	0.40	0.47	0.00	4.18	4.20
	CV (RSD, %)	3.85	1.38	0.41	0.09	0.11	0.00	0.96	1.09
	Absolute IMV (Index)	2.00	18.83	18.50	2.68	6.83	2.00	0.70	1.41
	Relative IMV (%)	1.67	10.50	7.19	0.59	1.60	0.43	0.16	0.37
Thermo 55i	Average*	0.07	0.21	0.40	1.65	2.02	4.06	6.07	8.11
	SD*	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
	CV (RSD, %)	2.59	1.10	0.70	0.46	0.32	0.23	0.19	0.11
IKEA Vindstyrka vs Thermo 55i	Pearson R^2	0.89 to 0.95				0.03 to 0.08			
	Slope	204.03 to 216.09				4.19 to 6.93			
	Intercept	122.06 to 150.15				393.22 to 410.03			
	MBE**								
	$nMBE_{mean}$**								
	MAE**								
	$nMAE_{mean}$**								
	RMSE**								
	$nRMSE_{mean}$**								

*Units in ppm

**These values cannot be calculated since the sensors only produce an Index value and not a concentration value that can be compared against the reference value.

Section 4: Summary Metrics

		Final VOC Concentration Ramp							
		0.06 ppm VOC	0.2 ppm VOC	0.4 ppm VOC	1.6 ppm VOC	2 ppm VOC	4 ppm VOC	6 ppm VOC	8 ppm VOC
IKEA Vindstyrka	Average (Index)	167.03	280.21	337.60	467.58	496.67	499.12	454.12	397.42
	SD (Index)	7.73	7.33	2.02	3.81	0.00	0.42	4.84	4.64
	CV (RSD, %)	4.63	2.62	0.64	0.82	0.00	0.08	1.06	1.17
	Absolute IMV (Index)	4.60	14.54	45.94	10.96	1.15	0.58	2.92	4.43
	Relative IMV (%)	2.76	5.19	13.61	2.34	0.23	0.12	0.64	1.11
Thermo 55i	Average*	0.08	0.22	0.40	1.61	2.04	4.02	6.02	8.05
	SD*	0.00	0.00	0.00	0.01	0.01	0.04	0.04	0.03
	CV (RSD, %)	3.39	1.85	0.99	0.33	0.69	0.95	0.68	0.35
IKEA Vindstyrka vs Thermo 55i	Pearson R^2	0.65 to 0.76				0.01 to 0.02			
	Slope	185.81 to 196.38				2.94 to 3.62			
	Intercept	196.02 to 227.38				479.60 to 482.05			
	MBE**								
	$nMBE_{mean}$**								
	MAE**								
	$nMAE_{mean}$**								
	RMSE**								
	$nRMSE_{mean}$**								

*Units in ppm

**These values cannot be calculated since the sensors only produce an Index value and not a concentration value that can be compared against the reference value.

Summary Metrics Guide

Average:	mean of individual sensor means at a given steady-state concentration; the grand mean
SD:	mean of individual sensor standard deviations (σ; measure of variation of the values about its mean) at a given steady-state concentration
CV (RSD):	mean of individual sensor coefficient of variations (relative standard deviation; the ratio of the standard deviation to the mean, expressed as a percentage) at a given steady-state concentration
Absolute IMV	intra-model variability expressed in absolute terms; standard deviation of individual sensor means at a given steady-state concentration
Relative IMV	intra-model variability expressed in relative terms; the ratio of the *Absolute IMV* to the *Average* at a given-steady-state concentration
SDL	estimated lower limit of detection of the sensors; calculated from the sensor vs. GC-FID reference regression line following ICH guidelines in *Validation of Analytical Procedures: Text and Methodology Q2(R1),* 2005
Pearson R^2:	the squared value of the Pearson correlation coefficient; the square of the covariance of the reference and sensor measurements divided by the product of their standard deviations (a value from 0 to 1)
Slope:	change in the sensor's value per unit increase in the reference monitor's value
Intercept:	the sensor's predicted value when the reference monitor observes zero
MBE:	mean bias error; mean of the differences between reference and sensor measurements at a given steady-state concentration
$nMBE_{mean}$:	mean bias error normalized with respect to the reference mean value at a given steady-state concentration
MAE:	mean absolute error; mean of the absolute differences between reference and sensor measurements at a given steady-state concentration
$nMAE_{mean}$:	mean absolute error normalized with respect to the reference mean value at a given steady-state concentration
RMSE:	root mean square error; the square root of the average squared differences between reference and sensor measurements at a given steady-state concentration
$nRMSE_{mean}$:	root mean square error normalized with respect to the reference mean value at a given steady-state concentration

Appendix: GC-FID VOC Results

Three **IKEA Vindstyrka** sensors (units IDs: 4, 5, 6) were evaluated in an AQ-SPEC environmental chamber under controlled temperatures, humidities, and volatile organic compound (VOC) concentrations. In addition to the Thermo 55i continuous VOC reference instrument, there was an Agilent 6890N GC-FID (coupled with an Entech 7100A preconcentrator) that served as a supplemental reference instrument. The supplemental reference instrument measured concentrations of each of the 4 species in the VOC blend test gas, was used as a check on the Thermo 55i reference instrument and to determine the sensor lower limit of detection, or SDL.

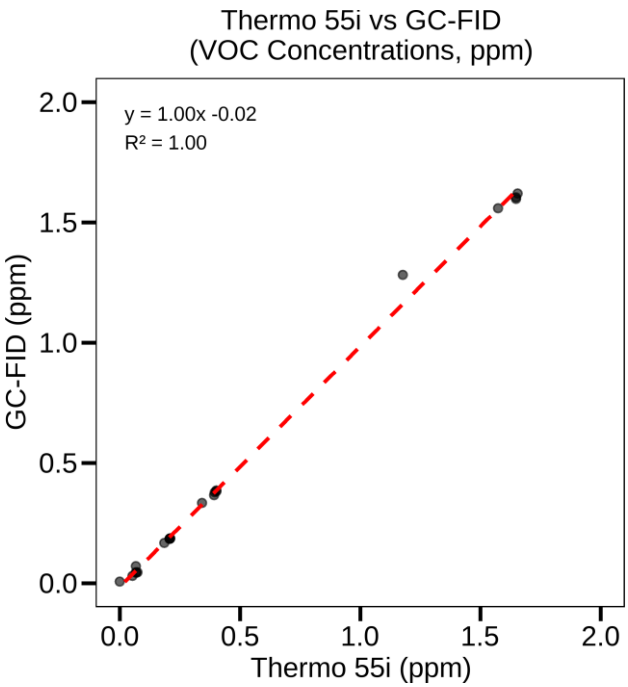
IKEA Vindstyrka

Agilent 6890N GC-FID

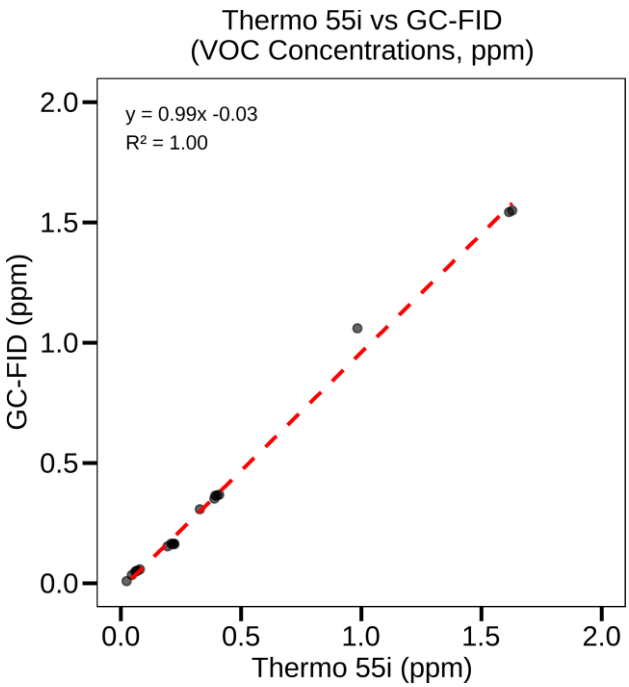
Parameter	Sensor: IKEA Vindstyrka (raw sensor is Sensirion SEN54)	Reference Instrument: Agilent 6890N GC-FID
Pollutant	Total VOC (hereinafter referred to as "VOC")	Speciated VOC
Cost	$60	~$44,000 (plus ~$65,000 for the preconcentrator)
Weight	0.3 pounds	108 pounds
Dimensions (LxWxD)	3.5 x 2 x 2.25 inches	19.7 x 22.8 x 21.6 inches
Power	5 VDC	115 - 240 VAC
Battery	No	No
Data transmission	None	Ethernet, serial, analog output
Internal memory	No	No
Operating temperature range	14 to 122 degrees F	59 to 95 degrees F
Operating RH range	0 to 90%	5% to 95%
Product website	https://www.ikea.com/us/en/p/vindstyrka-air-quality-sensor-smart-30498239/	https://www.agilent.com/cs/library/specifications/Public/5989-3290EN.pdf
Operating principle	Metal Oxide	Flame Ionization Detection
Time resolution	N/A (see note in page 4)	22 minutes (with preconcentrator and sequence specific to current method)
Concentration range	0 – 500 VOC Index	< 2 ppm per current method

Appendix: GC-FID VOC Results

Beginning of Evaluation



End of Evaluation



Interpretation:

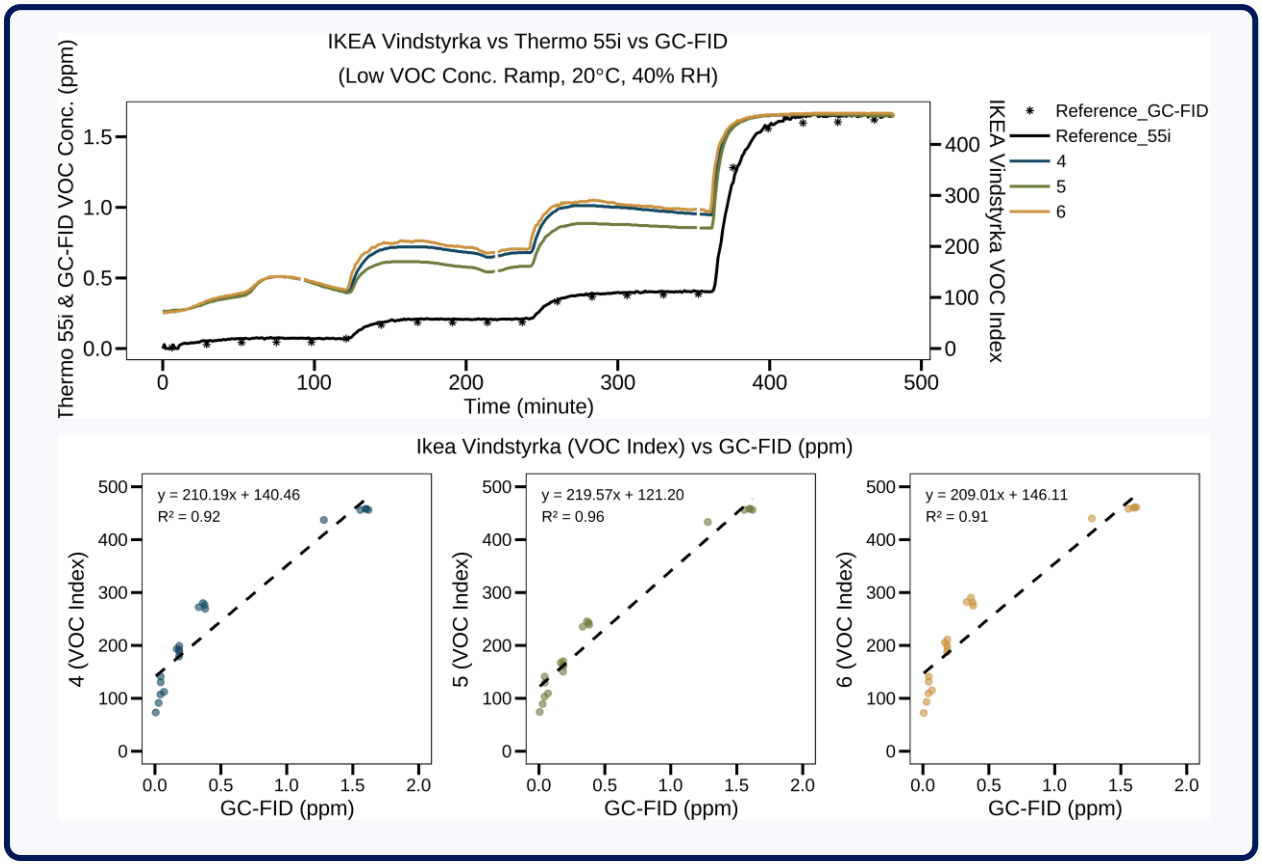
- Very strong correlations between the Thermo 55i and GC-FID (R^2 = 1.00).
- The two reference instruments reported similar VOC concentrations at both the beginning and the end of evaluation.

Appendix: GC-FID VOC Results

Linearity (R^2) – Initial Low Conc. Ramp

Basic QA/QC procedures were used to validate the collected data (i.e., obvious outliers, negative values, readings flagged by the sensor, and invalid data points were eliminated from the data-set.

A summary of the mean R^2 between the sensor and reference instruments across all units tested.



Appendix: GC-FID VOC Results

Linearity (R^2) – Final Low Conc. Ramp

Basic QA/QC procedures were used to validate the collected data (i.e., obvious outliers, negative values, readings flagged by the sensor, and invalid data points were eliminated from the data-set.

A summary of the mean R^2 between the sensor and reference instruments across all units tested.