# Supplement of Measurement report: In-depth characterization of ship emissions during operations in a Mediterranean port

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**Table S1. Specifications of the instruments used during the campaign. The term n/a means not applicable.**

| | Measured Quantity | Instrument | Size Range | Temporal resolution | Flow ($L.min^{-1}$) | Detection Limit | Uncertainty |
|---|---|---|---|---|---|---|---|
| PARTICULATE PHASE | **Particle number (PN)** Particle number concentration (PNC) | CPC TSI 3776 (TSI, Germany) | 2.5 nm – 3 µm[1] | 1 s | 1.5 | n/a | ±10% |
| | | Envi CPC 200 (PALAS, Germany) | 7 nm – 2.5 µm[1] | 1 s | 0.9 | n/a | ±5% |
| | **Particle size distribution** Particle number concentration (PNC) | SMPS 3936 (CPC 3775 - Classifier 3080 - Long DMA) (TSI, Germany) | 15 nm – 660 nm[2] | 2 min | 0.3 | n/a | $\pm\sqrt{N}/N$[4] |
| | | SMPS 3936 (CPC 3776 - Classifier 3080 - Long DMA) (TSI, Germany) | 15 nm – 660 nm[2] | 2 min | 0.3 | n/a | $\pm\sqrt{N}/N$[4] |
| | **Particle size distribution** Particle number and mass concentration | OPC model 1.109 (Grimm Aerosol Technik, Germany) | 0.25 µm – 32 µm[3] | 1 min | 1.2 | n/a | ±2% |
| | **Black Carbon (BC)** Particle mass concentration | MAAP 5012 (ThermoFisher, USA) | < 1 µm[1] | 1 min | 16,7 | 0.3 $µg.m^{-3}$ | ±10% |
| | | AE33 (Aerosol Magee Scientific, USA) | < 1 µm[1] | 1 min | 5 | 0.3 $µg.m^{-3}$ | ±10% |
| | **Non refractory chemical composition** Particle mass concentration | HR-ToF-AMS (Aerodyne, USA) | 30 nm – 600 nm[1] | 30 s | 0.08 | 0.005 - 0.05[5] $µg.m^{-3}$ | ±30% |
| | **Metals composition** Particle mass concentration | Xact 625i (Cooper Environment, USA) | < 1 µm[1] | 30 min | 16.7 | 0.1 - 50[5] $ng.m^{-3}$ | -[6] |
| GAS PHASE | **Volatils Organic Compounds (VOC)** Gazeous concentration | PTR-ToF-MS 8000 (Ionicon Analytik, Austria) | n/a | 10 s | 0.15 | 0.02 – 2[5] ppb | -[6] |
| | **Sulfur dioxide ($SO_2$)** Gazeous concentration | AF22 (Environnement SA, France) | n/a | 10 s | 0.42 | 1.5 ppb | ± max (1.5 ppb - 1%) |
| | | 100E (Teledyne API, USA) | n/a | 10 s | 0.6 | 0.6 ppb | ± max (0.6 ppb - 0.5%) |
| | **Nitrogen oxides ($NO_X$, NO, $NO_2$)** Gazeous concentration | 200E (Teledyne API, USA) | n/a | 10 s | 0.5 | 0.4 ppb | ± max (0.4 ppb - 0.5%) |
| | **Ozone ($O_3$)** Gazeous concentration | 400E (Teledyne API, USA) | n/a | 10 s | 0.8 | 0.6 ppb | ± max (0.6 ppb - 1%) |
| | **$CO_2$, CO, $CH_4$** Gazeous concentration | G2401 (PICARRO, USA) | n/a | 5 s | 0.35 | 50 ppb ($CO_2$); 15 ppb (CO); 1 ppb ($CH_4$) | ± 50 ppb ($CO_2$); ± 15 ppb (CO); ± 1 ppb ($CH_4$) |
| | **Ammoniac ($NH_3$)** Gazeous concentration | G2103 (PICARRO, USA) | n/a | 5 s | 1.5 | 0.03 ppb | ±0.058 - 0.19 ppb |
| AUXILIARY DATA | **Wind speed (ws), wind direction (wd), Temperature (T)** Meteorological data | Weather station (2D) | n/a | 1 min | n/a | 0.4 $m.s^{-1}$ (ws) | ± max (0.2 $m.s^{-1}$ - 1%) (ws); ± 3° (wd) |
| | | Weather station (3D sonic) | n/a | 10 s | n/a | 0.2 $m.s^{-1}$ (ws) | ± max (0.1 $m.s^{-1}$ - 1%) (ws); ± 1° (wd) |

(1) aerodynamic diameter; (2) electrical mobility diameter; (3) optical diameter (4) N is the number of particles measured (5) specific to each compound (6) defined for each measurement and compound

**Table S2. Quality control of the instruments used during the campaign. The term n/a means not applicable.**

| | Measured Quantity | Instrument | Calibration | Calibration checks | Flow checks | Blank or zero checks |
|---|---|---|---|---|---|---|
| PARTICULATE PHASE | **Particle number (PN)** Particle number concentration (PNC) | CPC TSI 3776 (TSI, Germany) | annual | Intercomparison of CPCs | start and end campaign | 1 per week |
| | | Envi CPC 200 (PALAS, Germany) | annual | | start and end campaign | 1 per week |
| | **Particle size distribution** Particle number concentration (PNC) | SMPS 3936 (CPC 3775 - Classifier 3080 - Long DMA) (TSI, Germany) | annual | - | start and end campaign | 1 per week |
| | | SMPS 3936 (CPC 3776 - Classifier 3080 - Long DMA) (TSI, Germany) | annual | - | start and end campaign | start and end campaign |
| | **Particle size distribution** Particle number and mass concentration (PNC, $PM_1$, $PM_{2.5}$, $PM_{10}$) | OPC model 1.109 (Grimm Aerosol Technik, Germany) | annual | - | start and end campaign | 1 per week |
| | **Black Carbon (BC)** Particle mass concentration | MAAP 5012 (ThermoFisher, USA) | annual | Intercomparison of BC analysers | start and end campaign | 1 per week |
| | | AE33 (Aerosol Magee Scientific, USA) | annual | | start and end campaign | start and end campaign |
| | **Non refractory chemical composition** Particle mass concentration | HR-ToF-AMS (Aerodyne, USA) | start and end campaign | - | start and end campaign | 1 per week |
| | **Metals composition** Particle mass concentration | Xact 625i (Cooper Environment, USA) | start and end campaign | 1 per day | start and end campaign | 1 per day |
| GAS PHASE | **Volatils Organic Compounds (VOC)** Gazeous concentration | PTR-ToF-MS 8000 (Ionicon Analytik, Austria) | start and end campaign | 1 per 2 weeks | start and end campaign | 1 per 2 weeks |
| | **Sulfur dioxide ($SO_2$)** Gazeous concentration | AF22 (Environnement SA, France) | start and end campaign | 1 per day | start and end campaign | 1 per day |
| | | 100E (Teledyne API, USA) | start and end campaign | 1 per day | start and end campaign | 1 per day |
| | **Nitrogen oxides ($NO_X$, NO, $NO_2$)** Gazeous concentration | 200E (Teledyne API, USA) | start and end campaign | 1 per day | start and end campaign | 1 per day |
| | **Ozone ($O_3$)** Gazeous concentration | 400E (Teledyne API, USA) | start and end campaign | 1 per day | start and end campaign | 1 per day |
| | **$CO_2$, CO, $CH_4$** Gazeous concentration | G2401 (PICARRO, USA) | start and end campaign with 3 levels of standard gas cylinders | 1 per week | start and end campaign | 1 per week |
| | **Ammoniac ($NH_3$)** Gazeous concentration | G2103 (PICARRO, USA) | start | - | start and end campaign | start and end campaign |
| AUXILIAR Y DATA | **Wind speed (ws), wind direction (wd), Temperature (T)** Meteorological data | Weather station (2D) | start and end campaign | 1 per week | n/a | n/a |
| | | Weather station (3D sonic) | start and end campaign | 1 per week | n/a | n/a |

**Table S3. Main organic molecules studied by PTR-ToF-MS during the field campaign in the port of Marseille at PEB station.**

| Exact mass (m/z) | Chemical formula | Assigned chemical compound | Detection Limit (DL) (ppb) | Uncertainty median (ppb) |
|---|---|---|---|---|
| 33.034 | $CH_4OH^+$ | Methanol | 0.25 | 0.70 |
| 43.054 | $C_3H_6H^+$ | Propene and unspecified hydrocarbon fragments | 0.29 | 0.93 |
| 45.034 | $C_2H_4OH^+$ | Acetaldehyde | 0.25 | 0.41 |
| 47.013 | $CH_2O_2H^+$ | Formic acid | 0.28 | 0.60 |
| 47.049 | $C_2H_6OH^+$ | Ethanol | 0.17 | 0.36 |
| 57.070 | $C_4H_8H^+$ | Butene | 1.92 | 4.20 |
| 59.049 | $C_3H_6OH^+$ | Acetone | 0.2 | 0.26 |
| 61.028 | $C_2H_4O_2H^+$ | Acetic acid | 0.34 | 0.98 |
| 63.023 | $C_2H_6SH^+$ | DMS | 0.08 | 0.07 |
| 69.070 | $C_5H_8H^+$ | Isoprene | 0.08 | 0.11 |
| 71.049 | $C_4H_6OH^+$ | MVK, methacrolein, crotonaldehyde | 0.04 | 0.09 |
| 71.086 | $C_5H_{10}H^+$ | Pentene | 0.14 | 0.86 |
| 73.065 | $C_4H_8OH^+$ | Butanone or butanal | 0.05 | 0.07 |
| 75.044 | $C_3H_6O_2H^+$ | Methyl acetate | 0.09 | 0.16 |
| 79.054 | $C_6H_6H^+$ | Benzene | 0.08 | 0.53 |
| 83.086 | $C_6H_{10}H^+$ | Cyclohexene | 0.05 | 0.56 |
| 85.101 | $C_6H_{12}H^+$ | Hydrocarbon | 0.08 | 0.63 |
| 87.080 | $C_5H_{10}OH^+$ | 3-methyl-2-butanone, methylbutanals, pentanones | 0.07 | 0.26 |
| 89.060 | $C_4H_8O_2H^+$ | Ethyl acetate | 0.05 | 0.07 |
| 93.070 | $C_7H_8H^+$ | Toluene | 0.04 | 0.07 |
| 93.091 | $C_4H_{12}O_2H^+$ | Dimethyl ether ethanol | 0.03 | 0.03 |
| 97.101 | $C_7H_{12}H^+$ | Cycloheptene | 0.05 | 0.31 |
| 99.044 | $C_6H_{10}OH^+$ | 2-methanolfuranone | 0.04 | 0.57 |
| 101.06 | $C_5H_8O_2H^+$ | Pentadione | 0.05 | 0.71 |
| 101.096 | $C_6H_{12}OH^+$ | Hexanals, Hexanones | 0.04 | 0.07 |
| 105.070 | $C_8H_8H^+$ | Styrene | 0.04 | 0.38 |
| 107.070 | $C_4H_{10}O_3H^+$ | Diethylene glycol | 0.04 | 0.02 |
| 107.086 | $C_8H_{10}H^+$ | C8 Aromatics | 0.04 | 0.07 |
| 111.117 | $C_8H_{14}H^+$ | Hydrocarbon | 0.04 | 0.79 |
| 117.091 | $C_6H_{12}O_2H^+$ | Butylesteraceticacid, Other C6 esters | 0.03 | 0.14 |
| 121.101 | $C_9H_{12}H^+$ | C9 Aromatics | 0.06 | 0.42 |
| 135.117 | $C_{10}H_{14}H^+$ | C10 Aromatics | 0.03 | 0.07 |
| 137.132 | $C_{10}H_{16}H^+$ | Monoterpenes | 0.05 | 0.34 |
| 139.148 | $C_{10}H_{18}H^+$ | Decahydronaphthalene | 0.03 | 0.25 |
| 143.143 | $C_9H_{18}OH^+$ | Nonanone | 0.05 | 0.24 |
| 149.132 | $C_{11}H_{16}H^+$ | C11 Aromatics | 0.03 | 0.02 |
| 151.112 | $C_{10}H_{14}OH^+$ | Terpenes | 0.02 | 0.01 |
| 151.148 | $C_{11}H_{18}H^+$ | (3E)-4,8-Dimethylnona-1,3,7-triene / 1-Methyladamantane | 0.02 | 0.03 |
| 153.127 | $C_{10}H_{16}OH^+$ | Camphor, Other oxygenated monoterpenes | 0.02 | 0.02 |
| 153.164 | $C_{11}H_{20}H^+$ | n/a | 0.02 | 0.02 |
| 165.164 | $C_{12}H_{20}H^+$ | 1-Ethyladamantane | 0.02 | 0.01 |

**Table S4. Classification of ship categories according to significance**

| Importance | Ship category |
|---|---|
| Important ships | Container Ship, Ro-Ro Cargo, Vehicles Carrier, Ro-Ro/Container Carrier, Dredger, Passenger Ship (Cruise), Ro-Ro/Passenger Ship (Ro-Ro Ferry), Buoy-Laying Vessel, Research/Survey Vessel, Fishing, Cement Carrier, Crude Oil Tanker, Oil/Chemical Tanker, Anchor Handling Vessel, Cargo/Containership, General Cargo, Supply Vessel, Tug |
| Other ships | Port Tender, Passenger, Pilot Vessel, Unspecified SAR, Dive Vessel, Reserved, Patrol Vessel, Law Enforce, Yacht, Pollution Control Vessel, Military Ops, Other |

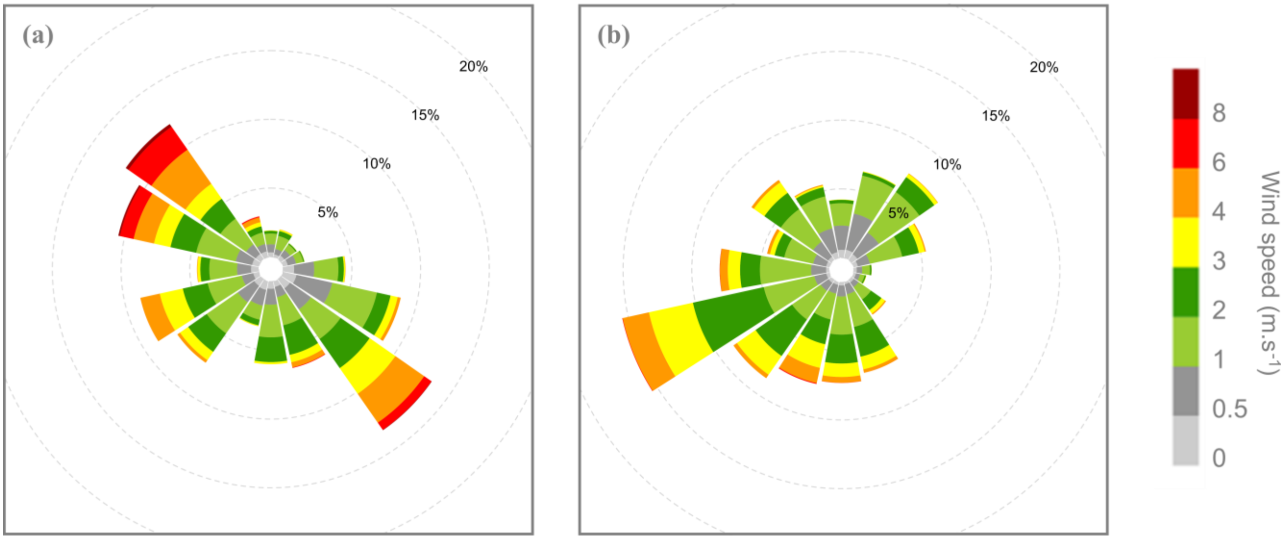



**Figure S1. Wind roses diagram (displayed as frequency of counts by wind direction and speed bin) during the monitoring campaign at PEB station (a) and at MAJOR station (b).**

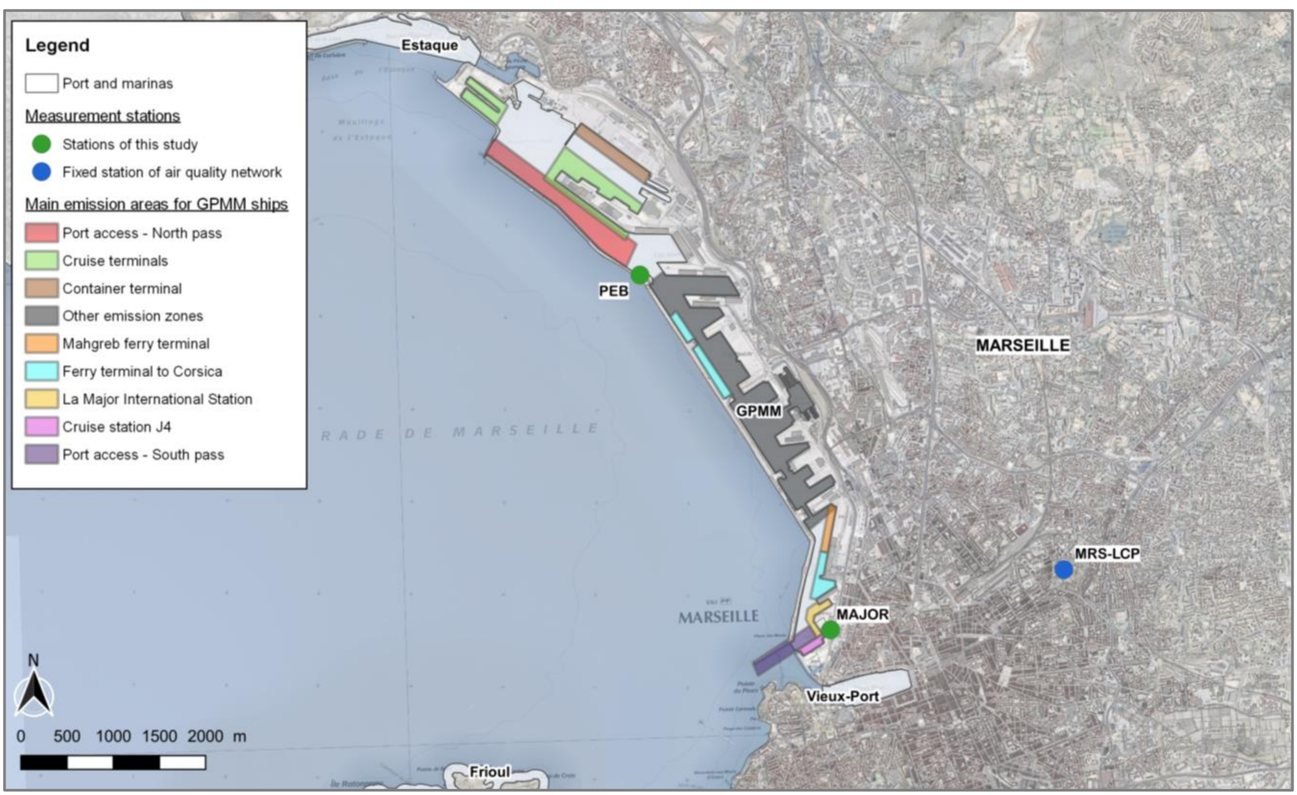



**Figure S2. Map of the port of Marseille (GPMM) and marinas with the measurement stations of this study (filled green circle) and the fixed station of air quality network (filled blue circle) as well as the main areas of ship emissions in GPMM. Maps taken from Google satellite images (© Google Maps) and topographic map SCAN 25 (© IGN – 2022).**

**Table S5. Probability of measurement stations being downwind of the main ship emission areas during the campaign**

| Station | Main areas of ship emissions (Figure S2.) | Probability to be downwind of ship emissions (%) | Associated wind speeds (m/s) Average (Q1 - Q3) |
|---|---|---|---|
| **PEB** | Port access - North channel | 17% | 3.4 (1.5 - 5.4) |
| | Cruise and container terminals | 10% | 2.6 (0.9 - 3.9) |
| | Other emission areas | 15% | 3.2 (1.3 - 5.1) |
| **MAJOR** | Port access - South channel and J4 cruise terminal | 13% | 2.6 (1.8 - 3.2) |
| | Other emission areas | 8% | 1.3 (0.8 - 1.6) |

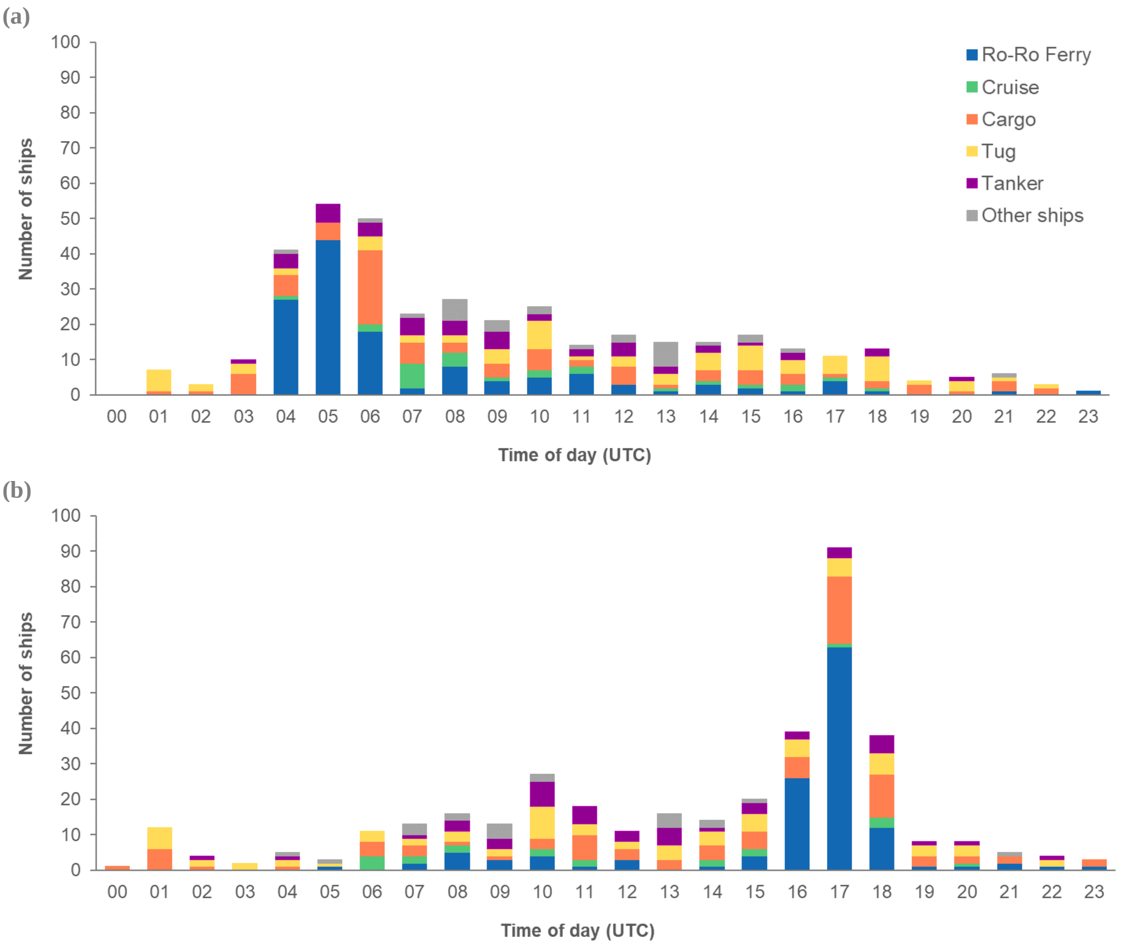



**Figure S3. Cumulative number of ship arrivals (a) and departures (b) in the port of Marseille in June 2021 by time of day and ship category (excluding pilot boats, pleasure crafts and passenger shuttles) (MarineTraffic, 2022).**

**Table S6. Main statistical parameters (25th percentile, mean, median, 75th percentile and maximum) of all compound's concentrations measured at both stations of this study (PEB and MAJOR) and at fixed station of air quality network (MRS-LCP).**

| Mesured Quantity | Species | Unit | Site | Time resolution | N | P25 | Median | Mean | P75 | Max | Missing | DL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **GAS PHASE** | | | | | | | | | | | | |
| **Nitrogen Oxides** | $NO_X$ | $\mu g.m^{-3}$ | PEB | 10 sec | 259 201 | 6.3 | 15.1 | 33.9 | 42.4 | 2 046.2 | 22% | 0.7 |
| | | | MAJOR | 10 sec | 259 201 | 8.6 | 15.3 | 31.3 | 36.3 | 1 423.1 | 6% | 0.7 |
| | | | MRS-LCP | 10 sec | 259 201 | 11.1 | 16.4 | 22.8 | 26.2 | 932.3 | 2% | 0.7 |
| | $NO_2$ | $\mu g.m^{-3}$ | PEB | 10 sec | 259 201 | 5.2 | 12.8 | 22.3 | 34.4 | 508.2 | 22% | 0.7 |
| | | | MAJOR | 10 sec | 259 201 | 7.1 | 13.0 | 20.8 | 28.7 | 395.8 | 5% | 0.7 |
| | | | MRS-LCP | 10 sec | 259 201 | 9.0 | 13.8 | 18.7 | 22.2 | 467.3 | 2% | 0.7 |
| | NO | $\mu g.m^{-3}$ | PEB | 10 sec | 259 201 | 0.6 | 1.1 | 7.6 | 4.1 | 1 180.9 | 22% | 0.5 |
| | | | MAJOR | 10 sec | 259 201 | < DL | 1.1 | 6.7 | 3.7 | 895.1 | 6% | 0.5 |
| | | | MRS-LCP | 10 sec | 259 201 | 1.0 | 1.5 | 2.7 | 2.6 | 545.7 | 2% | 0.5 |
| **Carbon Oxides** | $CO_2$ | ppm | PEB | 10 sec | 259 201 | 401.7 | 406.5 | 409.8 | 415.1 | 492.8 | 1% | 0.1 |
| | | | MAJOR | 10 sec | 259 201 | 402.9 | 407.4 | 410.4 | 415.6 | 484.0 | 5% | 0.1 |
| | | | MRS-LCP | 10 sec | 259 201 | 418.1 | 422.7 | 426.0 | 431.3 | 565.3 | 1% | 0.1 |
| | CO | ppm | PEB | 10 sec | 1 236 | < DL | < DL | < DL | < DL | 1.8 | 11% | 0.7 |
| | | | MAJOR | 10 sec | 259 201 | 0.1 | 0.1 | 0.1 | 0.2 | 11.4 | 5% | 0.0 |
| **Sulfur Dioxide** | $SO_2$ | $\mu g.m^{-3}$ | PEB | 10 sec | 259 201 | < DL | < DL | 1.5 | 2.9 | 35.7 | 30% | 1.3 |
| | | | MAJOR | 10 sec | 259 201 | < DL | < DL | 1.4 | 1.6 | 31.6 | 7% | 1.3 |
| | | | MRS-LCP | 10 sec | 259 201 | < DL | 1.4 | 1.4 | 1.8 | 14.0 | 8% | 1.3 |
| **Ozone** | $O_3$ | $\mu g.m^{-3}$ | PEB | 10 sec | 259 201 | 53.6 | 88.0 | 82.1 | 108.0 | 206.4 | 23% | 1.2 |
| | | | MAJOR | 10 sec | 259 201 | 65.0 | 81.8 | 78.4 | 95.4 | 179.0 | 25% | 1.2 |
| | | | MRS-LCP | 10 sec | 259 201 | 59.0 | 77.4 | 76.5 | 93.2 | 181.6 | 3% | 1.2 |
| **Ammoniac** | $NH_3$ | ppb | PEB | 10 sec | 259 201 | 2.34 | 2.98 | 3.17 | 3.74 | 11.35 | 60% | 0.03 |
| **Volatils Organics Compounds (VOC)** | $CH_4$ | ppm | PEB | 10 sec | 259 201 | 2.231 | 2.254 | 2.278 | 2.293 | 3.544 | 1% | 0.001 |
| | | | MAJOR | 10 sec | 259 201 | 1.973 | 1.998 | 2.021 | 2.038 | 3.054 | 5% | 0.001 |
| | | | MRS-LCP | 10 sec | 259 201 | 1.980 | 2.010 | 1.997 | 2.030 | 2.240 | 1% | 0.001 |
| | $(CH_2O_2)H^+$ | ppb | PEB | 10 sec | 259 201 | 3.59 | 5.11 | 4.78 | 5.89 | 8.22 | 20% | 0.28 |
| | $(CH_3OH)H$ | ppb | PEB | 10 sec | 259 201 | 2.74 | 4.32 | 4.92 | 6.21 | 15.86 | 20% | 0.25 |
| | $(C_2H_4O)H^+$ | ppb | PEB | 10 sec | 259 201 | 1.32 | 1.72 | 2.11 | 2.59 | 9.14 | 20% | 0.25 |
| | $(C_2H_4O_2)H^+$ | ppb | PEB | 10 sec | 259 201 | 2.57 | 3.38 | 3.83 | 4.49 | 62.82 | 20% | 0.34 |
| | $(C_2H_6O)H^+$ | ppb | PEB | 10 sec | 259 201 | 0.91 | 1.70 | 1.97 | 2.34 | 34.77 | 20% | 0.17 |
| | $(C_2H_6S)H^+$ | ppb | PEB | 10 sec | 259 201 | < DL | < DL | 0.10 | 0.17 | 1.20 | 20% | 0.08 |
| | $(C_3H_6)H^-$ | ppb | PEB | 10 sec | 259 201 | 0.31 | 0.46 | 0.55 | 0.70 | 5.81 | 20% | 0.29 |
| | $(C_3H_6O)H^+$ | ppb | PEB | 10 sec | 259 201 | 1.46 | 1.89 | 2.10 | 2.47 | 16.68 | 20% | 0.20 |
| | $(C_3H_8O_2)H^+$ | ppb | PEB | 10 sec | 259 201 | < DL | 0.15 | 0.18 | 0.26 | 1.26 | 20% | 0.09 |
| | $(C_4H_{10}O_3)H^+$ | ppb | PEB | 10 sec | 259 201 | < DL | < DL | < DL | < DL | 1.31 | 20% | 0.04 |
| | $(C_4H_{12}O_2)H^+$ | ppb | PEB | 10 sec | 259 201 | < DL | < DL | < DL | 0.04 | 0.70 | 20% | 0.03 |
| | $(C_4H_6O)H^+$ | ppb | PEB | 10 sec | 259 201 | < DL | 0.05 | 0.07 | 0.11 | 0.56 | 20% | 0.04 |
| | $(C_4H_8)H^-$ | ppb | PEB | 10 sec | 259 201 | < DL | < DL | < DL | 2.36 | 19.97 | 20% | 1.92 |
| | $(C_4H_8O)H^+$ | ppb | PEB | 10 sec | 259 201 | 0.08 | 0.13 | 0.18 | 0.23 | 3.48 | 20% | 0.05 |
| | $(C_4H_8O_2)H^+$ | ppb | PEB | 10 sec | 259 201 | < DL | < DL | 0.09 | 0.09 | 4.71 | 20% | 0.05 |
| | $(C_5H_{10})H^+$ | ppb | PEB | 10 sec | 259 201 | < DL | < DL | 0.14 | 0.17 | 3.04 | 20% | 0.14 |
| | $(C_5H_{10}O)H^+$ | ppb | PEB | 10 sec | 259 201 | 0.10 | 0.18 | 0.19 | 0.28 | 0.74 | 20% | 0.07 |
| | $(C_5H_8)H^-$ | ppb | PEB | 10 sec | 259 201 | < DL | 0.11 | 0.12 | 0.19 | 0.66 | 20% | 0.08 |
| | $(C_5H_8O_2)H^+$ | ppb | PEB | 10 sec | 259 201 | 0.06 | 0.12 | 0.12 | 0.16 | 0.61 | 20% | 0.05 |
| | $(C_6H_{10})H^+$ | ppb | PEB | 10 sec | 259 201 | < DL | 0.05 | 0.07 | 0.09 | 0.49 | 20% | 0.05 |
| | $(C_6H_{10}O)H^+$ | ppb | PEB | 10 sec | 259 201 | < DL | < DL | < DL | 0.04 | 0.26 | 20% | 0.04 |
| | $(C_6H_{12})H^+$ | ppb | PEB | 10 sec | 259 201 | < DL | < DL | < DL | < DL | 0.89 | 20% | 0.08 |
| | $(C_6H_{12}O)H^+$ | ppb | PEB | 10 sec | 259 201 | < DL | < DL | < DL | < DL | 2.13 | 20% | 0.04 |
| | $(C_6H_{12}O_2)H^+$ | ppb | PEB | 10 sec | 259 201 | < DL | < DL | < DL | < DL | 0.40 | 20% | 0.03 |
| | $(C_6H_6)H^-$ | ppb | PEB | 10 sec | 259 201 | < DL | < DL | < DL | < DL | 0.98 | 20% | 0.08 |
| | $(C_7H_{12})H^+$ | ppb | PEB | 10 sec | 259 201 | < DL | < DL | < DL | 0.05 | 0.29 | 20% | 0.05 |
| | $(C_7H_8)H^-$ | ppb | PEB | 10 sec | 259 201 | < DL | 0.10 | 0.22 | 0.27 | 6.55 | 20% | 0.04 |
| | $(C_8H_{10})H^+$ | ppb | PEB | 10 sec | 259 201 | 0.05 | 0.20 | 0.37 | 0.49 | 18.34 | 20% | 0.04 |
| | $(C_8H_{14})H^+$ | ppb | PEB | 10 sec | 259 201 | < DL | < DL | < DL | 0.04 | 0.23 | 20% | 0.04 |
| | $(C_8H_8)H^-$ | ppb | PEB | 10 sec | 259 201 | < DL | < DL | < DL | 0.05 | 0.37 | 20% | 0.04 |
| | $(C_9H_{12})H^+$ | ppb | PEB | 10 sec | 259 201 | < DL | 0.08 | 0.13 | 0.13 | 20.04 | 20% | 0.06 |
| | $(C_9H_{18}O)H^+$ | ppb | PEB | 10 sec | 259 201 | < DL | < DL | < DL | 0.07 | 0.42 | 20% | 0.05 |
| | $(C_{10}H_{14})H^+$ | ppb | PEB | 10 sec | 259 201 | < DL | < DL | 0.03 | 0.05 | 2.39 | 20% | 0.03 |
| | $(C_{10}H_{14}O)H^+$ | ppb | PEB | 10 sec | 259 201 | < DL | < DL | < DL | < DL | 0.09 | 20% | 0.02 |
| | $(C_{10}H_{16})H^+$ | ppb | PEB | 10 sec | 259 201 | < DL | 0.05 | 0.07 | 0.09 | 0.83 | 20% | 0.05 |
| | $(C_{10}H_{16}O)H^+$ | ppb | PEB | 10 sec | 259 201 | < DL | < DL | < DL | < DL | 0.11 | 20% | 0.02 |
| | $(C_{10}H_{18})H^+$ | ppb | PEB | 10 sec | 259 201 | < DL | < DL | < DL | < DL | 0.09 | 20% | 0.03 |
| | $(C_{11}H_{16})H^+$ | ppb | PEB | 10 sec | 259 201 | < DL | < DL | < DL | < DL | 0.16 | 20% | 0.03 |
| | $(C_{11}H_{18})H^+$ | ppb | PEB | 10 sec | 259 201 | < DL | < DL | < DL | < DL | 0.08 | 20% | 0.02 |
| | $(C_{11}H_{20})H^+$ | ppb | PEB | 10 sec | 259 201 | < DL | < DL | < DL | < DL | 0.06 | 20% | 0.02 |
| | $(C_{12}H_{20})H^+$ | ppb | PEB | 10 sec | 259 201 | < DL | < DL | < DL | < DL | 0.07 | 20% | 0.02 |

| Mesured Quantity | Species | Unit | Site | Time resolution | N | P25 | Median | Mean | P75 | Max | Missing | DL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **PARTICULATE PHASE** | | | | | | | | | | | | |
| **Particle number** | PN (2.5 nm - 3 µm) | part.cm$^{-3}$ | PEB | 10 sec | 259 201 | 4 939 | 10 612 | 13 734 | 18 098 | 219 270 | 13% | |
| | PN (7 nm - 2.5 µm) | part.cm$^{-3}$ | MAJOR | 10 sec | 259 201 | 6 708 | 10 156 | 12 751 | 15 306 | 116 457 | 6% | |
| **Particle size distribution** | PN (15 nm - 660 nm) | part.cm$^{-3}$ | PEB | 5 min | 8 641 | 5 473 | 10 723 | 12 449 | 16 365 | 87 566 | 19% | |
| | | | MAJOR* | 5 min | 8 641 | 7 750 | 10 907 | 12 744 | 15 431 | 80 330 | 40% | |
| | | | MRS-LCP | 5 min | 8 641 | 4 249 | 6 735 | 7 661 | 9 747 | 112 637 | 9% | |
| | PN (250 nm - 32 µm) | part.cm$^{-3}$ | PEB | 1 min | 43 201 | 65 | 102 | 117 | 151 | 1 673 | 1% | |
| | | | MAJOR | 1 min | 43 201 | 63 | 99 | 110 | 140 | 1 204 | 9% | |
| **Particle masse concentration** | $PM_{10}$ | µg.m$^{-3}$ | PEB | 1 min | 43 201 | 9.0 | 14.9 | 16.7 | 22.4 | 153.6 | 1% | 0.2 |
| | | | MAJOR | 1 min | 43 201 | 7.2 | 10.6 | 11.6 | 14.9 | 89.8 | 9% | 0.2 |
| | | | MRS-LCP | 1 min | 43 201 | 12.1 | 16.0 | 20.0 | 22.6 | 139.7 | 11% | 0.2 |
| | $PM_{2.5}$ | µg.m$^{-3}$ | PEB | 1 min | 43 201 | 6.0 | 11.2 | 12.7 | 18.0 | 109.5 | 1% | 0.2 |
| | | | MAJOR | 1 min | 43 201 | 6.0 | 9.0 | 9.8 | 12.8 | 83.8 | 9% | 0.2 |
| | | | MRS-LCP | 1 min | 43 201 | 5.0 | 7.3 | 8.1 | 9.9 | 28.5 | 11% | 0.2 |
| | $PM_1$ | µg.m$^{-3}$ | PEB | 1 min | 43 201 | 3.4 | 8.0 | 8.9 | 13.1 | 107.2 | 1% | 0.2 |
| | | | MAJOR | 1 min | 43 201 | 4.6 | 7.3 | 7.8 | 10.1 | 70.2 | 9% | 0.2 |
| | | | MRS-LCP | 1 min | 43 201 | 3.2 | 5.1 | 5.4 | 7.2 | 18.0 | 11% | 0.2 |
| **Chemical Composition** | BC | µg.m$^{-3}$ | PEB | 1 min | 43 201 | 0.3 | 0.5 | 0.7 | 0.9 | 22.8 | 1% | 0.3 |
| | | | MAJOR | 1 min | 43 201 | 0.4 | 0.7 | 0.9 | 1.2 | 19.7 | 4% | 0.3 |
| | | | MRS-LCP | 1 min | 43 201 | 0.5 | 0.7 | 0.9 | 1.1 | 56.1 | 4% | 0.3 |
| | Cl | µg.m$^{-3}$ | PEB | 30 sec | 86 401 | < DL | < DL | 0.04 | 0.04 | 0.97 | 6% | 0.03 |
| | $NH_4^-$ | µg.m$^{-3}$ | PEB | 30 sec | 86 401 | 0.52 | 0.80 | 0.90 | 1.13 | 3.68 | 6% | 0.04 |
| | $NO_3^-$ | µg.m$^{-3}$ | PEB | 30 sec | 86 401 | 0.14 | 0.22 | 0.34 | 0.38 | 5.75 | 6% | 0.04 |
| | OA | µg.m$^{-3}$ | PEB | 30 sec | 86 401 | 4.3 | 6.5 | 7.6 | 9.7 | 163.9 | 6% | 0.4 |
| | $SO_4^{2-}$ | µg.m$^{-3}$ | PEB | 30 sec | 86 401 | 1.5 | 2.4 | 2.6 | 3.3 | 29.1 | 6% | 0.03 |
| **Metals Composition** | Ag | ng.m$^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | < DL | < DL | 29 | 11% | 10 |
| | Al | ng.m$^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | < DL | < DL | 3 296 | 11% | 2 029 |
| | | | MRS-LCP | 120 min | 360 | < DL | < DL | < DL | < DL | 315 | 2% | 61 |
| | As | ng.m$^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | 0.4 | 0.5 | 4.8 | 11% | 0.3 |
| | | | MRS-LCP | 120 min | 360 | < DL | < DL | < DL | < DL | < DL | 2% | 0.04 |
| | Au | ng.m$^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | < DL | < DL | 1.1 | 11% | 0.5 |
| | | | MRS-LCP | 120 min | 360 | < DL | < DL | < DL | < DL | 0.8 | 2% | 0.2 |
| | Ba | ng.m$^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | < DL | < DL | 33.9 | 11% | 1.9 |
| | Bi | ng.m$^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | < DL | < DL | 4.4 | 11% | 0.6 |
| | | | MRS-LCP | 120 min | 360 | < DL | < DL | < DL | < DL | 2.2 | 2% | 0.1 |
| | Br | ng.m$^{-3}$ | PEB | 30 min | 1 236 | 1.6 | 2.5 | 3.2 | 3.7 | 147.5 | 11% | 0.5 |
| | | | MRS-LCP | 120 min | 360 | 2.1 | 3.1 | 3.4 | 4.1 | 41.4 | 2% | 0.1 |
| | Ca | ng.m$^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | 28 | 21 | 1 076 | 11% | 19 |
| | | | MRS-LCP | 120 min | 360 | 7 | 13 | 39 | 27 | 1 188 | 2% | 2 |
| | Cd | ng.m$^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | < DL | < DL | 39 | 11% | 18 |
| | | | MRS-LCP | 120 min | 360 | < DL | < DL | < DL | < DL | 3.0 | 2% | 1.8 |
| | Ce | ng.m$^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | < DL | < DL | 3.6 | 11% | 1.5 |
| | Cl | ng.m$^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | 23 | 25 | 305 | 11% | 19 |
| | | | MRS-LCP | 120 min | 360 | < DL | 4.0 | 13.1 | 13.2 | 226.5 | 2% | 3.4 |
| | Co | ng.m$^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | < DL | < DL | 1.8 | 11% | 0.7 |
| | | | MRS-LCP | 120 min | 360 | < DL | < DL | < DL | < DL | 0.3 | 2% | 0.1 |
| | Cr | ng.m$^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | < DL | < DL | 20.3 | 11% | 0.6 |
| | | | MRS-LCP | 120 min | 360 | < DL | < DL | 0.2 | 0.1 | 24.7 | 2% | 0.1 |
| | Cs | ng.m$^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | < DL | < DL | 6.5 | 11% | 1.9 |
| | Cu | ng.m$^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | 1.3 | 1.2 | 52.8 | 11% | 1.0 |
| | | | MRS-LCP | 120 min | 360 | 0.9 | 1.2 | 2.0 | 1.8 | 55.7 | 2% | 0.6 |
| | Fe | ng.m$^{-3}$ | PEB | 30 min | 1 236 | 7 | 12 | 22 | 23 | 654 | 11% | 6 |
| | | | MRS-LCP | 120 min | 360 | 12 | 20 | 33 | 36 | 413 | 2% | 1 |
| | Ga | ng.m$^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | < DL | < DL | 0.7 | 11% | 0.3 |
| | | | MRS-LCP | 120 min | 360 | < DL | < DL | < DL | < DL | < DL | 2% | 0.1 |
| | Ge | ng.m$^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | < DL | < DL | 0.6 | 11% | 0.3 |
| | | | MRS-LCP | 120 min | 360 | < DL | < DL | < DL | < DL | < DL | 2% | 0.0 |
| | Hg | ng.m$^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | < DL | < DL | 1.3 | 11% | 0.6 |
| | | | MRS-LCP | 120 min | 360 | 0.4 | 0.4 | 0.3 | 0.4 | 0.4 | 2% | 0.1 |
| | I | ng.m$^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | < DL | < DL | 185.0 | 11% | 55.0 |
| | In | ng.m$^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | < DL | < DL | 44.5 | 11% | 15.0 |
| | K | ng.m$^{-3}$ | PEB | 30 min | 1 236 | 8 | 14 | 20 | 25 | 398 | 11% | 6 |
| | | | MRS-LCP | 120 min | 360 | 20 | 26 | 32 | 38 | 162 | 2% | 1 |
| | La | ng.m$^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | < DL | < DL | 4.7 | 11% | 1.8 |
| | Mn | ng.m$^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | < DL | < DL | 29.3 | 11% | 0.7 |
| | | | MRS-LCP | 120 min | 360 | < DL | < DL | 0.3 | 0.3 | 4.6 | 2% | 0.1 |
| | Mo | ng.m$^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | < DL | < DL | 7.4 | 11% | 2.4 |
| | | | MRS-LCP | 120 min | 360 | < DL | < DL | < DL | < DL | < DL | 2% | 0.3 |

| Mesured Quantity | Species | Unit | Site | Time resolution | N | P25 | Median | Mean | P75 | Max | Missing | DL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **PARTICULATE PHASE** | | | | | | | | | | | | |
| **Metals Composition** | Ni | $ng.m^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | 1.5 | 1.5 | 44.1 | 11% | 0.6 |
| | | | MRS-LCP | 120 min | 360 | 0.3 | 0.8 | 1.1 | 1.3 | 9.9 | 2% | 0.2 |
| | P | $ng.m^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | < DL | < DL | 38.0 | 11% | 33.8 |
| | Pb | $ng.m^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | < DL | < DL | 31.2 | 11% | 0.6 |
| | | | MRS-LCP | 120 min | 360 | 1.2 | 1.9 | 2.7 | 3.2 | 43.6 | 2% | 0.2 |
| | Pd | $ng.m^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | < DL | < DL | 127 | 11% | 56 |
| | | | MRS-LCP | 120 min | 360 | < DL | < DL | < DL | < DL | 8 | 2% | 7 |
| | Pt | $ng.m^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | < DL | < DL | 0.9 | 11% | 0.6 |
| | | | MRS-LCP | 120 min | 360 | < DL | < DL | < DL | < DL | < DL | 2% | 0.1 |
| | Rb | $ng.m^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | < DL | < DL | 2.5 | 11% | 1.0 |
| | S | $ng.m^{-3}$ | PEB | 30 min | 1 236 | 356 | 596 | 639 | 857 | 1 711 | 11% | 16 |
| | | | MRS-LCP | 120 min | 360 | 411 | 605 | 668 | 849 | 1 697 | 2% | 2 |
| | Sb | $ng.m^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | < DL | < DL | 91 | 11% | 50 |
| | | | MRS-LCP | 120 min | 360 | < DL | < DL | < DL | < DL | 11 | 2% | 3 |
| | Sc | $ng.m^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | < DL | < DL | 3.2 | 11% | 1.5 |
| | Se | $ng.m^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | < DL | < DL | 3.2 | 11% | 0.4 |
| | | | MRS-LCP | 120 min | 360 | 0.1 | 0.2 | 0.2 | 0.3 | 1.1 | 2% | 0.1 |
| | Si | $ng.m^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | < DL | < DL | 165 | 11% | 89 |
| | | | MRS-LCP | 120 min | 360 | < DL | < DL | 25 | < DL | 704 | 2% | 11 |
| | Sn | $ng.m^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | < DL | < DL | 138 | 11% | 20 |
| | | | MRS-LCP | 120 min | 360 | < DL | < DL | < DL | < DL | < DL | 2% | 2.5 |
| | Sr | $ng.m^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | < DL | < DL | 12.5 | 11% | 1.1 |
| | Te | $ng.m^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | < DL | < DL | 149 | 11% | 79 |
| | Ti | $ng.m^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | < DL | < DL | 43 | 11% | 1 |
| | | | MRS-LCP | 120 min | 360 | 0.2 | 0.4 | 1.1 | 0.8 | 26.2 | 2% | 0.2 |
| | Tl | $ng.m^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | < DL | < DL | 0.9 | 11% | 0.6 |
| | | | MRS-LCP | 120 min | 360 | < DL | < DL | < DL | < DL | < DL | 2% | 0.1 |
| | V | $ng.m^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | 1.2 | 1.1 | 46.0 | 11% | 0.6 |
| | | | MRS-LCP | 120 min | 360 | 0.2 | 0.7 | 1.0 | 1.4 | 10.1 | 2% | 0.1 |
| | Y | $ng.m^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | < DL | < DL | 3.2 | 11% | 1.4 |
| | | | MRS-LCP | 120 min | 360 | < DL | < DL | < DL | < DL | 1.0 | 2% | 0.7 |
| | Zn | $ng.m^{-3}$ | PEB | 30 min | 1 236 | < DL | 4.0 | 6.5 | 6.4 | 309.5 | 11% | 4.0 |
| | | | MRS-LCP | 120 min | 360 | 3.4 | 5.0 | 6.1 | 7.0 | 37.9 | 2% | 0.3 |
| | Zr | $ng.m^{-3}$ | PEB | 30 min | 1 236 | < DL | < DL | < DL | < DL | 3.0 | 11% | 1.6 |
| | | | MRS-LCP | 120 min | 360 | < DL | < DL | < DL | < DL | 1.6 | 2% | 0.4 |

* Data corrected with CPC data

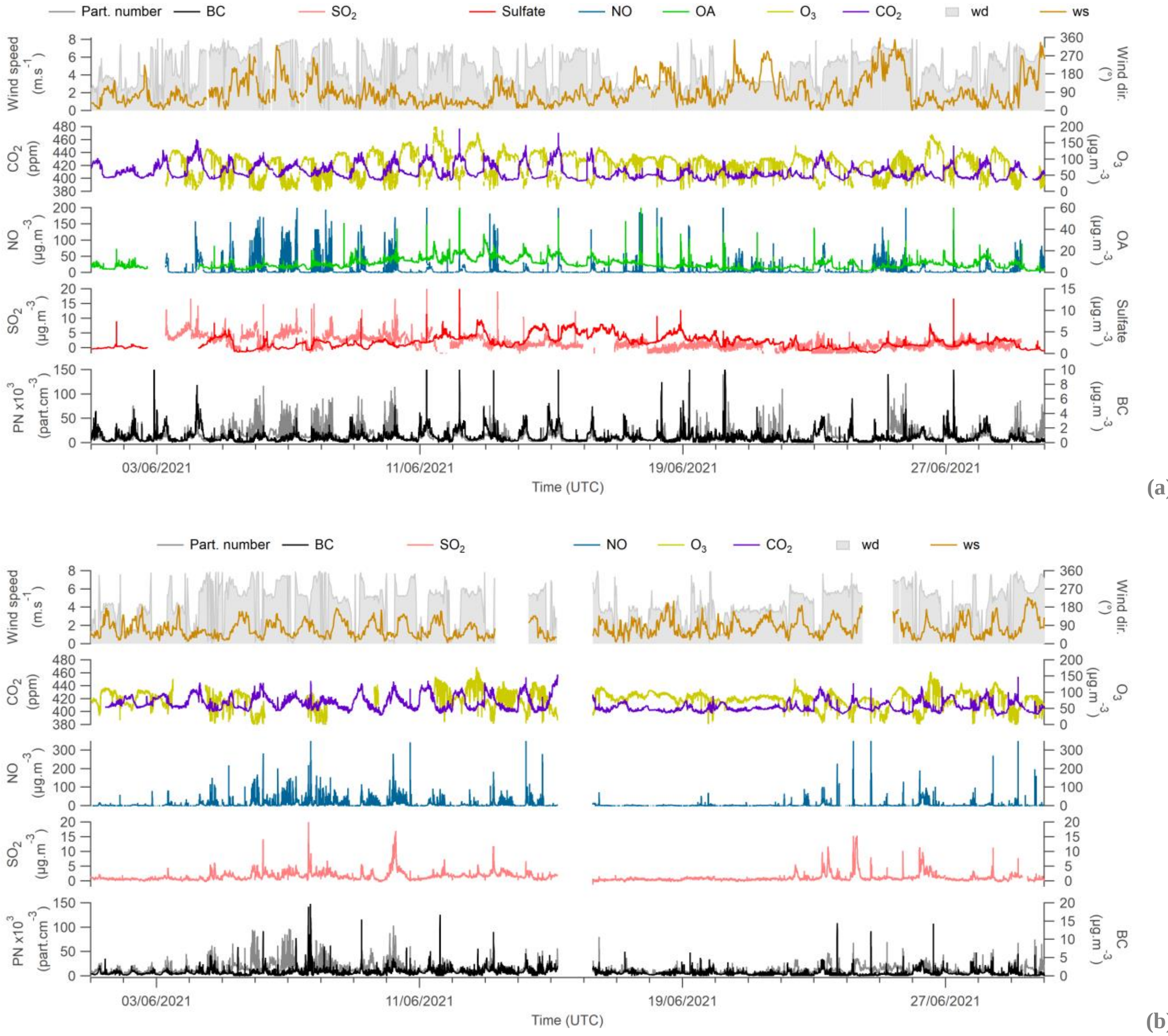



**Figure S4. Temporal evolution of the main pollutants at the two measurement stations located in the port area (PEB station (a) and MAJOR station (b))**

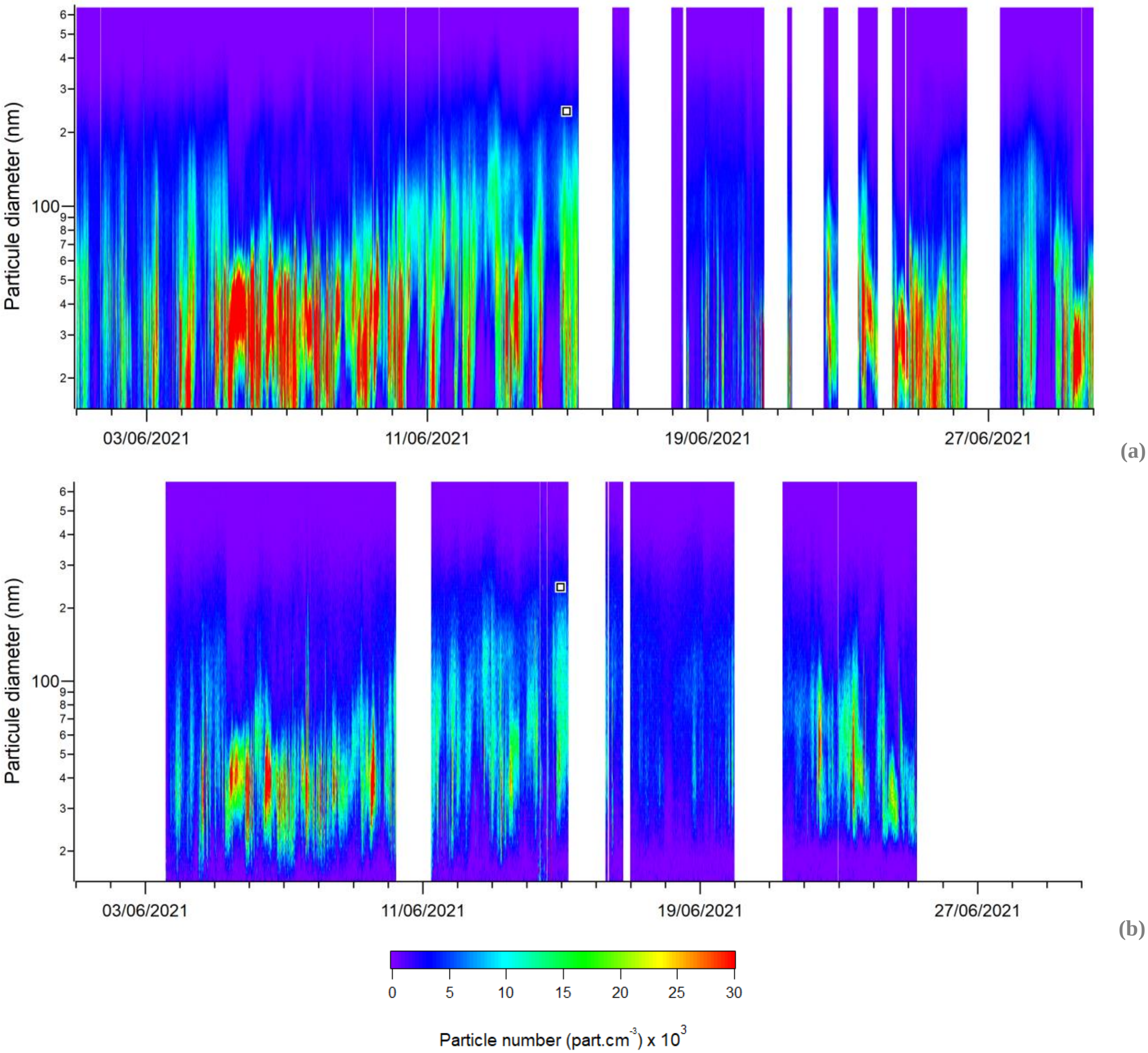



**Figure S5. Temporal evolution of the particle size distribution during the campaign at measurement stations located in the port area (PEB station (a) and MAJOR station (b)). The y-axis corresponds to the particle diameter Dp in nm and the colour bar indicates the concentration dN/dlogDp (part.cm$^{-3}$).**

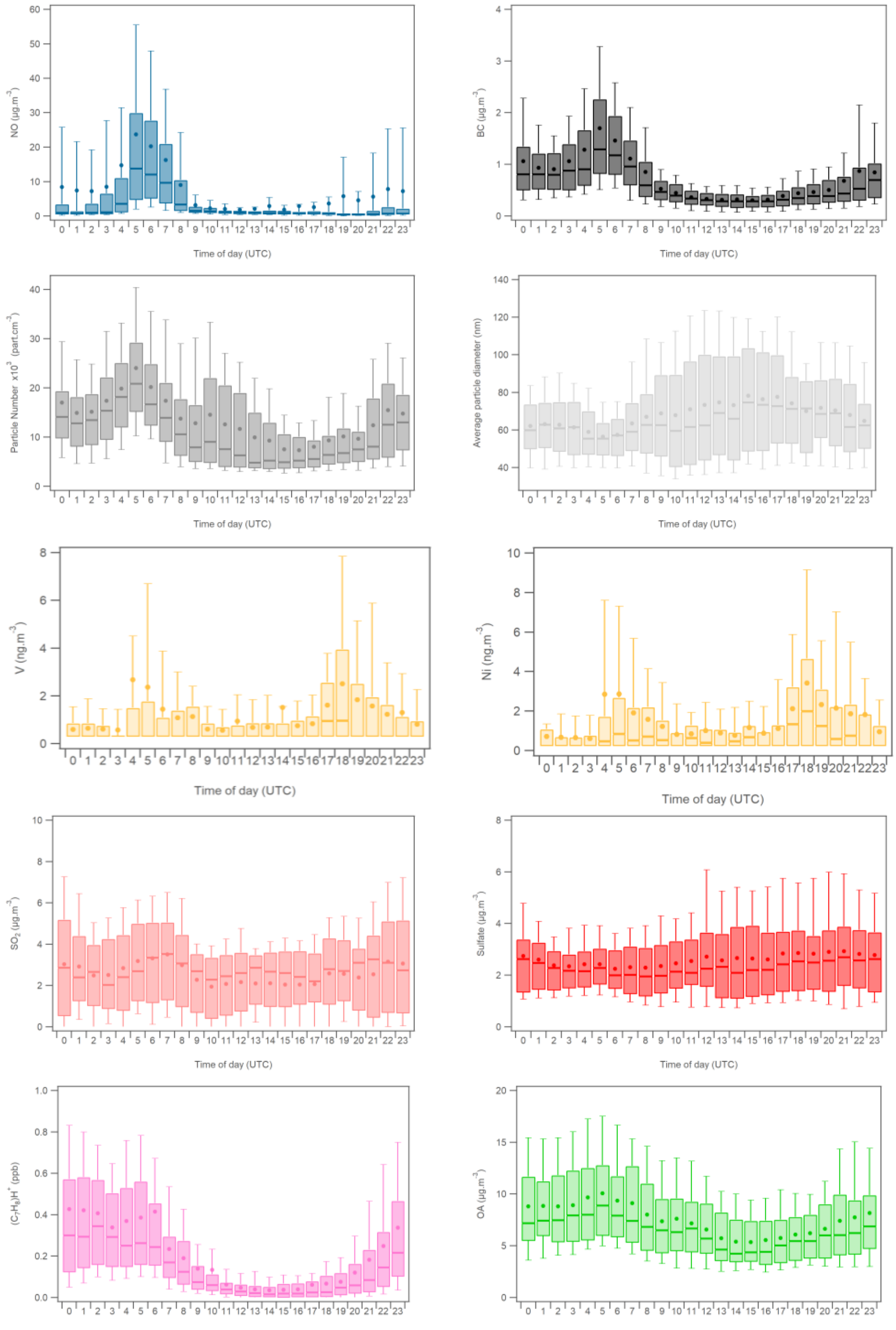



**Figure S6. Daily profiles of nitrogen monoxide (NO), black carbon (BC), ultrafine particles and their average diameter, vanadium (V), nickel (Ni), sulphur dioxide ($SO_2$), sulphate ($SO_4^{2-}$), toluene (($C_7H_8$)$H^+$) and organic aerosol (OA) during the campaign at the PEB station. For each box plot, the coloured box represents the interval between the 25th percentile and the 75th percentile, the vertical error bar represents the interval between the 10th percentile and the 90th percentile, the horizontal line represents the median and the circle represents the mean.**

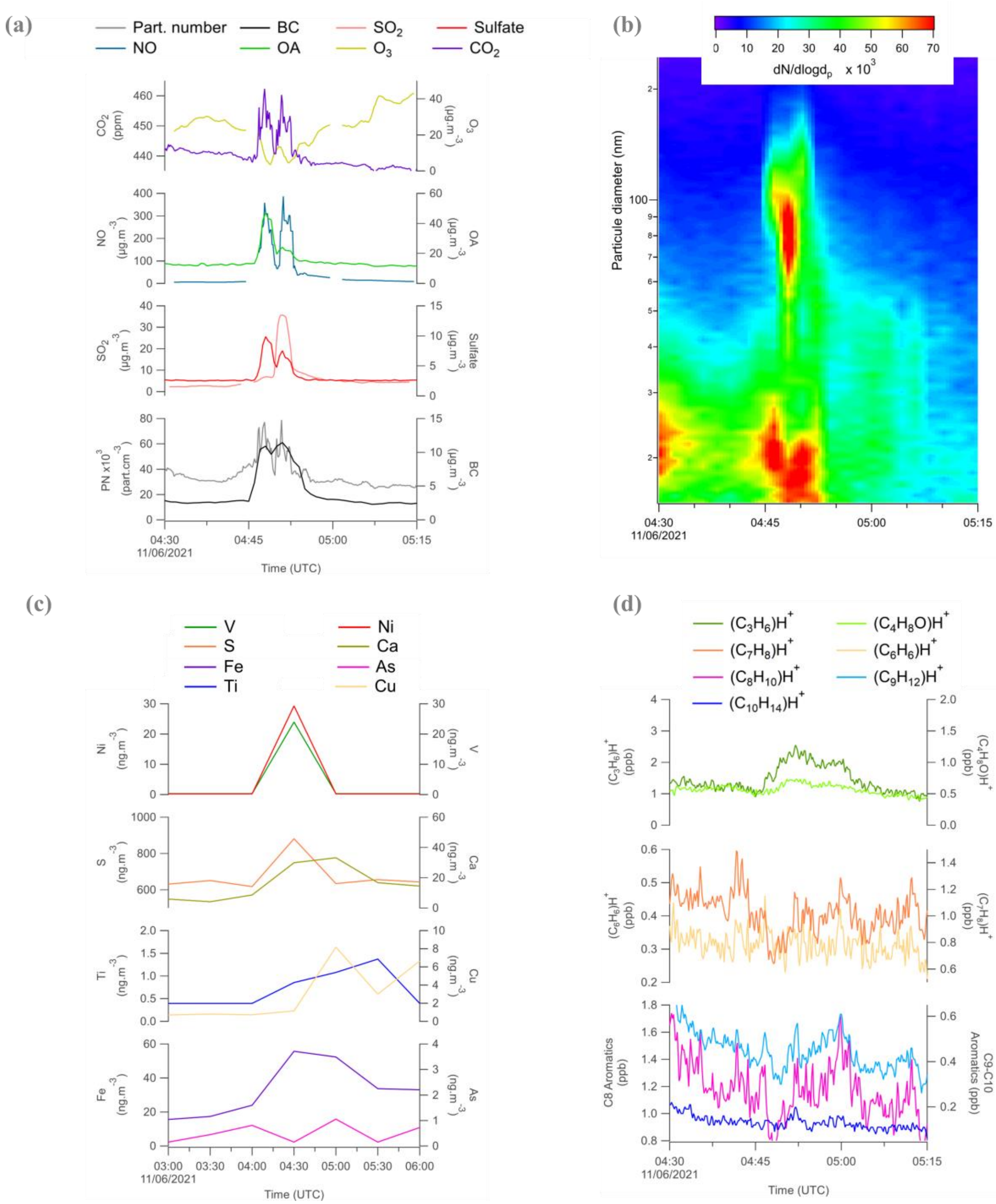



**Figure S7. Ship plumes detected at the PEB station on June 11, 2021. Temporal evolution of (a) concentrations of the main pollutants, (b) particle size distribution, (c) concentrations of selected metals, and (d) concentrations of selected NMVOCs measured using PTR-ToF-MS.**

**Table S7. Sensitivity of emission factors to measurement time resolution for the 353 plumes: median relative deviation from the finest resolution values [values in brackets represent the 25th and 75th percentiles].**

| Species | Plume duration (min) | $N_{plumes}$ | Temporal resolution compared to 10 s | | | |
|---|---|---|---|---|---|---|
| | | | **30 s** | **1 min** | **2 min** | **5 min** |
| **PN** | **All** | 353 | 2.8% [1.1% / 6.0%] | 5.1% [2.1% / 11.2%] | 11.5% [4.3% / 74.5%] | 85.7% [19.7% / 130.5%] |
| | **<5** | 82 | 3.2% [1.5% / 6.2%] | 5.4% [2.8% / 20.7%] | 62.3% [7.3% / 100.0%] | 100.0% [34.0% / 355.2%] |
| | **5-10** | 113 | 2.7% [1.0% / 6.1%] | 5.7% [2.1% / 10.3%] | 11.2% [3.5% / 45.4%] | 100.0% [22.4% / 211.4%] |
| | **10-15** | 69 | 3.1% [1.2% / 8.3%] | 7.3% [2.2% / 13.9%] | 7.9% [4.3% / 27.6%] | 94.1% [21.0% / 306.6%] |
| | **15-20** | 25 | 3.7% [0.7% / 8.3%] | 5.2% [1.9% / 8.3%] | 11.6% [5.4% / 46.5%] | 55.7% [12.6% / 100.0%] |
| | **20-30** | 64 | 2.2% [1.1% / 4.2%] | 3.5% [1.9% / 5.6%] | 8.0% [3.2% / 19.2%] | 27.7% [12.7% / 96.5%] |
| **$NO_X$** | **All** | 353 | 4.5% [2.0% / 9.0%] | 10.0% [3.9% / 25.6%] | 27.0% [8.4% / 100.0%] | 100.0% [28.7% / 100.0%] |
| | **<5** | 82 | 4.4% [1.8% / 7.1%] | 10.6% [3.1% / 26.1%] | 62.8% [11.0% / 100.0%] | 100.0% [40.3% / 100.0%] |
| | **5-10** | 113 | 4.0% [1.7% / 10.5%] | 8.6% [3.3% / 32.2%] | 25.9% [6.8% / 100.0%] | 100.0% [32.1% / 100.0%] |
| | **10-15** | 69 | 5.5% [3.0% / 10.1%] | 14.6% [5.7% / 43.9%] | 29.0% [11.5% / 73.3%] | 100.0% [37.2% / 100.0%] |
| | **15-20** | 25 | 5.3% [2.4% / 8.7%] | 9.9% [5.5% / 18.3%] | 29.7% [14.7% / 86.8%] | 79.2% [21.2% / 100.0%] |
| | **20-30** | 64 | 4.8% [2.1% / 8.9%] | 6.8% [3.8% / 13.6%] | 15.2% [6.6% / 35.6%] | 47.1% [17.6% / 100.0%] |

**Table S8. EF literature review: Statistical summary of ship emission factors by fuel type, presented as mean ± standard deviation (number of EFs considered).**

| Phase | Species | Unit | LNG | Fuel % S < 0.001 % | Fuel % S < 0.1 % | Fuel % S < 0.5 % | Fuel % S < 1.5 % | Fuel % S < 3.5 % |
|---|---|---|---|---|---|---|---|---|
| GAS PHASE | **$CO_2$** | g/(kg fuel) | 3 060 ± 1 440 (15) | 3 078 ± 225 (2) | 3 405 ± 678 (56) | 3 317 ± 620 (22) | 2 995 ± 166 (35) | 2 936 ± 356 (47) |
| | **$NO_X$** | g/(kg fuel) | 9.4 ± 8.4 (15) | 53.2 ± 32.4 (10) | 57.9 ± 30.2 (62) | 55.5 ± 16.4 (157) | 46.9 ± 22.2 (289) | 67.7 ± 18.3 (40) |
| | **NO** | g/(kg fuel) | - | - | 32.9 ± 1.7 (3) | 55.7 ± 18.5 (145) | 7.0 ± 1.0 (252) | 95.8 ± 24.4 (10) |
| | **$NO_2$** | g/(kg fuel) | - | - | - | 11.2 ± 11.5 (145) | 35.0 ± 6.0 (252) | 9.2 ± 0.7 (10) |
| | **CO** | g/(kg fuel) | 30.0 ± 51.8 (15) | 4.2 ± 2.8 (8) | 5.7 ± 8.6 (62) | 14.7 ± 9.0 (24) | 8.0 ± 5.7 (287) | 7.8 ± 8.0 (48) |
| | **$SO_2$** | g/(kg fuel) | 0.01 ± 0.00 (2) | 1.13 ± 0.70 (8) | 1.06 ± 0.98 (34) | 4.31 ± 2.60 (151) | 19.50 ± 4.27 (257) | 39.53 ± 14.44 (26) |
| | **$NH_3$** | g/(kg fuel) | - | - | 0.11 ± 0.22 (10) | - | 0.05 ± 0.07 (15) | - |
| | **$CH_4$** | g/(kg fuel) | 100 ± 239 (15) | - | 0.17 ± 0.40 (19) | 0.12 ± 0.15 (2) | 0.71 ± 0.08 (4) | 0.06 ± 0.07 (7) |
| | **NMVOC** | mg/(kg fuel) | - | - | 551 ± 398 (3) | 295 ± 304 (5) | 48 ± 38 (7) | 113 ± 9 (9) |
| | **$O_3$** | g/(kg fuel) | - | - | - | - | -48 ± 5 (252) | - |
| PARTICULATE PHASE | **PN** | $.10^{15}$ part/(kg fuel) | 2.1 ± 4.1 (20) | 6.1 ± 11.1 (19) | 8.1 ± 14.1 (4) | 18.1 ± 21.1 (225) | 4.1 ± 6.1 (255) | 13.1 ± 12.1 (65) |
| | **$D_{mode}$** | nm | 22.5 ± 16.3 (12) | 44.3 ± 23.0 (3) | 35.0 (1) | 34.5 ± 0.7 (140) | 41.0 ± 12.7 (2) | 50.5 ± 6.4 (2) |
| | **$PM_1$** | g/(kg fuel) | - | 0.07 ± 0.03 (5) | 0.61 ± 0.21 (5) | 0.88 ± 0.92 (151) | 3.77 ± 3.67 (254) | 1.26 ± 0.64 (24) |
| | **$PM_{2,5}$** | g/(kg fuel) | 0.19 ± 0.31 (5) | 0.39 ± 0.13 (2) | 2.33 ± 3.55 (30) | 0.82 ± 0.83 (6) | 3.39 ± 3.84 (4) | 3.72 ± 3.13 (32) |
| | **$PM_{10}$** | g/(kg fuel) | - | - | 0.31 ± 0.04 (2) | 1.06 ± 1.01 (6) | 1.71 ± 0.24 (3) | 2.05 ± 1.33 (12) |
| | **$PM_{TOT}$** | g/(kg fuel) | 0.06 ± 0.07 (11) | 0.31 ± 0.13 (5) | 0.68 ± 0.47 (21) | 2.53 ± 1.65 (14) | 3.33 ± 1.30 (18) | 6.36 ± 3.12 (19) |
| | **BC** ($PM_1$) | g/(kg fuel) | 8 ± 7 (24) | 98 ± 59 (5) | 238 ± 305 (40) | 241 ± 392 (201) | 351 ± 872 (271) | 214 ± 319 (80) |
| | **OA** ($PM_1$) | mg/(kg fuel) | - | - | 624 ± 335 (5) | 1 350 ± 636 (154) | 3 000 ± 1 000 (252) | 1 600 ± 700 (23) |
| | **$SO_4$** ($PM_1$) | mg/(kg fuel) | - | - | 120 ± 50 (5) | 300 ± 339 (154) | 4 000 ± 1000 (252) | 2 100 ± 1 600 (23) |
| | **$NH_4$** ($PM_1$) | mg/(kg fuel) | - | - | 2 ± 3 (5) | 0 ± 1 000 (15) | 1 300.0 (252) | 0 ± 1 000 (23) |
| | **$NO_3$** ($PM_1$) | mg/(kg fuel) | - | - | 3 ± 6 (5) | 0 ± 1 000 (15) | 800.0 (252) | 0 ± 1 000 (23) |
| | **$Cl^-$** ($PM_1$) | mg/(kg fuel) | - | - | 0 (5) | 15.5 ± 13.2 (4) | 15.7 ± 7.8 (15) | - |

Note: References for the scientific articles consulted for each compound are summarized in Table S10.

**Table S9. Scientific References used in Table S8, Organized by compound**

| Species | | Unit |
|---|---|---|
| GAS PHASE | $CO_2$ | Aakko-Saksa et al. (2016), Agrawal et al. (2008a), Agrawal et al. (2008b), Agrawal et al. (2010), Anderson et al. (2015a), Bai et al. (2020), Celo et al. (2015), Comer et al. (2017), Cooper et al. (1996), Cooper(2001), Fridell et al. (2008), Gysel et al. (2017), Huang et al. (2018), Lehtoranta et al. (2019), McCaffery et al. (2021), Moldanová et al. (2013), Peng et al. (2020), Timonen et al. (2017), Winnes et al. (2020), Zhao et al. (2020) |
| | $NO_X$ | Aakko-Saksa et al. (2016), Agrawal et al. (2008a), Agrawal et al. (2008b), Agrawal et al. (2010), Anderson et al. (2015a), Bai et al. (2020), Celik et al. (2020), Celo et al. (2015), Comer et al. (2017), Cooper et al. (1996), Cooper(2001), Diesch et al. (2013), Fridell and Salo (2016), Fridell et al. (2008), Gysel et al. (2017), Huang et al. (2018), Jeong et al. (2023), Lehtoranta et al. (2019), McCaffery et al. (2021), Moldanová et al. (2013), Peng et al. (2020), Timonen et al. (2017), Timonen et al. (2022), Winnes et al. (2020), Zetterdahl et al. (2016) |
| | NO | Celik et al. (2020), Diesch et al. (2013), Timonen et al. (2022), Zhao et al. (2020) |
| | $NO_2$ | Celik et al. (2020), Diesch et al. (2013), Zhao et al. (2020) |
| | CO | Aakko-Saksa et al. (2016), Agrawal et al. (2008a), Agrawal et al. (2008b), Agrawal et al. (2010), Anderson et al. (2015a), Bai et al. (2020), Celik et al. (2020), Celo et al. (2015), Comer et al. (2017), Cooper et al. (1996), Cooper(2001) , Fridell and Salo (2016), Fridell et al. (2008) , Gysel et al. (2017), Huang et al. (2018), Lehtoranta et al. (2019), McCaffery et al. (2021), Moldanová et al. (2013), Peng et al. (2020), Timonen et al. (2017), Timonen et al. (2022), Winnes et al. (2020), Zetterdahl et al. (2016), Zhao et al. (2020) |
| | $SO_2$ | Agrawal et al. (2008a), Agrawal et al. (2010), Bai et al. (2020), Celik et al. (2020), Comer et al. (2017), Diesch et al. (2013), Jeong et al. (2023), Lehtoranta et al. (2019), McCaffery et al. (2021), Moldanová et al. (2013), Timonen et al. (2022), Winnes et al. (2020), Zetterdahl et al. (2016), Zhao et al. (2020) |
| | $NH_3$ | Aakko-Saksa et al. (2016), Aakko-Saksa et al. (2019), Cooper(2001), Timonen et al. (2017) |
| | $CH_4$ | Aakko-Saksa et al. (2016), Anderson et al. (2015a), Comer et al. (2017), Cooper(2001), Lehtoranta et al. (2019), Peng et al. (2020), Timonen et al. (2017), Timonen et al. (2022), Winnes et al. (2020) |
| | NMVOC | Agrawal et al. (2008a), Agrawal et al. (2010), Cooper et al. (1996), Cooper(2001), Huang et al. (2018) |
| | $O_3$ | Celik et al. (2020) |
| PARTICULATE PHASE | PN | Anderson et al. (2015a), Celik et al. (2020), Corbin et al. (2020), Diesch et al. (2013), Fridell and Salo (2016), Jeong et al. (2023), Kuittinen et al. (2021), Lack et al. (2009), Winnes et al. (2020), Zetterdahl et al. (2016), Zhao et al. (2020) |
| | Dmode | Corbin et al. (2020), Diesch et al. (2013), Jeong et al. (2023), Zetterdahl et al. (2016) |
| | $PM_1$ | Celik et al. (2020), Diesch et al. (2013), Fridell et al. (2008) , Lack et al. (2009), Moldanová et al. (2013), Winnes et al. (2020), Zetterdahl et al. (2016) |
| | $PM_{2.5}$ | Agrawal et al. (2008a), Agrawal et al. (2008b), Agrawal et al. (2010), Celo et al. (2015), Fridell et al. (2008), Gysel et al. (2017), Jeong et al. (2023), McCaffery et al. (2021), Moldanová et al. (2013), Peng et al. (2020) |
| | $PM_{10}$ | Fridell et al. (2008), Moldanová et al. (2013) |
| | $PM_{TOT}$ | Aakko-Saksa et al. (2016), Anderson et al. (2015a), Comer et al. (2017), Cooper(2001), Fridell et al. (2008), Gysel et al. (2017), Huang et al. (2018), Lehtoranta et al. (2019), Moldanová et al. (2013), Timonen et al. (2022), Winnes et al. (2020), Zetterdahl et al. (2016) |
| | BC | Aakko-Saksa et al. (2016), Agrawal et al. (2008a), Agrawal et al. (2008b), Agrawal et al. (2010), Anderson et al. (2015a), Celik et al. (2020), Celo et al. (2015), Comer et al. (2017), Corbin et al. (2020), Diesch et al. (2013), Fridell and Salo (2016), Jeong et al. (2023), Lack et al. (2009), Lanzafame et al. (2022), McCaffery et al. (2021), Peng et al. (2020), Timonen et al. (2017), Timonen et al. (2022), Zetterdahl et al. (2016), Zhao et al. (2020) |
| | OA | Celik et al. (2020), Diesch et al. (2013), Lack et al. (2009), Lanzafame et al. (2022), Timonen et al. (2022) |
| | $SO_4^{2-}$ | Celik et al. (2020), Celo et al. (2015), Diesch et al. (2013), Huang et al. (2018), Jeong et al. (2023), Lack et al. (2009), Lanzafame et al., 2022, McCaffery et al. (2021), Timonen et al. (2022) |
| | $NH_4^+$ | Celik et al. (2020), Lack et al. (2009), Lanzafame et al. (2022), Huang et al. (2018), Timonen et al. (2022) |
| | $NO_3^-$ | Celik et al. (2020), Lack et al. (2009), Lanzafame et al. (2022), Huang et al. (2018), Timonen et al. (2022) |
| | $Cl^-$ | Huang et al. (2018), Lanzafame et al. (2022), Timonen et al. (2022) |

**Table S10. Emission factors statistics for the 353 ship plumes identified during the campaign.**

| Mesured Quantity | Species | Unit | Temporal resolution | $N_{plume}$ | Min | P10 | P25 | Median | Mean | P75 | P90 | Max | DL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **PARTICULATE PHASE** | | | | | | | | | | | | | |
| **Particle number** | PN | part.(kg fuel)$^{-1}$ | 10 sec | 335 | < DL | 3.0E+15 | 4.2E+15 | 6.7E+15 | 8.1E+15 | 1.1E+16 | 1.5E+16 | 3.6E+16 | 4.5E+14 |
| **Particle masse concentration** | $PM_{1\ (SMPS)}$ | g.(kg fuel)$^{-1}$ | 2 min | 236 | < DL | < DL | < DL | 1.0 | 1.6 | 2.3 | 4.0 | 9.8 | 0.4 |
| | $PM_{1\ (OPC)}$ | g.(kg fuel)$^{-1}$ | 1 min | 342 | < DL | < DL | 0.2 | 0.5 | 0.9 | 1.1 | 2.0 | 8.5 | 0.1 |
| | $PM_{2.5\ (OPC)}$ | g.(kg fuel)$^{-1}$ | 1 min | 341 | < DL | < DL | < DL | 0.5 | 1.0 | 1.3 | 2.5 | 8.4 | 0.3 |
| | $PM_{10\ (OPC)}$ | g.(kg fuel)$^{-1}$ | 1 min | 341 | < DL | < DL | < DL | 0.6 | 1.2 | 1.6 | 3.3 | 9.2 | 0.5 |
| **Chemical Composition ($PM_1$)** | BC | mg.(kg fuel)$^{-1}$ | 1 min | 342 | < DL | < DL | 163 | 298 | 477 | 592 | 1 056 | 3 602 | 84 |
| | $Cl^-$ | mg.(kg fuel)$^{-1}$ | 30 sec | 178 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 69.6 | 2.9 |
| | $NH_4^+$ | mg.(kg fuel)$^{-1}$ | 30 sec | 178 | < DL | < DL | < DL | < DL | 10.1 | 16.6 | 31.6 | 96.0 | 5.0 |
| | $NO_3^-$ | mg.(kg fuel)$^{-1}$ | 30 sec | 178 | < DL | < DL | < DL | < DL | 12.9 | 18.2 | 43.2 | 124.5 | 5.4 |
| | OA | mg.(kg fuel)$^{-1}$ | 30 sec | 178 | < DL | 355 | 543 | 863 | 1 872 | 1 742 | 4 044 | 25 445 | 153 |
| | $SO_4^{2-}$ | mg.(kg fuel)$^{-1}$ | 30 sec | 178 | < DL | < DL | < DL | 50 | 175 | 174 | 567 | 2 002 | 28 |
| **GAS PHASE** | | | | | | | | | | | | | |
| **Nitrogen Oxides** | $NO_X$ | g.(kg fuel)$^{-1}$ | 10 sec | 328 | < DL | 18.6 | 27.8 | 37.1 | 38.5 | 48.4 | 58.8 | 98.8 | 0.6 |
| | NO | g.(kg fuel)$^{-1}$ | 10 sec | 329 | < DL | 5.3 | 9.4 | 14.2 | 15.8 | 20.8 | 28.2 | 50.6 | 0.2 |
| | $NO_2$ | g.(kg fuel)$^{-1}$ | 10 sec | 328 | < DL | 4.7 | 9.1 | 14.0 | 15.0 | 19.7 | 25.8 | 49.3 | 0.5 |
| **Carbon Oxides** | CO | g.(kg fuel)$^{-1}$ | 10 sec | 353 | < DL | < DL | < DL | 5.4 | 7.4 | 9.3 | 14.7 | 114.1 | 4.0 |
| **Sulfur Dioxide** | $SO_2$ | g.(kg fuel)$^{-1}$ | 10 sec | 286 | < DL | < DL | < DL | 0.4 | 0.6 | 0.7 | 1.5 | 6.7 | 0.1 |
| **Ozone** | $O_3$ | g.(kg fuel)$^{-1}$ | 10 sec | 279 | < DL | -3.7 | -7.5 | -13.4 | -14.8 | -19.0 | -26.8 | -62.5 | 0.6 |
| **Ammoniac** | $NH_3$ | g.(kg fuel)$^{-1}$ | 10 sec | 51 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 0.2 | 0.1 |
| **Volatils Organics Compounds (VOC)** | $CH_4$ | g.(kg fuel)$^{-1}$ | 10 sec | 353 | < DL | < DL | < DL | 0.4 | 1.3 | 1.0 | 2.9 | 23.4 | 0.3 |
| | $(CH_2O_2)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 132 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 138 |
| | $(CH_3OH)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 132 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 869 | 182 |
| | $(C_2H_4O)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 132 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 1 093 | 137 |
| | $(C_2H_4O_2)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 132 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 1 981 | 275 |
| | $(C_2H_6O)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 131 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 1 040 | 89 |
| | $(C_2H_6S)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 132 | < DL | < DL | < DL | < DL | 6 | < DL | < DL | 755 | 4 |
| | $(C_3H_6)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 131 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 575 | 87 |
| | $(C_3H_6O)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 132 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 915 | 128 |
| | $(C_3H_6O_2)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 131 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 46 |
| | $(C_4H_{10}O_3)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 132 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 269 | 29 |
| | $(C_4H_{12}O_2)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 132 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 48 | 33 |
| | $(C_4H_6O)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 132 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 121 | 23 |
| | $(C_4H_8)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 132 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 1 474 | 147 |
| | $(C_4H_8O)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 132 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 124 | 31 |
| | $(C_4H_8O_2)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 132 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 31 |
| | $(C_5H_{10})H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 131 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 282 | 44 |
| | $(C_5H_{10}O)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 131 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 40 |
| | $(C_5H_8)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 132 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 46 |
| | $(C_5H_8O_2)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 132 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 31 |
| | $(C_6H_{10})H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 132 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 32 |
| | $(C_6H_{10}O)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 131 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 26 |
| | $(C_6H_{12})H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 132 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 166 | 34 |
| | $(C_6H_{12}O)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 132 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 308 | 28 |
| | $(C_6H_{12}O_2)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 132 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 14 |
| | $(C_6H_6)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 132 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 82 | 37 |
| | $(C_7H_{12})H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 131 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 32 |
| | $(C_7H_8)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 132 | < DL | < DL | < DL | < DL | < DL | < DL | 108 | 1 347 | 80 |
| | $(C_8H_{10})H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 132 | < DL | < DL | < DL | < DL | 201 | 176 | 460 | 7 598 | 122 |
| | $(C_8H_{14})H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 131 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 33 |
| | $(C_8H_8)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 131 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 25 |
| | $(C_9H_{12})H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 132 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 525 | 42 |
| | $(C_9H_{18}O)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 132 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 28 |
| | $(C_{10}H_{14})H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 132 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 118 | 29 |
| | $(C_{10}H_{14}O)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 132 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 15 |
| | $(C_{10}H_{16})H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 132 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 145 | 56 |
| | $(C_{10}H_{16}O)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 131 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 19 |
| | $(C_{10}H_{18})H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 132 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 19 |
| | $(C_{11}H_{16})H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 132 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 8 |
| | $(C_{11}H_{18})H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 131 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 20 |
| | $(C_{11}H_{20})H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 132 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 17 |
| | $(C_{12}H_{20})H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | 131 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 25 |

Note: The number of plumes for which compounds were quantified using HR-ToF-AMS analyzers (OA, $SO_4^{2-}$, $NH_4^+$ et $Cl^-$) and PTR-ToF-MS (NMVOCs such as $C_8H_{10}H^+$) is nearly half that of other species due to the exclusive deployment of these analyzers at the PEB station.

**Table S11. Emission factors statistics categorized by operational phase for the 353 ship plumes identified during the campaign.**

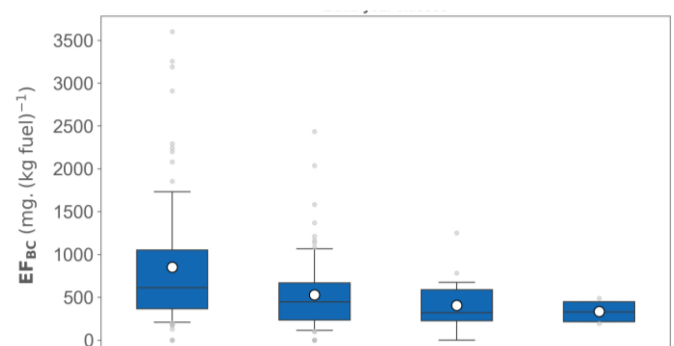
| Mesured Quantity | Species | Unit | Time resolution | Operating phase | $N_{plume}$ | Min | P10 | P25 | Median | Mean | P75 | P90 | Max | DL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **PARTICULATE PHASE** | | | | | | | | | | | | | | |
| **Particle number** | PN | part.(kg fuel)$^{-1}$ | 10 sec | At berth | 115 | 3.5E+15 | 6.2E+15 | 7.9E+15 | 9.9E+15 | 1.0E+16 | 1.2E+16 | 1.5E+16 | 2.9E+16 | 4.5E+14 |
| | | | | Manoeuvring | 44 | 9.0E+14 | 2.9E+15 | 3.6E+15 | 5.6E+15 | 6.5E+15 | 9.2E+15 | 1.1E+16 | 2.1E+16 | 4.5E+14 |
| | | | | Navigation | 161 | < DL | 2.7E+15 | 3.3E+15 | 4.9E+15 | 6.9E+15 | 8.7E+15 | 1.5E+16 | 3.6E+16 | 4.5E+14 |
| | | | | Mixed phase | 15 | 2.3E+15 | 3.2E+15 | 4.2E+15 | 5.9E+15 | 7.9E+15 | 9.3E+15 | 1.5E+16 | 2.4E+16 | 4.5E+14 |
| **Particle masse concentration** | $PM_{1 (SMPS)}$ | g.(kg fuel)$^{-1}$ | 2 min | At berth | 89 | < DL | < DL | < DL | 0.6 | 0.5 | 0.9 | 1.1 | 2.9 | 0.4 |
| | | | | Manoeuvring | 27 | < DL | < DL | < DL | 1.1 | 1.1 | 1.7 | 2.6 | 2.7 | 0.4 |
| | | | | Navigation | 110 | < DL | < DL | 1.1 | 2.0 | 2.4 | 3.6 | 5.0 | 9.8 | 0.4 |
| | | | | Mixed phase | 10 | < DL | 0.7 | 1.2 | 3.3 | 3.3 | 4.7 | 5.3 | 8.3 | 0.4 |
| | $PM_{1 (OPC)}$ | g.(kg fuel)$^{-1}$ | 1 min | At berth | 114 | < DL | < DL | 0.1 | 0.2 | 0.3 | 0.4 | 0.6 | 4.6 | 0.1 |
| | | | | Manoeuvring | 46 | < DL | < DL | 0.2 | 0.7 | 1.2 | 1.1 | 3.0 | 6.4 | 0.1 |
| | | | | Navigation | 166 | < DL | 0.3 | 0.4 | 0.6 | 1.1 | 1.5 | 2.3 | 8.5 | 0.1 |
| | | | | Mixed phase | 16 | < DL | < DL | 0.6 | 1.4 | 1.6 | 1.9 | 3.0 | 6.4 | 0.1 |
| | $PM_{2.5 (OPC)}$ | g.(kg fuel)$^{-1}$ | 1 min | At berth | 114 | < DL | < DL | < DL | < DL | 0.3 | 0.4 | 0.7 | 5.8 | 0.3 |
| | | | | Manoeuvring | 46 | < DL | < DL | 0.4 | 0.7 | 1.2 | 1.3 | 3.0 | 6.5 | 0.3 |
| | | | | Navigation | 165 | < DL | < DL | 0.3 | 0.8 | 1.3 | 1.8 | 2.9 | 8.4 | 0.3 |
| | | | | Mixed phase | 16 | < DL | < DL | 0.7 | 1.9 | 1.8 | 2.1 | 3.1 | 6.5 | 0.3 |
| | $PM_{10 (OPC)}$ | g.(kg fuel)$^{-1}$ | 1 min | At berth | 113 | < DL | < DL | < DL | < DL | < DL | 0.6 | 1.0 | 6.2 | 0.5 |
| | | | | Manoeuvring | 46 | < DL | < DL | < DL | 0.7 | 1.4 | 1.7 | 3.9 | 8.9 | 0.5 |
| | | | | Navigation | 166 | < DL | < DL | < DL | 1.0 | 1.5 | 2.2 | 3.5 | 9.2 | 0.5 |
| | | | | Mixed phase | 16 | < DL | < DL | 1.1 | 2.0 | 2.1 | 2.9 | 3.6 | 5.7 | 0.5 |
| **Chemical Composition ($PM_1$)** | BC | mg.(kg fuel)$^{-1}$ | 1 min | At berth | 114 | < DL | < DL | 105 | 165 | 196 | 247 | 318 | 2 080 | 84 |
| | | | | Manoeuvring | 45 | < DL | 112 | 207 | 436 | 637 | 683 | 1 286 | 3 602 | 84 |
| | | | | Navigation | 167 | < DL | < DL | 268 | 477 | 594 | 791 | 1 226 | 3 254 | 84 |
| | | | | Mixed phase | 16 | 136 | 185 | 380 | 796 | 806 | 1 063 | 1 278 | 2 200 | 84 |
| | $Cl^-$ | mg.(kg fuel)$^{-1}$ | 30 sec | At berth | 91 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 37 | 2.9 |
| | | | | Manoeuvring | 12 | < DL | < DL | < DL | < DL | < DL | < DL | 3 | 13 | 2.9 |
| | | | | Navigation | 66 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 70 | 2.9 |
| | | | | Mixed phase | 9 | < DL | < DL | < DL | < DL | 3 | < DL | 10 | 19 | 2.9 |
| | $NH_4^+$ | mg.(kg fuel)$^{-1}$ | 30 sec | At berth | 91 | < DL | < DL | < DL | < DL | < DL | < DL | 21 | 41 | 5.0 |
| | | | | Manoeuvring | 12 | < DL | < DL | < DL | < DL | 15 | 31 | 40 | 45 | 5.0 |
| | | | | Navigation | 66 | < DL | < DL | < DL | < DL | 15 | 22 | 54 | 96 | 5.0 |
| | | | | Mixed phase | 9 | < DL | < DL | 11 | 30 | 23 | 36 | 41 | 41 | 5.0 |
| | $NO_3^-$ | mg.(kg fuel)$^{-1}$ | 30 sec | At berth | 91 | < DL | < DL | < DL | < DL | 6 | 9 | 23 | 67 | 5.4 |
| | | | | Manoeuvring | 12 | < DL | < DL | < DL | < DL | 15 | 23 | 48 | 67 | 5.4 |
| | | | | Navigation | 66 | < DL | < DL | < DL | < DL | 18 | 32 | 56 | 123 | 5.4 |
| | | | | Mixed phase | 9 | < DL | < DL | 18 | 22 | 37 | 29 | 103 | 125 | 5.4 |
| | OA | mg.(kg fuel)$^{-1}$ | 30 sec | At berth | 91 | < DL | 334 | 470 | 611 | 658 | 799 | 950 | 2 538 | 153 |
| | | | | Manoeuvring | 12 | < DL | 181 | 487 | 861 | 969 | 1 394 | 1 986 | 2 237 | 153 |
| | | | | Navigation | 66 | < DL | 752 | 1 250 | 2 247 | 3 716 | 4 301 | 6 626 | 25 445 | 153 |
| | | | | Mixed phase | 9 | 429 | 759 | 1 137 | 2 164 | 1 827 | 2 371 | 2 692 | 3 177 | 153 |
| | $SO_4^{2-}$ | mg.(kg fuel)$^{-1}$ | 30 sec | At berth | 91 | < DL | < DL | < DL | < DL | 33 | 50 | 80 | 289 | 28 |
| | | | | Manoeuvring | 12 | < DL | < DL | < DL | < DL | 58 | 120 | 149 | 190 | 28 |
| | | | | Navigation | 66 | < DL | < DL | 75 | 235 | 390 | 580 | 944 | 2 002 | 28 |
| | | | | Mixed phase | 9 | < DL | 53 | 87 | 182 | 189 | 270 | 351 | 365 | 28 |
| **GAS PHASE** | | | | | | | | | | | | | | |
| **Nitrogen Oxides** | $NO_X$ | g.(kg fuel)$^{-1}$ | 10 sec | At berth | 114 | < DL | 21.2 | 29.4 | 40.0 | 39.8 | 50.8 | 58.3 | 78.3 | 0.6 |
| | | | | Manoeuvring | 45 | 3.7 | 14.4 | 23.1 | 33.5 | 36.3 | 44.8 | 65.0 | 98.8 | 0.6 |
| | | | | Navigation | 155 | < DL | 17.3 | 28.0 | 36.2 | 38.3 | 48.2 | 61.8 | 97.8 | 0.6 |
| | | | | Mixed phase | 14 | 14.7 | 26.1 | 30.9 | 39.1 | 38.3 | 46.5 | 52.9 | 59.2 | 0.6 |
| | NO | g.(kg fuel)$^{-1}$ | 10 sec | At berth | 114 | < DL | 6.9 | 11.0 | 15.9 | 16.6 | 22.1 | 27.4 | 38.1 | 0.2 |
| | | | | Manoeuvring | 45 | 0.5 | 5.2 | 8.0 | 14.3 | 15.9 | 19.2 | 31.0 | 41.6 | 0.2 |
| | | | | Navigation | 155 | < DL | 4.4 | 8.8 | 12.3 | 15.1 | 19.4 | 30.1 | 50.6 | 0.2 |
| | | | | Mixed phase | 15 | 5.9 | 12.5 | 13.1 | 16.2 | 16.4 | 19.9 | 22.4 | 25.0 | 0.2 |
| | $NO_2$ | g.(kg fuel)$^{-1}$ | 10 sec | At berth | 114 | < DL | 5.9 | 10.0 | 14.6 | 15.2 | 19.2 | 25.7 | 48.2 | 0.5 |
| | | | | Manoeuvring | 45 | < DL | 3.3 | 4.9 | 9.9 | 12.6 | 19.0 | 23.7 | 41.0 | 0.5 |
| | | | | Navigation | 155 | < DL | 5.3 | 10.4 | 15.1 | 15.8 | 20.5 | 26.5 | 49.3 | 0.5 |
| | | | | Mixed phase | 14 | 1.4 | 5.4 | 7.6 | 12.9 | 13.7 | 20.0 | 22.5 | 28.7 | 0.5 |
| **Carbon Oxides** | CO | g.(kg fuel)$^{-1}$ | 10 sec | At berth | 118 | < DL | < DL | < DL | < DL | < DL | 5.4 | 7.1 | 27.9 | 4.0 |
| | | | | Manoeuvring | 46 | < DL | < DL | < DL | 7.1 | 8.3 | 12.1 | 16.9 | 46.5 | 4.0 |
| | | | | Navigation | 173 | < DL | < DL | < DL | 7.2 | 9.8 | 10.9 | 17.9 | 114.1 | 4.0 |
| | | | | Mixed phase | 16 | < DL | < DL | 4.9 | 8.6 | 7.3 | 10.7 | 11.8 | 13.2 | 4.0 |
| **Sulfur Dioxide** | $SO_2$ | g.(kg fuel)$^{-1}$ | 10 sec | At berth | 94 | < DL | < DL | < DL | 0.4 | 0.4 | 0.6 | 1.0 | 2.1 | 0.1 |
| | | | | Manoeuvring | 43 | < DL | < DL | 0.2 | 0.4 | 0.9 | 1.5 | 2.4 | 4.3 | 0.1 |
| | | | | Navigation | 136 | < DL | < DL | < DL | 0.4 | 0.6 | 0.6 | 1.5 | 5.9 | 0.1 |
| | | | | Mixed phase | 13 | < DL | < DL | 0.2 | 0.7 | 1.5 | 1.8 | 3.9 | 6.7 | 0.1 |
| **Ozone** | $O_3$ | g.(kg fuel)$^{-1}$ | 10 sec | At berth | 103 | < DL | -4.1 | -6.8 | -13.4 | -13.8 | -18.6 | -23.8 | -45.7 | 0.6 |
| | | | | Manoeuvring | 37 | -2.5 | -4.2 | -6.5 | -9.8 | -12.5 | -13.6 | -23.3 | -50.3 | 0.6 |
| | | | | Navigation | 126 | < DL | -3.5 | -10.0 | -14.5 | -16.5 | -21.7 | -27.9 | -62.5 | 0.6 |
| | | | | Mixed phase | 13 | -1.4 | -4.1 | -5.7 | -13.3 | -12.7 | -16.7 | -18.3 | -35.8 | 0.6 |
| **Ammoniac** | $NH_3$ | g.(kg fuel)$^{-1}$ | 10 sec | At berth | 24 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 0.1 |
| | | | | Manoeuvring | 3 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 0.1 |
| | | | | Navigation | 20 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 0.2 | 0.1 |
| | | | | Mixed phase | 4 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 0.1 |
| **Volatils Organics Compounds (VOC)** | $CH_4$ | g.(kg fuel)$^{-1}$ | 10 sec | At berth | 118 | < DL | < DL | < DL | 0.6 | 1.9 | 1.7 | 4.5 | 23.4 | 0.3 |
| | | | | Manoeuvring | 46 | < DL | < DL | < DL | 0.4 | 1.7 | 1.9 | 4.3 | 15.8 | 0.3 |
| | | | | Navigation | 173 | < DL | < DL | < DL | 0.3 | 0.6 | 0.7 | 1.4 | 10.4 | 0.3 |
| | | | | Mixed phase | 16 | < DL | < DL | < DL | 0.3 | 2.1 | 0.7 | 7.3 | 15.2 | 0.3 |
| | $(CH_2O_2)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 138 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 138 |
| | | | | Navigation | 54 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 138 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 138 |

| Mesured Quantity | Species | Unit | Time resolution | Operating phase | $N_{plume}$ | Min | P10 | P25 | Median | Mean | P75 | P90 | Max | DL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Volatils Organics Compounds (VOC) | $(CH_3OH)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 869 | 182 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | 316 | 426 | 621 | 182 |
| | | | | Navigation | 54 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 182 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 829 | 182 |
| | $(C_2H_4O)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 821 | 137 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | 153 | < DL | 447 | 1 093 | 137 |
| | | | | Navigation | 54 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 216 | 137 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 137 |
| | $(C_2H_4O_2)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 1 733 | 275 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 466 | 275 |
| | | | | Navigation | 54 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 1 981 | 275 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 275 |
| | $(C_2H_6O)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 911 | 89 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | 235 | 390 | 89 |
| | | | | Navigation | 53 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 1 040 | 89 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | 94 | 221 | 271 | 89 |
| | $(C_2H_6S)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 4 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 4 |
| | | | | Navigation | 54 | < DL | < DL | < DL | < DL | 14 | < DL | < DL | 755 | 4 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 4 |
| | $(C_3H_6)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 575 | 87 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 87 |
| | | | | Navigation | 53 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 103 | 87 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 87 |
| | $(C_3H_6O)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 915 | 128 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 348 | 128 |
| | | | | Navigation | 54 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 128 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | < DL | 201 | 277 | 128 |
| | $(C_3H_6O_2)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 46 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 46 |
| | | | | Navigation | 53 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 46 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 46 |
| | $(C_4H_{10}O_3)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 269 | 29 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 41 | 29 |
| | | | | Navigation | 54 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 29 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 29 |
| | $(C_4H_{12}O_2)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 48 | 33 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 33 |
| | | | | Navigation | 54 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 33 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 33 |
| | $(C_4H_6O)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 23 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | 24 | 121 | 23 |
| | | | | Navigation | 54 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 36 | 23 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 23 |
| | $(C_4H_8)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 147 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 147 |
| | | | | Navigation | 54 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 1 474 | 147 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 147 |
| | $(C_4H_8O)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 31 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 124 | 31 |
| | | | | Navigation | 54 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 86 | 31 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 31 |
| | $(C_4H_8O_2)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 31 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 31 |
| | | | | Navigation | 54 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 31 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 31 |
| | $(C_5H_{10})H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 44 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | 56 | 282 | 44 |
| | | | | Navigation | 53 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 44 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 44 |
| | $(C_5H_{10}O)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 40 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 40 |
| | | | | Navigation | 53 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 40 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 40 |
| | $(C_5H_8)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 46 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 46 |
| | | | | Navigation | 54 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 46 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 46 |
| | $(C_5H_8O_2)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 31 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 31 |
| | | | | Navigation | 54 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 31 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 31 |
| | $(C_6H_{10})H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 32 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 32 |
| | | | | Navigation | 54 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 32 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 32 |
| | $(C_6H_{10}O)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 26 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 26 |
| | | | | Navigation | 53 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 26 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 26 |
| | $(C_6H_{12})H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 34 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 166 | 34 |
| | | | | Navigation | 54 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 34 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 34 |

| Mesured Quantity | Species | Unit | Time resolution | Operating phase | $N_{plume}$ | Min | P10 | P25 | Median | Mean | P75 | P90 | Max | DL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Volatils Organics Compounds (VOC)** | $(C_6H_{12}O)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 308 | 28 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 28 |
| | | | | Navigation | 54 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 28 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 28 |
| | $(C_6H_{12}O_2)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 14 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 14 |
| | | | | Navigation | 54 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 14 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 14 |
| | $(C_6H_6)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 37 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 37 |
| | | | | Navigation | 54 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 82 | 37 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 37 |
| | $(C_7H_{12})H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 32 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 32 |
| | | | | Navigation | 53 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 32 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 32 |
| | $(C_7H_8)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | 94 | 800 | 80 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | 183 | 191 | 442 | 1 108 | 80 |
| | | | | Navigation | 54 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 1 347 | 80 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | < DL | 190 | 473 | 80 |
| | $(C_8H_{10})H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | 335 | 291 | 669 | 7 598 | 122 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | 143 | 257 | 370 | 466 | 122 |
| | | | | Navigation | 54 | < DL | < DL | < DL | < DL | < DL | < DL | 284 | 937 | 122 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | 217 | 333 | 359 | 122 |
| | $(C_8H_{14})H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 33 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 33 |
| | | | | Navigation | 53 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 33 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 33 |
| | $(C_8H_8)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 25 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 25 |
| | | | | Navigation | 53 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 25 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 25 |
| | $(C_9H_{12})H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | 52 | 525 | 42 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | 50 | < DL | 165 | 327 | 42 |
| | | | | Navigation | 54 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 151 | 42 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 107 | 42 |
| | $(C_9H_{18}O)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 28 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 28 |
| | | | | Navigation | 54 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 28 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 28 |
| | $(C_{10}H_{14})H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 118 | 29 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 75 | 29 |
| | | | | Navigation | 54 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 29 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 29 |
| | $(C_{10}H_{14}O)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 15 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 15 |
| | | | | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 15 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 15 |
| | $(C_{10}H_{16})H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 145 | 56 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 56 |
| | | | | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 145 | 56 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 56 |
| | $(C_{10}H_{16}O)H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 19 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 19 |
| | | | | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 19 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 19 |
| | $(C_{10}H_{18})H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 19 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 19 |
| | | | | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 19 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 19 |
| | $(C_{11}H_{16})H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 8 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 8 |
| | | | | Navigation | 54 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 8 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 8 |
| | $(C_{11}H_{18})H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 20 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 20 |
| | | | | Navigation | 53 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 20 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 20 |
| | $(C_{11}H_{20})H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 17 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 17 |
| | | | | Navigation | 54 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 17 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 17 |
| | $(C_{12}H_{20})H^+$ | mg.(kg fuel)$^{-1}$ | 10 sec | At berth | 59 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 25 |
| | | | | Manoeuvring | 9 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 25 |
| | | | | Navigation | 53 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 25 |
| | | | | Mixed phase | 10 | < DL | < DL | < DL | < DL | < DL | < DL | < DL | < DL | 25 |

**Table S12. Potential hypotheses for elevated methane emission factors in the study area**

| N° | Hypothesis details |
|---|---|
| **1** | Some plumes may originate from multiple ships of the same category, particularly “at berth” ships. In such cases, one ship might be using a hybrid engine running on both fuel (fuel oil and LNG), or an engine operating on natural gas or LNG, which could elevate the emission factor without reaching the levels typically associated with LNG-powered ships. This scenario is most plausible for the EFs observed from “at berth.” cruise ships, which often consist of several vessels |
| **2** | Capture of emissions at engine starts-up, where incomplete combustion could result in higher $CH_4$ emissions. However, the lack of correlation between $CH_4$ and CO (a known tracer of incomplete combustion (Latarche, 2021)) does not support this hypothesis. |
| **3** | A GTL (liquefied methane gas) pilot boat that routinely accompanies ships entering or leaving the port could also contribute to the observed EFs. This boat operates from the channel entrance to the berth and vice versa. Thus, one likely explanation for higher EFs for ships in “manoeuvring/navigation” is the simultaneous measurement of emissions from both the ship and pilot boat. In this case, the $CH_4$ emission factor calculated underestimates $CH_4$ emissions from the pilot boat because concentrations are related to the combined $CO_2$ emissions of both the ship and the pilot boat (dominated by the ship). Conversely, this calculation overestimates the $EF_{CH4}$ for the ship alone. |
| **4** | Diffuse oceanic emissions of $CH_4$ from ships in “manoeuvring/navigation” was also considered due to the shallow seabed near the measurement stations (less than 10 m (Pairaud et al., 2011)), as well as water temperature and weather conditions at this time of year. Specific studies on methane emitted by oceans show that diffuse oceanic emissions close to the coasts (<2,000 m) contribute to the greatest diffusive flux of methane due to surface water supersaturation (Vogt et al., 2023). This supersaturation is linked both to emissions from the ocean floor and methanogenesis of the microbial cycle of organic matter compounds dissolved in water, particularly DMS (Weber et al., 2019). The stirring up of the water by passing ships could increase these diffuse emissions. However, the absence of DMS in plumes with higher $CH_4$ levels does not support this hypothesis. |




| | Tier 0 | Tier I | Tier II | Tier III |
|---|---|---|---|---|
| NSP* | 89 | 79 | 15 | 4 |
| NQP** | 86 | 76 | 15 | 4 |
| TDQP*** | 13 | 17 | 2 | 0 |
| NDVQP**** | 17 | 19 | 5 | 4 |

* NSP: Number of plumes studied - ** NQP: Number of quantified plumes - *** TDQP: Total duration of quantified plumes (hours)
**** NDVQP: Number of different vessels in the quantified plumes

**Figure S8. $EF_{BC}$ distribution as a function of Tier regulations imposed by the MARPOL Convention. For each box plot, the coloured box represents the interquartile range between the 25th percentile (P25) and the 75th percentile (P75), the vertical error bar represents the interval between the 10th percentile (P10) and the 90th percentile (P90), the black horizontal line represents the median, the white circle represents the mean and the grey dots represent the extremes.**

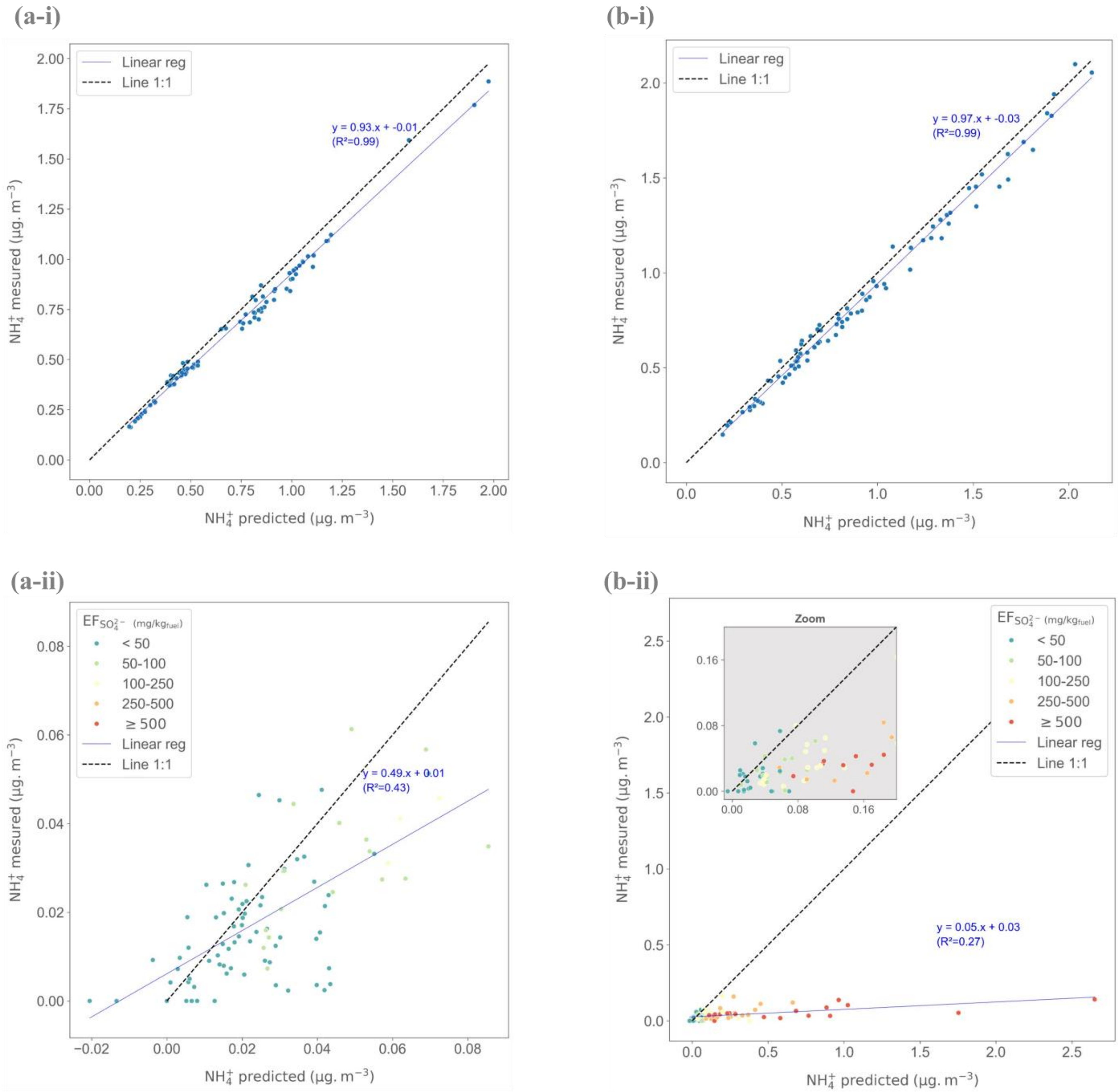



**Figure S9. Correlation between $NH_4$ measured and $NH_4$ predicted to evaluate the ion balance or neutralisation of the aerosol for (a) ships "at berth" and (b) ships "manoeuvring/navigation" during (i) the periods defining the background noise before and after each plume and (ii) the duration of the plumes (each point is coloured according to the sulphate emission factor of the plume considered).**

**Table S13. Metals - additional concentrations and contribution from shipping in plumes by operating phases. The 25th and 75th percentiles are indicated for each median value and are presented as follows median [25th percentile / 75th percentile].**

| Measured Quantity | Species | units | Operating phase | $N_{plumes}$[1] | Additional concentrations from shipping[2] | Relative contribution of shipping[3] |
|---|---|---|---|---|---|---|
| **Metals Composition ($PM_1$)** | Ca | $ng.m^{-3}$ | At berth | 22 | <DL [<DL / <DL] | - [- / -] |
| | | | In Manoeuvring/Navigation (arrival) | 27 | <DL [<DL / 2.5] | - [- / 3.7%] |
| | | | In Manoeuvring/Navigation (departure) | 20 | <DL [<DL / 4.3] | - [- / 12.2%] |
| | Fe | $ng.m^{-3}$ | At berth | 22 | <DL [<DL / <DL] | - [- / -] |
| | | | In Manoeuvring/Navigation (arrival) | 27 | 2.4 [<DL / 4.7] | 11.2% [- / 31.2%] |
| | | | In Manoeuvring/Navigation (departure) | 20 | 1.2 [<DL / 3.8] | 5.2% [- / 16.2%] |
| | K | $ng.m^{-3}$ | At berth | 22 | <DL [<DL / 1.5] | - [- / 9.5%] |
| | | | In Manoeuvring/Navigation (arrival) | 27 | <DL [<DL / 3.0] | - [- / 15.7%] |
| | | | In Manoeuvring/Navigation (departure) | 20 | <DL [<DL / 2.0] | - [- / 10.8%] |
| | Ni | $ng.m^{-3}$ | At berth | 22 | <DL [<DL / <DL] | - [- / -] |
| | | | In Manoeuvring/Navigation (arrival) | 27 | 4.4 [0.4 / 7.5] | 86.4% [10.8% / 94.3%] |
| | | | In Manoeuvring/Navigation (departure) | 20 | 2.1 [0.6 / 3.0] | 67.5% [23.5% / 91.1%] |
| | V | $ng.m^{-3}$ | At berth | 22 | <DL [<DL / <DL] | - [- / -] |
| | | | In Manoeuvring/Navigation (arrival) | 27 | 1.9 [0.4 / 8.5] | 71.8% [12.7% / 93.8%] |
| | | | In Manoeuvring/Navigation (departure) | 20 | 1.3 [0.3 / 2.1] | 58.1% [39.4% / 84.8%] |
| | Zn | $ng.m^{-3}$ | At berth | 22 | <DL [<DL / <DL] | - [- / -] |
| | | | In Manoeuvring/Navigation (arrival) | 27 | <DL [<DL / 1.0] | - [- / 13%] |
| | | | In Manoeuvring/Navigation (departure) | 20 | <DL [<DL / 0.1] | - [- / 0.8%] |

(1) $N_{plumes}$ represents the total number of plumes used as the basis for the statistical calculations; (2) statistics from the average excess concentration of each plume; (3) statistics from the relative contribution of each plume, relative to global concentrations; (4) Below detection limit (<DL).