**Air pollution impacts** **during 2020 COVID-19 pandemic: emphasis on urban, suburban and rural zones**

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**Table 1S**

Characterization of Portuguese territory

|  |  |  |  |
| --- | --- | --- | --- |
| Region | Areakm2 (%) | Populationn (%) | Population density Inhabitants km–2 |
| North | 21 286.86(23.1) | 3 575 338(34.7) | 168.0 |
| Centre | 28 199.35(30.1) | 2 217 285(21.5) | 78.6 |
| Lisbon MAa  | 3 015.24(3.3) | 2 863 272(27.8) | 949.6 |
| Alentejo | 31 604.90(34.3) | 704 558(6.8) | 22.3 |
| Algarve | 4 99.7(5.4) | 438 406(4.3) | 87.8 |
| Madeira | 801.51(0.9) | 254 254(2.5) | 317.2 |
| Azores | 2 323.96(2.5) | 242 796(2.4) | 104.6 |
| Total | 92 226 | 10 295 909  | 111.6 |

afrom January 1 2015, Lisbon and Tejo Valley Region with area of 11 633 km² (~12% of the total area) and population of 3 631 738 (~35%) was transformed to Lisbon Metropolitan Area (Law 56/2012, Law 11-A/2013). However, the Qualar system still uses the previous division, hence it was kept was this work.

**Table 2S**

Air pollution standards in ambient air (Directive 2008/50/EU)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Pollutant** | **Averaging time** | **Standard type** | **Value** | **Note/permitted exceedances** |
| PM10 | annual  | EU limit  | 40 μg m–3 | n/a |
|  | 24 h  | EU limit  | 50 μg m–3 | not to be exceeded more than 35 times in a calendar year |
| PM2.5 | annual  | EU limit | 25 μg m–3 | n/a |
| EU exposure concentration obligation | 20 μg m–3 | average exposure indicator (AEI)a in 2015 (2013-2015 average) |
| EU national exposure reduction target | 0–20% | AEIa in 2020, the percentage reduction depends on the initial AEI |
| Sulphur dioxide | 24 h | EU limit | 125 μg m–3  |  not to be exceeded more than 3 times over a calendar year |
|  | 1 h  | EU limit | 350 μg m–3 | not to be exceeded more than 24 times |
|  |  | EU alert threshold | 500 μg m–3 | to be measured over 3 consecutive hours over100 km2 or an entire zone |
| Nitrogen dioxide | annual  | EU limit | 40 μg m–3 | n/a |
|  | 1 h  | EU limit | 200 μg m–3 | not to be exceeded more than 18 times in any calendar year |
|  |  | EU alert threshold | 400 μg m–3 | to be measured over 3 consecutive hours over 100 km2 or an entire zone |
| Ozone | maximum daily 8 h mean | EU target | 120 μg m–3 | not to be exceed more than 25 days per calendar year averaged over 3 years |
|  | 1 h | EU information threshold | 180 μg m–3 |  |
|  |  | EU alert threshold | 240 μg m–3 |  |
| Carbon monoxide | maximum daily 8 h mean | EU limit | 10 mg m–3 | n/a |
| Benzene | annual | EU limit | 5 μg m–3 | n/a |
| Arsenic | annual | EU target | 6 ng m–3 | n/a |
| Cadmium | annual | EU limit | 5 ng m–3 | n/a |
| Nickel | annual | EU limit | 20 ng m–3 | n/a |
| Lead | annual | EU limit | 0.5 μg m–3 | n/a |
| Polycyclic aromatic hydrocarbonsc | annuala | EU target | 1 ng m–3  | n/a |

aAEI: based upon measurements in urban background locations established for this purpose by the Member States, assessed as a 3-year running annual mean

b Measured as content in PM10;

cexpressed as concentration of concentration of benzo(a)pyrene;

**Table 3S**

Share of transport (percentage) in main metropolitan areas (Statistics Portugal, 2018)

|  |  |  |
| --- | --- | --- |
| Mean of transport | Metropolitan Area of Oporto  | Metropolitan Area of Lisbon |
| Private car | 67.6 | 58.9 |
| Soft modes | 18.9 | 23.5 |
|  Walking |  18.5 |  23.0 |
|  Bicycle |  0.4 |  0.5 |
| Bus  | 8.2 | 8.8 |
| Train  | 2.8 | 6.3 |
| Motorcycle | 1.3 | 0.9 |
| Other (taxi, boat, etc.) | 1.2 | 1.6 |

**Table 3S**

Air pollution in different rural, suburban and urban zones of seven Portuguese regions: 2019 (January–May) descriptive statistics

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Rural** | **Suburban** | **Urban** |
|  |  |  |  |
|  | N | C | LTV | Al | Ag | Ma | Az | N | C | LTV | Al | Ag | Ma | Az | N | C | LTV | Al | Ag | Ma | Az |
| **PM10**  | 24 h means (µg m–3) |
| Mean  | 12 | 18 | 20 | 17 | 17 | 11 | 7 | 18 | 18 | 21 | 19 | – | – | – | 19 | 23 | 24 |  | 20 | 19 | – |
| Min | 2 | 1 | 2 | 5 | 5 | 2 | 2 | 2 | 2 | 7 | 5 | – | – | – | 2 | 2 | 6 |  | 1 | 1 | – |
| Max | 36 | 69 | 53 | 74 | 48 | 41 | 17 | 82 | 68 | 79 | 60 | – | – | – | 92 | 70 | 99 |  | 116 | 119 | – |
| 25th  | 8 | 9 | 12 | 12 | 12 | 6 | 4 | 12 | 10 | 13 | 12 | – | – | – | 11 | 15 | 14 |  | 10 | 11 | – |
| 50th  | 10 | 15 | 17 | 16 | 16 | 9 | 6 | 16 | 15 | 20 | 17 | – | – | – | 17 | 20 | 19 |  | 16 | 15 | – |
| 75th  | 14 | 23 | 23 | 20 | 21 | 14 | 8 | 22 | 22 | 26 | 23 | – | – | – | 23 | 27 | 28 |  | 26 | 21 | – |
| Total exceedanceN (Min-Max)a | – | 25(6-18) | 32(4-20) | 1 | – | – | – | 26(0-11) | 11 | 3– | 116 | – | – | – | 12(0-7) | 14(4-6) | 61(1-8) | – | 12(5-7) | 15(7-8) | – |
| **PM2.5** | 24 h means (µg m–3) |
| Mean  | – | 7 | 9 | 5 | 6 | 3 | 3 | – | 9 | 21 | 19 | – | – | – | 11 | 13 | 9 | 6 | 8 | 5 | – |
| Min | – | 2 | 1 | 1 | 3 | 1 | 1 | – | 1 | 7 | 5 | – | – | – | 1 | 2 | 1 | 1 | 1 | 1 | – |
| Max | – | 47 | 38 | 23 | 29 | 11 | 7 | – | 54 | 58 | 60 | – | – | – | 33 | 53 | 51 | 17 | 27 | 30 | – |
| 25th  | – | 4 | 5 | 3 | 4 | 2 | 2 | – | 3 | 13 | 12 | – | – | – | 4 | 6 | 5 | 2 | 3 | 2 | – |
| 50th  | – | 6 | 7 | 5 | 7 | 3 | 2 | – | 5 | 19,5 | 17 | – | – | – | 8 | 10 | 8 | 5 | 5 | 4 | – |
| 75th  | – | 11 | 11 | 8 | 9 | 4 | 3 | – | 10 | 26 | 23 | – | – | – | 17 | 17 | 12 | 7 | 7 | 6 | – |
| **SO2** | 1 h maximum (µg m–3)  |  |
| Mean  |  8  |  12  |  5  |  8  | 16 |  2  |  2  | 13 | 3 | 3 | 4 | – | – | – | 19 | 5 | 3 | – |  29  | 4 | – |
| Min |  3  |  1  |  1  |  1  | 2 |  1  |  1  | 2 | 2 | 1 | 1 | – | – | – | 4 | 1 | 1 | – |  25  | 1 | – |
| Max |  23  |  44  |  26  |  12  | 32 |  5  |  4  | 55 | 12 | 20 | 13 | – | – | – | 212 | 65 | 18 | – |  34  | 28 | – |
| 25th  |  7  |  4  |  2  |  3  | 10 |  2  |  2  | 6 | 2 | 2 | 3 | – | – | – | 6 | 2 | 2 | – |  27  | 2 | – |
| 50th  |  8  |  10  |  3  |  8  | 18 |  2  |  2  | 7 | 2 | 2 | 3 | – | – | – | 7 | 3 | 3 | – |  28  | 3 | – |
| 75th  |  9  |  18  |  5  |  9  | 23 |  3  |  3  | 15 | 3 | 3 | 4 | – | – | – | 13 | 7 | 4 | – |  30  | 5 | – |
| Exceedance 24hn (Min-Max)a | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 3(0-3) | – | – | – | – | – | – |
| Exceedance 1h n (Min-Max)a | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **NO2** | 1 h maximum (µg m–3)  |  |
| Mean  | 16 | 15 | 23 | 12 | 9 | 4 | 3 | 64 | 32 | 45 | 33 | – | – | – | 74 | 58 | 56 | – | 37 | 45 | – |
| Min | 1 | 1 | 4 | 2 | 1 | 1 | 2 | 8 | 5 | 8 | 2 | – | – | – | 5 | 6 | 2 | – | 1 | 2 | – |
| Max | 39 | 58 | 52 | 20 | 14 | 56 | 13 | 175 | 91 | 102 | 105 | – | – | – | 228 | 166 | 231 | – | 129 | 147 | – |
| 25th  | 10 | 6 | 19 | 4 | 5 | 2 | 2 | 34 | 20 | 26 | 6 | – | – | – | 35 | 20 | 19 | – | 4 | 7 | – |
| 50th  | 25 | 11 | 26 | 8 | 7 | 3 | 2 | 58 | 28 | 41 | 20 | – | – | – | 62 | 53 | 39 | – | 32 | 34 | – |
| 75th  | 30 | 29 | 31 | 16 | 8 | 5 | 3 | 90 | 39 | 63 | 62 | – | – | – | 109 | 90 | 72 | – | 60 | 79 | – |
| Exceedance 24hn (Min-Max)a | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 4(0-2) | – | 5(0-2) | – |  |  | – |
| **O3** | 1 h maximum (µg m–3)  |
| Mean  | 74 | 86 | 89 | 95 | 104 | 88 | 84 | 62 | 78 | 86 | 90 | – | – | – | 67 | 70 | 85 | – | 102 | 101 |  |
| Min | 19 | 29 | 14 | 42 | 61 | 47 | 43 | 11 | 11 | 31 | 55 | – | – | – | 11 | 21 | 11 | – | 57 | 66 |  |
| Max | 183 | 144 | 166 | 136 | 147 | 137 | 118 | 115 | 134 | 139 | 140 | – | – | – | 179 | 116 | 145 | – | 154 | 154 |  |
| 25th  | 56 | 78 | 72 | 87,25 | 89,25 | 78 | 74 | 48 | 63 | 75 | 75,25 | – | – | – | 52 | 59 | 72 | – | 91 | 88 |  |
| 50th  | 75 | 88 | 88 | 95 | 103 | 88 | 88 | 61 | 80,5 | 87 | 92 | – | – | – | 64 | 69 | 85 | – | 105 | 97 |  |
| 75th  | 89 | 97 | 99 | 104 | 115 | 99 | 97 | 74 | 92 | 98 | 103 | – | – | – | 79 | 80 | 98 |  | 116 | 112 |  |
| Exceedance 1h alert | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |

Abbreviation: N=North, C= Centre, LTV=Lisbon and Tejo Valley, Ag= Algarve, Aj= Alentejo, M= Madeira, Az=Azores

Note: aMinimal and maximal number of limit exceedances registered per individual monitoring station

**Table 4S**

Air pollution in different rural, suburban and urban zones of seven Portuguese regions: 2020 (January–May) descriptive statistics

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Rural** | **Suburban** | **Urban** |
|  |  |  |  |
|  | N | C | LTV | Al | Ag | Ma | Az | N | C | LTV | Al | Ag | Ma | Az | N | C | LTV | Al | Ag | Ma | Az |
| **PM10**  | 24 h means (µg m–3) |
| Mean  | 8 | 13 | 15 | 17 | 10 | 14 | 10 | 21 | 24 | 22 | 17 | – | – | – | 19 | 18 | 19 | – | 25 | 18 | – |
| Min | 2 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 4 | 2 | – | – | – | 2 | 2 | 3 | – | 2 | 2 | – |
| Max | 35 | 100 | 51 | 83 | 94 | 111 | 34 | 68 | 90 | 75 | 118 | – | – | – | 84 | 67 | 66 | – | 166 | 121 | – |
| 25th  | 5 | 5 | 9 | 7 | 4 | 7 | 6 | 12 | 14 | 14 | 11 | – | – | – | 11 | 11 | 12 | – | 13 | 10 | – |
| 50th  | 8 | 10 | 14 | 10 | 7 | 11 | 8 | 21 | 22 | 19 | 15 | – | – | – | 17 | 16 | 17 | – | 19 | 14 | – |
| 75th  | 10 | 17 | 19 | 19 | 11 | 16 | 13 | 27 | 29 | 28 | 21 | – | – | – | 24 | 24 | 24 | – | 28 | 20 | – |
| Total exceedanceN (Min-Max)a | 0 | 3(1-2) | 1– | 3(1-1) | 3– | 3– | 0 | 9(1-4) | 19(9-10) | 8– | 1– | – | – | – | 9(1-4) | 11(2-7) | 27(1-4) | – | 22(3-16) | 15(6-9) | – |
| **PM2.5** | 24 h means (µg m–3) |
| Mean  | – | 7 | 7 | 4 | 6 | 4 | 6 | – | 12 | 12 | 6 | – | – | – | 6 | 13 | 11 | 6 | 8 | 5 | – |
| Min | – | 1 | 1 | 1 | 1 | 1 | 1 | – | 2 | 3 | 1 | – | – | – | 1 | 2 | 1 | 1 | 3 | 1 | – |
| Max | – | 36 | 23 | 19 | 26 | 32 | 29 | – | 56 | 63 | 25 | – | – | – | 19 | 53 | 38 | 17 | 23 | 30 | – |
| 25th  | – | 3 | 3 | 2 | 4 | 2 | 4 | – | 5 | 6 | 3 | – | – | – | 2 | 6 | 6 | 2 | 5 | 3 | – |
| 50th  | – | 5 | 6 | 4 | 5 | 3 | 5 | – | 10 | 10 | 5 | – | – | – | 4 | 10 | 9 | 5 | 8 | 4 | – |
| 75th  | – | 10 | 9 | 6 | 7 | 5 | 7 | – | 15 | 13 | 8 | – | – | – | 9 | 17 | 14 | 7 | 10 | 7 | – |
| **SO2** | 1 h maximum (µg m–3)  |  |
| Mean  |  10  |  3  |  6  |  4  |  5  |  1  |  3  | 23 | 6 | 6 | 3 | – | – | – | 18 | – |  3  | – |  15  | 5 | – |
| Min |  5  |  1  |  1  |  2  |  2  |  1  |  1  | 2 | 1 | 1 | 2 | – | – | – | 2 | – |  1  | – |  14  | 1 | – |
| Max |  18  |  6  |  92  |  5  |  8  |  3  |  9  | 150 | 17 | 47 | 4 | – | – | – | 55 | – |  25  | – |  16  | 32 | – |
| 25th  |  6  |  2  |  3  |  3  |  3  |  1  |  2  | 10 | 3 | 3 | 2 | – | – | – | 10 | – |  2  | – |  15  | 2 | – |
| 50th  |  10  |  3  |  5  |  3  |  5  |  1  |  3  | 12 | 5 | 5 | 3 | – | – | – | 11 | – |  3  | – |  15  | 3 | – |
| 75th  |  14  |  4  |  7  |  4  |  6  |  2  |  4  | 36 | 8 | 7 | 3 | – | – | – | 30 | – | 4 | – |  15  | 5 | – |
| Exceedance 24hn (Min-Max)a | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – | 0) | – | – | – | – | – | – |
| Exceedance 1h n (Min-Max)a | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **NO2** | 1 h maximum (µg m–3)  |  |
| Mean  | 10 | 6 | 9 | 5 | 2 | 4 | 3 | 64 | 17 | 37 | 14 | – | – | – | 53 | 38 | 43 | – | 29 | 52 |  |
| Min | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 8 | 5 | 8 | 1 | – | – | – | 6 | 5 | 4 | – | 1 | 3 |  |
| Max | 22 | 39 | 51 | 20 | 15 | 24 | 9 | 175 | 73 | 100 | 66 | – | – | – | 187 | 121 | 200 | – | 105 | 144 |  |
| 25th  | 5 | 3 | 6 | 3 | 1 | 2 | 2 | 34 | 10 | 22 | 6 | – | – | – | 27 | 21 | 20 | – | 11 | 29 |  |
| 50th  | 10 | 5 | 8 | 4 | 1 | 3 | 2 | 58 | 14 | 30 | 12 | – | – | – | 46 | 33 | 36 | – | 22 | 54 |  |
| 75th  | 13 | 7 | 13 | 6 | 2 | 5 | 3 | 90 | 21 | 50 | 19 | – | – | – | 70 | 52 | 59 | – | 45 | 81 |  |
| Exceedance 24hn (Min-Max)a | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |  |
| **O3** | 1 h maximum (µg m–3)  |
| Mean  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Min |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Max |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 25th  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 50th  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 75th  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Exceedance 1h alert | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |

Abbreviation: N=North, C= Centre, LTV=Lisbon and Tejo Valley, Ag= Algarve, Aj= Alentejo, M= Madeira, Az=Azores

Note: aMinimal and maximal number of limit exceedances registered per individual monitoring station

**Figure 1S**

Portuguese air pollution monitoring network: abundance of zone- and emission influence-specific monitoring sites. Note: The territory is composed of five regions for continental Portugal (North, Centre, Lisbon and Tejo Valley, Alentejo, and Algarve) and two in Portuguese islands (Madeira, and Azores).

Note: the specific definition of the monitoring site si located in close proximity to a single major road; • industrial stations — located in close proximity to an industrial area or an industrial source; • background stations — pollution levels are representative of the average exposure of the general population or vegetation. Depending on the distribution/density of buildings, the area surrounding the station is classified as follows: • urban — continuously built-up urban area; • suburban — largely built-up urban area; • rural — all other areas.

**Figure 2S**

System of motorways in Continental Portugal. Note: System of motorways in Portugal includes 3087 km. There are 15 principal motorways (A1–A8, A13, A17, A22– A25, A35) and 14 secondary ones. The urban motorways include 23 connections (12 for Lisbon Metropolitan Area, 8 for Oporto Metropolitan Area, and 3 for cities of Coimbra, Leiria and Pombal (Infraestruturas de Portugal, 2020).

 

**Figure 3S**

Quarterly evolution of average daily traffic (motorways) in Portugal (BCR, 2020a, 2020b).

**Figure 4S**

Composition of traffic (on motorways) in Portugal (BCR, 2020a, 2020b): (a) in 2019, and (b) 2020.

|  |  |
| --- | --- |
|  |  |
| (a) | (b) |

Note: 2020 data are based on evaluation of the 1st quarter(Q1).

**Figure 5S**

Assessment of traffic related PM2.5 in Portugal: (a) monthly (January – May) evolution in 2019 (continuous line) and 2020 (dashed line); (b) representation of concentration changes in 2020 *vs.* 2019. Note: 22 urban/traffic monitoring stations were considered but no PM2.5 data exited for in 2020 for Centre and Algarve regions in 2020, and North (both years).

(a)

(b)

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