



CO-LOCATION FIELD STUDY Full Report Barcelona (SPAIN) March – May 2017 (2 months) Season: Spring

Test Conditions



- DEVICE UNDER TEST: KUNAKAIR version 2 provided with CO, NO2, NO, O3, NOx, PM10, PM2.5, PM1 and Temperature and Humidity sensors.
- LOCATION AND TYPE STATION: Barcelona, urban background.
- INSTRUMENTAION AVAILABLE IN THE OFFICIAL AIR QUALITY STATION (Barcelona CSIC -IDAEA c/Jordi Girona - c/Tinent Coronel Valenzuela):
 - O3 Analyzer
 - NO Analyzer
 - NO2 Analyzer
 - NOx Analyzer
 - CO Analyzer
 - Particle size Analyzer
- TEST PERIOD: March 2017 May 2017
- ENVIROMENTAL CONDITIONS :

Aquí mesurem la qualitat de l'aire que respires	

	Min	Avg	Max
T (ºC)	5.27	15.99	29.01
RH (%)	22.98	63.13	96.15

Test Procedure

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- INSTALLATION: On top of AQS (3-4meters)
- STABILIZATION TIME BEFORE CALIBRATION: 2 days
- CALIBRATION PROCEDURE: Zero and Span calibration compared to a Reference (AQS) using KUNAK Calibration Tool. First 4 days.
- POST-PROCESSING: <u>None</u>. Real corrected data is calculated directly in the device without any delay. No re-calibrations or corrections are applied during the field tests unless specified. Then, the initial calibration is maintained during the whole field tests and the results are shown in this study.
- SAMPLING PERIOD: data is averaged every hour to match data from reference station.
- <u>100% of KUNAKAIR data</u> is used for analysis, therefore, any possible outlier is included in the statistics to show real time performance without post-processing.
- VALIDATION: statistics are only calculated if valid Reference Data is available. All KUNAKAIR data within the measurement range is used.



Analysis and Characterization Procedure



- ACCURACY: is obtained as the mean absolute error (MAE) between KUNAKAIR measurements and the reference instruments.
- **90% CONFIDENCE INTERVAL**: the 90% of the measurements are below this error

• **RELATIVE EXPANDED UNCERTAINTY**: U (y) = 2 *
$$\left(\frac{\sqrt{\left(\frac{\text{RSS}}{n-2}\right) + [a+(b-1)*Xi]^2}}{Xi}\right)$$

- DATA QUALITY OBJECTIVE (DQO): concentration value from which DQO defined in the EU Air Quality Directive (2008/50/EC) is met. Also, the absolute relative error (%) in 10 ppb increments (or 100ppb in the CO) is calculated within the DQO plot as: (Avg. DUT Errors /Average Ref.) for each interval.
- AVAILABILITY: is defined as the number of 1 hour averaged samples sent by the device / number of hours in the month.
- Results also include the average concentrations (AVG. GC) during the whole tests.
- Temporal plots, Scatter plots, DQO plot and Time Variation of the Mean are used to analyze the test results.
- FIELD TEST MAIN OBJECTIVES:
 - 1. Check the performance of KUNAKAIR V2 device vs. Reference equipment over time, obtaining the statistics defined previously during spring time in a seacoast city like Barcelona.
 - Analyze the performance of KUNAKAIR V2, including gases and particles PM10 and PM2.5 and PM1

FIELD TEST RESULTS

BARCELONA

MARCH'17 – MAY'17

CARBON MONOXIDE (CO), BARCELONA (Spain), MAR'17-MAY'17



Comments: The Reference AQS is not accurate enough for low CO concentrations. Besides, there was lot of missing data form the reference station (yellow bubble inside the time series) and many weeks the station was broken reporting only baseline values. In the time series and statistics all the available data is presented, even if it is not valid, just to show that reference instruments can suffer from errors due to their bigger complexity and the high cost and efforts for maintenance.

Version: KUNAKAIR V2.



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DQO / Relative error /

Conc. [ppb]

CARBON MONOXIDE (CO), BARCELONA (Spain), MAR'17-MAY'17



Comments: The KunakAir V2 shows higher reliability and availability than the reference instrument. The missing and invalid data from the reference instrument doesn't allow us to make any conclusions regarding the co-locations results instead for he availability of the instruments, where KunakAir V2 showed a greater performance.

Time variation of Kunak Air V2 and Ref. Palau Reial : CO GCc

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NITROGEN MONOXIDE (NO), BARCELONA (Spain), MAR'17-MAY'17 KUNCK®



Comments: very good liner relationship with optimal correlation between the KUNAKAIR V2 (red color) and the reference instrument in the AQS (bluet color). DQO is met above 45ppb, with very small relative errors. (yellow bubble in the time series shows missing data from reference instrument).







Time variation of Kunak Air V2 and Ref. Palau Reial : NO GCc

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R²	ACCURAY	90% CONF.	DOQ	AVG. GC. REF	AVG. GC. DUT	AV
	(PPB)	(PPB)	(PPB)	(PPB)	(PPB)	REF/DUT
0,93	3,27	8,66	45	7,68	8,31	97,8% / 99,3%

Comments: The KunakAir V2, tracks perfectly the weekly variations as well as the hourly, daily and monthly concentrations comparing to the reference instrument. Average data is below 1ppb for the whole tests. DQO is met with excellent accuracy and correlation.

NITROGEN DIOXIDE (NO2), BARCELONA (Spain), MAR'17-MAY'17



Comments: very good liner relationship with good correlation between the KUNAKAIR V2 (red color) and the reference instrument in the AQS (bluet color). Yellow bubble in the time series shows missing data from reference instrument.

Version: KUNAKAIR V2.



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DQO / Relative error /



Time variation of Kunak Air V2 and Ref. Palau Reial : NO2 GCc

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R²	(PPB)	(PPB)	(PPB)	(PPB)	(PPB)	REF/DUT
0,87	4,80	9,01	48	19,64	21,79	97,7% / 99,3%

Comments: The KunakAir V2, tracks perfectly the weekly variations as well as the hourly, daily and monthly concentrations comparing to the reference instrument. DQO is met with excellent accuracy and correlation with very high data availability.

OZONE (O3), BARCELONA (Spain), MAR'17-MAY'17



Comments: perfect performance of KUNAKAIR V2 against reference instrument at high and low temperatures form low to high concentrations, achieving the DQO on field. Missing data from reference instrument is marked with a yellow bubble.





OZONE (O3), BARCELONA (Spain), MAR'17-MAY'17



Time variation of Kunak Air V2 and Ref. Palau Reial : O2 GCc

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Comments: Outstanding performance of KunakAir V2, which tracks perfectly the weekly variations as well as the hourly, daily and monthly concentrations comparing to the reference instrument. DQO is met about 20ppb with excellent accuracy and correlation with very high data availability. Average concentration is totally matched. 90% of absolute errors are below 4.5ppb.

NITROGEN OXIDE (NOx), BARCELONA (Spain), MAR'17-MAY'17



Comments: very good linear relationship with high correlation between the KUNAKAIR V2 (red color) and the reference instrument in the AQS (bluet color). Yellow bubble in the time series shows missing data from reference instrument. DQO is met.

Version: KUNAKAIR V2.



DQO / Relative error / **Expanded Uncertainty**

Conc. [ppb]



NITROGEN OXIDE (NOx), BARCELONA (Spain), MAR'17-MAY'17



Time variation of Kunak Air V2 and Ref. Palau Reial : NOx GCc

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R²	ACCY	90% CONF.	DOQ	AVG. GC. REF	AVG. GC. DUT	AV
	(PPB)	(PPB)	(PPB)	(PPB)	(PPB)	REF/DUT
0,96	4,49	8,73	49	27,51	30,30	98% / 99,2%

Comments: The KunakAir V2, tracks perfectly the weekly variations as well as the hourly, daily and monthly concentrations comparing to the reference instrument. DQO is met with excellent accuracy and correlation with very high data availability.

PM10, BARCELONA (Spain), MAR'17-MAY'17



Comments: good linear relationship and correlation between the KUNAKAIR V2 (red color) and the reference instrument in the AQS (bluet color). High concentration values are easier to track than low concentration values.





PM10, BARCELONA (Spain), MAR'17-MAY'17

12 18 23 6 12 18 23 6 12 18 23 lunes martes miércoles ueves viernes sábado domingo 250 200 150 dqd 100 50 0 0 12 18 23 12 18 23 0 6 12 18 23 12 23 6 0 6 0 6 18 Hourly evolution during the week PM₁₀ Kunak Air V2 PM10 Ref. Palau Reial 60 35 25 50 30 40 25 20 dqq dqq qdd 30 20 15 20 15 10 10 0 12 18 23 8 e f m а i. a s o n d mar mié jue vie sáb dom m lun Hourly evolution Monthly evolution Evolution by days of the week Mean and 95% confidence interval in mean

Time variation of Kunak Air V2 and Ref. Palau Reial : PM10

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R ²	ACCY	90% CONF.	DOQ	AVG. GC. REF	AVG. GC. DUT	AV
	(UG/M3)	(UG/M3)	(UG/M3)	(UG/M3)	(UG/M3)	REF/DUT
0,82	10,37	12,38	104	15,88	21,6	95% / 99,3%

Comments: Daily, weekly and monttly trends are tracked, although averages concentrations suggest that a calibration should be require to obtain more accurately absolute average concentrations.

PM2.5, BARCELONA (Spain), MAR'17-MAY'17



Comments: weak linear relationship and correlation between the KUNAKAIR V2 (red color) and the reference instrument in the AQS (blue color). Time series shows that the KUNAKAIRV2 follows the reference trends. However, underestimates the mass concentration, suggesting that a calibration is required.

8 NewGroupVar=0.66(PMz_Ref)=0.33 R²=0.54 . R² = 0,54 25 60 Y = 0,66*X - 0.3380 Rel. exp. unc. [%] 20 PM₂₅ Kunak Air V2 40 60 15 20 40 . 10 0 50 10 20 40

PM25 Ref. Palau Reial



Conc. [ppb]

DC

PM2.5, BARCELONA (Spain), MAR'17-MAY'17



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Comments: Daily and weekly trends are tracked, although averages concentrations suggest that a calibration should be require to obtain more accurately absolute average concentrations. DQO is met above 34ug/m3.