Status report of air quality in Europe for year 2021, using validated and up-to-date data

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1 Summary

The 2021 Status report of air quality in Europe presents summarized information on the air quality data for the protection of health reported in the previous years. The reported 2021 data used in this analysis was reported as up-to-date (UTD) data, prior to final quality control and validated data reporting by the countries(1). It provides information on the following pollutants, regulated by the Ambient Air Quality Directives:

- \( \text{PM}_{10} \): Particulate matter with a diameter of 10 \( \mu \text{m} \) or less
- \( \text{PM}_{2.5} \): Particulate matter with a diameter of 2.5 \( \mu \text{m} \) or less
- \( \text{O}_3 \): Tropospheric ozone
- \( \text{NO}_2 \): Nitrogen dioxide
- \( \text{SO}_2 \): Sulphur dioxide

It also offers a comparison with the situation in the previous three years. For those years, validated data are considered.

Data included in this report was received by 24 March 2022 from the reporting countries. By that date the reporting status of 2021 up-to-date data is summarized in Figure 1, where a green box indicates that the referred pollutant was reported by the referred country and a grey box indicates the contrary (that the referred pollutant was not reported by the referred country). Please see editorial notes at the end of this Chapter on additional information on the data used.

The number of stations by country reporting each pollutant is summarized in Table 3.

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The countries included in Figure 1 are the EU-27 (Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain and Sweden); the five other member countries of the EEA (Iceland, Liechtenstein, Norway, Switzerland and Turkey) that, together with the EU-27 form the EEA-32; the six EEA’s cooperating countries from the Western Balkans (Albania, Bosnia and Herzegovina, Kosovo under UN Security Council Resolution 1244/99, Montenegro, North Macedonia and Serbia) that, together with the EEA-32 form the EEA-38; and the voluntary reporting country of Andorra.

The air quality data are stored (UTD data only temporarily) at the EEA’s e-reporting database (\(^2\)). Therefore, this is the source for all maps and figures in the report.

1.1 Particulate matter

For PM\(_{10}\), concentrations above the EU daily limit value (50 µg/m\(^3\)) were registered at 11% of the reporting stations in 12 countries in EU-27 and in four other reporting countries. For PM\(_{2.5}\),

\(^2\)https://discomap.eea.europa.eu/map/fme/AirQualityExport.htm
concentrations above the annual limit value (25 μg/m³) were registered at 2 % of the reporting stations in three countries in EU-27 and three other reporting countries.

The long-term world health organization air quality guidelines (WHO AQG) for PM$_{10}$ (15 μg/m³) was exceeded at 66 % of the stations in 24 countries of the EU-27 and 7 other reporting countries. The long-term WHO AQG for PM$_{2.5}$ (5 μg/m³) was exceeded at 94 % of the stations located in 23 countries of the EU-27 and 7 other reporting countries.

1.2 Ozone

9 % of stations registered concentrations above the EU O$_{3}$ target value (120 μg/m³) for the protection of human health. These stations were located in 16 countries of the EU-27 and four other reporting European countries. The long-term EU objective (120 μg/m³) was met in only 19 % of the stations. The short-term WHO AQG for O$_{3}$ (100 μg/m³) was exceeded in 92 % of all the reporting stations, and 98 % of stations registered concentrations above the long-term WHO AQG for O$_{3}$ (60 μg/m³).

1.3 Nitrogen dioxide

Around 1 % of all the reporting stations recorded concentrations above the annual limit value for NO$_{2}$ (40 μg/m³). These stations were located in 7 countries of the EU-27 and one other reporting countries. 100 % of concentrations above this limit value were observed at traffic stations.

On the contrary, 73 % of stations, located in 27 countries of the EU-27 and eight other reporting countries reported concentrations above the WHO AQG level of 10 μg/m³.

1.4 Sulphur dioxide

Only 14 stations (out of more than 1178) in two countries of the EU-27 and one other reporting countries measured values for SO$_{2}$ above the EU daily limit value (125 μg/m³). However, 4 % of all SO$_{2}$ stations, located in 13 reporting countries, measured SO$_{2}$ concentrations above the daily WHO AQG (40 μg/m³).
1.5 Editorial note

France informed that a measurement change for PM$_{10}$ was introduced in 2007, and that the number of PM$_{2.5}$ stations before 2008 was low. Both issues could affect the comparability over the years shown in the heatmaps.

Italy informed that the values of NO$_2$ and SO$_2$ from station IT2090A, Schiavonea are wrong.
2 Introduction

The 2021 Status report of air quality in Europe presents summarized information on the air quality data reported in the previous years. 2021 data was reported as up-to-date (UTD) data in a continuous basis prior to final quality control and official reporting of validated data by the countries, which will be done under the 2022 September reporting cycle (validated assessment data for 2021, deadline of submission 30 September 2022). It aims at informing on the current status of ambient air quality in Europe, based on the most updated data available for the analysis of a complete calendar year. Furthermore, it informs on progress towards meeting the air quality standards established for the protection of health in the Ambient Air Quality Directive (EU, 2008) (Table 1) and the World Health Organization (WHO) air quality guidelines (WHO, 2000, 2006, 2021) (Table 2)(3).

This report builds on the former EEA “Air quality in Europe report” (EEA, 2020) content, figures and maps regarding the status of monitored air quality in Europe. The report focuses on the analysis of the main pollutants, to allow a meaningful preliminary analysis of their concentration status in Europe. It provides:

- a European overview of the monitoring stations that reported UTD 2021 data, and of their concentrations in relation to the EU legal standards and WHO AQGs for each pollutant;
- a map with the 2021 UTD concentrations at station level for each pollutant;
- a boxplot graph summarizing for each country the range of concentrations (highlighting the lowest, highest, average and the 25 and 75 percentiles) for PM$_{10}$, PM$_{2.5}$, NO$_2$ and O$_3$.

Furthermore, it provides:

- maps with the situation at station level for the previous three years (using validated data). In this way, any significant change in the spatial distribution of the values above the set thresholds in the legends can be observed (assuming the UTD stations dataset is complete);

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3 Nevertheless, in this report the following standards and guidelines are not analysed: information and alert thresholds for O$_3$, alert threshold for NO$_2$, annual target value for BaP, alert threshold for SO$_2$, limit value for CO maximum daily 8-hour mean, annual limit value for C$_6$H$_6$, annual limit value for Pb, target value for As, target value for Cd, and target value for Ni in Table 1; and hourly air quality guideline for NO$_2$, reference level for annual mean of BaP, 10 minutes air quality guideline for SO$_2$, air quality guidelines for CO, reference level for annual mean of C$_6$H$_6$, air quality guideline for Pb, reference level for annual mean of As, air quality guideline for Cd, and reference level for annual mean of Ni in Table 2.
heatmaps with the evolution of the mean and the maximum measured concentrations at
country level since 2000 (using validated data for all years up to 2020).

Please be aware that the number of stations can vary once the validated dataset for 2021
is received by 30 September 2022. In some figures like the boxplots, the final order of the
countries may vary once the validated data are submitted.
<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Averaging period</th>
<th>Legal nature and concentration</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM₁₀</td>
<td>1 day</td>
<td>Limit value: 50 µg/m³</td>
<td>Not to be exceeded on more than 35 days per year</td>
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<tr>
<td>Calendar year</td>
<td>Limit value: 40 µg/m³</td>
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<td></td>
</tr>
<tr>
<td>PM₂.₅</td>
<td>Calendar year</td>
<td>Limit value: 25 µg/m³</td>
<td>Stage 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Indicative limit value: 20 µg/m³</td>
<td>Stage 2: indicative limit value to be reviewed by the Commission in 2013. It remained unchanged after that revision</td>
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<td></td>
<td></td>
<td>Exposure concentration obligation: 20 µg/m³</td>
<td>Average Exposure Indicator (AEI) (a) in 2015 (2013-2015 average)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>National Exposure reduction target: 0-20 percentage reduction in exposure AEI (b) in 2020, the percentage reduction depends on the initial AEI</td>
<td></td>
</tr>
<tr>
<td>O₃</td>
<td>Maximum daily 8-hour mean</td>
<td>Target value: 120 µg/m³</td>
<td>Not to be exceeded on more than 25 days/year, averaged over 3 years (b)</td>
</tr>
<tr>
<td></td>
<td>1 hour</td>
<td>Information threshold: 180 µg/m³</td>
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<tr>
<td></td>
<td></td>
<td>Alert threshold: 240 µg/m³</td>
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</tr>
<tr>
<td></td>
<td>Long term objective: 120 µg/m³</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NO₂</td>
<td>1 hour</td>
<td>Limit value: 200 µg/m³</td>
<td>Not to be exceeded on more than 18 hours per year</td>
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<td></td>
<td></td>
<td>Alert threshold: 400 µg/m³</td>
<td>To be measured over 3 consecutive hours over 100 km² or an entire zone</td>
</tr>
<tr>
<td>Calendar year</td>
<td>Limit value: 40 µg/m³</td>
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<td></td>
</tr>
<tr>
<td>BaP</td>
<td>Calendar year</td>
<td>Target value: 1 ng/m³</td>
<td>Measured as content in PM₁₀</td>
</tr>
<tr>
<td>SO₂</td>
<td>1 hour</td>
<td>Limit value: 350 µg/m³</td>
<td>Not to be exceeded on more than 24 hours per year</td>
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<td></td>
<td></td>
<td>Alert threshold: 500 µg/m³</td>
<td>To be measured over 3 consecutive hours over 100 km² or an entire zone</td>
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<td>1 day</td>
<td>Limit value: 125 µg/m³</td>
<td>Not to be exceeded on more than 3 days per year</td>
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<tr>
<td>CO</td>
<td>Maximum daily 8-hour mean</td>
<td>Limit value: 10 mg/m³</td>
<td></td>
</tr>
<tr>
<td>C₆H₆</td>
<td>Calendar year</td>
<td>Limit value: 5 µg/m³</td>
<td>Measured as content in PM₁₀</td>
</tr>
<tr>
<td>Pb</td>
<td>Calendar year</td>
<td>Limit value: 0.5 µg/m³</td>
<td>Measured as content in PM₁₀</td>
</tr>
<tr>
<td>As</td>
<td>Calendar year</td>
<td>Target value: 6 ng/m³</td>
<td>Measured as content in PM₁₀</td>
</tr>
<tr>
<td>Cd</td>
<td>Calendar year</td>
<td>Target value: 5 ng/m³</td>
<td>Measured as content in PM₁₀</td>
</tr>
<tr>
<td>Ni</td>
<td>Calendar year</td>
<td>Target value: 20 ng/m³</td>
<td>Measured as content in PM₁₀</td>
</tr>
</tbody>
</table>

**Notes:**

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

b In the context of this report, only the maximum daily 8-hour means in 2021 are considered, so no average over the period 2019 - 2021 is presented.

**Sources:**

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Averaging period</th>
<th>AQG</th>
<th>RL</th>
<th>Comments</th>
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<td>PM\textsubscript{2.5}</td>
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<td>45 (\mu g/m^3)</td>
<td>99th percentile (3-4 exceedance days per year). Updated 2021 guideline</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Calendar year</td>
<td>15 (\mu g/m^3)</td>
<td>Updated 2021 guideline</td>
<td></td>
</tr>
<tr>
<td>PM\textsubscript{2.5}</td>
<td>1 day</td>
<td>15 (\mu g/m^3)</td>
<td>99th percentile (3-4 exceedance days per year). Updated 2021 guideline</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Calendar year</td>
<td>5 (\mu g/m^3)</td>
<td>Updated 2021 guideline</td>
<td></td>
</tr>
<tr>
<td>O\textsubscript{3}</td>
<td>Maximum daily 8-hour mean</td>
<td>100 (\mu g/m^3)</td>
<td>99th percentile (3-4 exceedance days per year). New 2021 guideline</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Peak season (^{(b)})</td>
<td>60 (\mu g/m^3)</td>
<td>New 2021 guideline</td>
<td></td>
</tr>
<tr>
<td>NO\textsubscript{2}</td>
<td>1 hour</td>
<td>200 (\mu g/m^3)</td>
<td>99th percentile (3-4 exceedance days per year). New 2021 guideline</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 day</td>
<td>25 (\mu g/m^3)</td>
<td>New 2021 guideline</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Calendar year</td>
<td>10 (\mu g/m^3)</td>
<td>Updated 2021 guideline</td>
<td></td>
</tr>
<tr>
<td>BaP</td>
<td>Calendar year</td>
<td>0.12 (\mu g/m^3)</td>
<td></td>
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</tr>
<tr>
<td>SO\textsubscript{2}</td>
<td>10 minutes</td>
<td>500 (\mu g/m^3)</td>
<td>99th percentile (3-4 exceedance days per year). New 2021 guideline</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 day</td>
<td>40 (\mu g/m^3)</td>
<td>New 2021 guideline</td>
<td></td>
</tr>
<tr>
<td>CO</td>
<td>1 hour</td>
<td>30 (mg/m^3)</td>
<td>99th percentile (3-4 exceedance days per year). New 2021 guideline</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maximum daily 8-hour mean</td>
<td>10 (mg/m^3)</td>
<td>New 2021 guideline</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 day</td>
<td>4 (mg/m^3)</td>
<td>New 2021 guideline</td>
<td></td>
</tr>
<tr>
<td>C\textsubscript{6}H\textsubscript{6}</td>
<td>Calendar year</td>
<td>1.7 (\mu g/m^3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pb</td>
<td>Calendar year</td>
<td>0.5 (\mu g/m^3)</td>
<td></td>
<td></td>
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<tr>
<td>As</td>
<td>Calendar year</td>
<td>6.6 (\mu g/m^3)</td>
<td></td>
<td></td>
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<tr>
<td>Cd</td>
<td>Calendar year</td>
<td>5 (ng/m^3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ni</td>
<td>Calendar year</td>
<td>25 (ng/m^3)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**

\(^{(a)}\) As WHO has not set an AQG for BaP, C\textsubscript{6}H\textsubscript{6}, As and Ni, the RL was estimated assuming an acceptable risk of additional lifetime cancer risk of approximately 1 in 100 000.

\(^{(b)}\) Average of daily maximum 8-hour mean concentration in the six consecutive months with the highest six-month running average O\textsubscript{3} concentration.

\(^{(c)}\) AQG set to prevent any further increase of Cd in agricultural soil, likely to increase the dietary intake of future generations.

**Sources:**

Box 1.1 Classification of monitoring stations

Fixed sampling points in Europe are situated at different types of stations following rules for macro- and micro-scale siting. Briefly, depending on the predominant emission sources, stations are classified as follows:

- traffic stations: 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: where 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.

For most of the pollutants, monitoring stations have to fulfil the criterion of reporting more than 75% of valid data out of all the possible data in a year to be included in this assessment. Reporting stations not fulfilling the minimum data coverage could be found at the Annual AQ statistics table. Measurement data are rounded following the general recommendations under (EU, 2011). The number of considered decimals are indicated in the legend of the corresponding maps.

The assessments, in the cases of PM and SO$_2$, do not account for the fact that the Ambient Air Quality Directive (EU, 2008) provides Member States with the possibility of subtracting contributions to the measured concentrations from natural sources and winter road sanding/salting under specific circumstances.
3 Status of particulate matter ambient air concentrations

3.1 Status of PM$_{10}$ concentrations

The EEA received PM$_{10}$ data for 2021, with sufficient valid measurements from 2253 stations for the calculation of annual mean concentrations and from 2250 stations in relation to the daily limit value. The stations were located in all the reporting countries shown in Figure 1.

Twelve countries in EU-27, and four other reporting countries reported PM$_{10}$ concentrations above the EU daily limit value of 50 µg/m$^3$ (Figure 2). This was the case for 11 % (240) of reporting stations. In total, 96 % of those stations were either urban (82 %) or suburban (14 %). The stricter value of the WHO AQG for PM$_{10}$ daily mean (45 µg/m$^3$) was exceeded at 67 % (1514) of the stations in all the reporting countries (Figure 8).

Concentrations above the PM$_{10}$ annual limit value (40 µg/m$^3$) were monitored in 1 % (24 stations) of all the reporting stations, located in 5 countries in EU-27, and 3 other reporting countries. The stricter value of the WHO AQG for PM$_{10}$ annual mean (15 µg/m$^3$) was exceeded at 66 % (1486) of the stations in all the reporting countries, except in Iceland (Figure 5).
Figure 2: UTD Map and boxplot of PM$_{10}$ concentrations in 2021 - daily limit value

Note: Observed concentrations of PM$_{10}$ in 2021. The possibility of subtracting contributions to the measured concentrations from natural sources and winter road sanding/salting has not been considered. The map shows the 90.4 percentile of the PM$_{10}$ daily mean concentrations, representing the 36th highest value in a complete series. It is related to the PM$_{10}$ daily limit value, allowing 35 exceedances of the 50 µg/m$^3$ threshold over 1 year. The last two colour categories indicate stations with concentrations above this daily limit value. Only stations with more than 75% of valid data, and more than 14% in the case of fixed random measurements, have been included in the map.

The graph is based, for each country, on the 90.4 percentile of daily mean concentration values corresponding to the 36th highest daily mean. For each country, the number of stations considered (in brackets) and the lowest, highest and average 90.4 percentile values (in µg/m$^3$) recorded at its stations are given. The rectangles mark the 25th and 75th percentiles. At 25% of the stations, levels are below the lower percentile; at 25% of the stations, concentrations are above the upper percentile. The daily limit value set by EU legislation is marked by the horizontal line. The graph should be read in relation to the above map, as a country’s situation depends on the number of stations considered.
Figure 3 shows the maps of the 90.4 percentile of PM$_{10}$ daily mean concentrations (equivalent to the PM$_{10}$ daily limit value) for four years. In this way, any significant change in the spatial distribution of the values above the set thresholds in the legends can be observed. Note that only the last year’s map (2021) is based on UTD data, while the previous three years are based on officially reported validated data (CDR).

*Figure 3: Maps of PM$_{10}$ concentrations (daily limit value) for the last 4 years*

Heatmaps with the evolution from 2000 of the mean (top) and the maximum (bottom) 90.4 percentile of PM$_{10}$ daily mean concentrations at country level are shown in figure 4. In this way, the evolution along years of the average and maximum measured concentration levels can be seen for each country. Note that meteorological variability has a considerable impact on year-to-year changes in ambient air concentrations of air pollutants (EEA, 2020), and the last year (2021) is based on UTD data, while the previous years are based on officially reported validated data.
Note: It is important to note that the figure is not based on a consistent set of stations. The number, location and classification of the stations included may vary from year to year.
Note: Observed concentrations of PM10 in 2021. The possibility of subtracting contributions to the measured concentrations from natural sources and winter road sanding/salting has not been considered. The last two colour categories indicate stations reporting concentrations above the EU annual limit value (40 µg/m³). The first colour category indicate stations reporting values below the WHO AQG for PM10 (15 µg/m³). Only stations with more than 75% of valid data, and more than 14% in the case of fixed random measurements, have been included in the map.

Note: The graph is based on annual mean concentration values. For each country, the number of stations considered (in brackets) and the lowest, highest and average values (in µg/m³) recorded at its stations are given. The rectangles mark the 25th and 75th percentiles. At 25% of the stations, levels are below the lower percentile; at 25% of the stations, concentrations are above the upper percentile. The annual limit value set by EU legislation is marked by the upper continuous horizontal line. The WHO AQG is marked by the lower dashed horizontal line. The graph should be read in relation to the above map, as a country’s situation depends on the number of stations considered.
Figure 6 shows the maps of PM$_{10}$ annual mean concentrations at station level for the last four years. In this way, any significant change in the spatial distribution of the values above the set thresholds in the legends can be observed. Note that only the last year’s map (2021) is based on UTD data, while the previous three years are based on officially reported validated data (CDR).

*Figure 6: Maps of PM$_{10}$ concentrations (annual limit value) for the last 4 years*

Maps for years before 2020 are different to the ones published in previous reports because the bands in the legend have been modified to accommodate the 2021 WHO AQG level.

Heatmaps with the evolution from 2000 of the mean (top) and the maximum (bottom) annual mean PM$_{10}$ concentrations at country level are shown in figure 7. In this way, the evolution along years of the average and maximum measured concentration levels can be seen for each country. Note that meteorological variability has a considerable impact on year-to-year changes in ambient air concentrations of air pollutants (EEA, 2020), and the last year (2021) is based on UTD data, while the previous years are based on officially reported validated data.
Figure 7: Evolution of mean (top) and maximum (bottom) PM$_{10}$ annual mean concentrations (annual limit value) per country from 2000

Note: It is important to note that the figure is not based on a consistent set of stations. The number, location and classification of the stations included may vary from year to year.
Note: Observed concentrations of PM10 in 2021. The map shows the 99 percentile of the PM10 daily mean concentrations, equivalent to 3−4 exceedance days per year, according to the definition of the daily WHO AQG level (45 µg/m³). The first colour category indicates stations with concentrations below this AQG level. Only stations with more than 75 % of valid data, and more than 14 % in the case of fixed random measurements, have been included in the map.
Figure 9 shows the maps of the 99 percentile of PM$_{10}$ daily mean concentrations (equivalent to the WHO AQG for PM$_{10}$ daily mean level) for the last four years. In this way, any significant change in the spatial distribution of the values above the set thresholds in the legends can be observed. Note that only the last year’s map (2021) is based on UTD data, while the previous three years are based on officially reported validated data (CDR).

**Figure 9: Maps of PM$_{10}$ concentrations (daily WHO AQG level) for the last 4 years**

Heatmaps with the evolution from 2013 of the mean (top) and the maximum (bottom) 99 percentile of PM$_{10}$ daily mean concentrations at country level are shown in figure 10. In this way, the evolution along years of the average and maximum measured concentration levels can be seen for each country. Note that meteorological variability has a considerable impact on year-to-year changes in ambient air concentrations of air pollutants (EEA, 2020), and the last year (2021) is based on UTD data, while the previous years are based on officially reported validated data.
Figure 10: Evolution of mean (top) and maximum (bottom) 99 percentile of PM$_{10}$ daily mean concentrations (daily WHO AQG level) per country from 2013

Note: It is important to note that the figure is not based on a consistent set of stations. The number, location and classification of the stations included may vary from year to year.
3.2 Status of PM$_{2.5}$ concentrations

Regarding PM$_{2.5}$, data with sufficient valid measurements were received from 1248 stations for the calculation of annual mean concentrations and from 1246 stations in relation to the short-term WHO AQG. These stations were located in all the reporting countries shown in Figure 1.

The PM$_{2.5}$ concentrations were higher than the annual limit value (25 µg/m$^3$) in three countries in EU-27 and three other reporting countries (Figure 11). These concentrations above the limit value were registered in 2 % of all the reporting stations and occurred primarily (100 % of cases) in urban (70 %) or suburban (30 %) areas.

The WHO AQG for PM$_{2.5}$ annual mean (5 µg/m$^3$) was exceeded at 94 % of the stations, located in 30 of the 30 countries reporting PM$_{2.5}$ data (Figure 11).

Although the EU has not set any short-term standard for PM$_{2.5}$, the WHO defined in 2021 a daily AQG level of 15 µg/m$^3$, expressed as percentile 99. It was exceeded at 98 % (1224 stations) of the stations in all the reporting countries (Figure 14).
Figure 11: UTD Map and boxplot of PM$_{2.5}$ concentrations in 2021 - annual limit value

Note: Observed concentrations of PM$_{2.5}$ in 2021. The possibility of subtracting contributions to the measured concentrations from natural sources and winter road sanding/salting has not been considered. The last two colour categories indicate stations reporting concentrations above the EU indicative annual limit value (20 µg/m$^3$) or the EU annual limit value (25 µg/m$^3$). The first colour category indicates stations reporting values below the WHO AQG for PM$_{2.5}$ (5 µg/m$^3$). Only stations with more than 75% of valid data, and more than 14% in the case of fixed random measurements, have been included in the map.

Note: The graph is based on annual mean concentration values. For each country, the number of stations considered (in brackets) and the lowest, highest and average values (in µg/m$^3$) recorded at its stations are given. The rectangles mark the 25th and 75th percentiles. At 25% of the stations, levels are below the lower percentile; at 25% of the stations, concentrations are above the upper percentile. The annual limit value and the indicative annual limit value set by EU legislation are marked by the upper continuous horizontal lines at 25 and 20, respectively. The WHO AQG is marked by the lower dashed horizontal line. The graph should be read in relation to the above map, as a country’s situation depends on the number of stations considered.
Figure 12 shows the maps of measured PM$_{2.5}$ annual mean concentrations for the last four years. In this way, any significant change in the spatial distribution of the values above the set thresholds in the legends can be observed. Note that only the last year’s map (2021) is based on UTD data, while the previous three years are based on officially reported validated data (CDR).

Maps for years before 2020 are different to the ones published in previous reports because the bands in the legend have been modified to accommodate the 2021 WHO AQG level.

Heatmaps with the evolution from 2000 of the mean (top) and the maximum (bottom) PM$_{2.5}$ annual mean concentrations at country level are shown in figure 13. In this way, the evolution along years of the average and maximum measured concentration levels can be seen for each country. Note that meteorological variability has a considerable impact on year-to-year changes in ambient air concentrations of air pollutants (EEA, 2020), and the last year (2021) is based on UTD data, while the previous years are based on officially reported validated data.
Figure 13: Evolution of mean (top) and maximum (bottom) PM$_{2.5}$ annual mean concentrations (annual limit value) per country from 2000

Note: It is important to note that the figure is not based on a consistent set of stations. The number, location and classification of the stations included may vary from year to year.
Figure 14: UTD Map of PM$_{2.5}$ concentrations in 2021 - daily WHO AQG level

Note: Observed concentrations of PM$_{2.5}$ in 2021. The map shows the 99 percentile of the PM$_{2.5}$ daily mean concentrations, equivalent to 3–4 exceedance days per year, according to the definition of the daily WHO AQG level (15 µg/m$^3$). The first colour category indicates stations with concentrations below this AQG level. Only stations with more than 75 % of valid data, and more than 14 % in the case of fixed random measurements, have been included in the map.
Figure 15 shows the maps of the 99 percentile of PM$_{2.5}$ daily mean concentrations (equivalent to the WHO AQG for PM$_{2.5}$ daily mean level) for the last four years. In this way, any significant change in the spatial distribution of the values above the set thresholds in the legends can be observed. Note that only the last year’s map (2021) is based on UTD data, while the previous three years are based on officially reported validated data (CDR).

Figure 15: Maps of PM$_{2.5}$ concentrations (daily WHO AQG level) for the last 4 years

Heatmaps with the evolution from 2013 of the mean (top) and the maximum (bottom) 99 percentile of PM$_{2.5}$ daily mean concentrations at country level are shown in figure 16. In this way, the evolution along years of the average and maximum measured concentration levels can be seen for each country. Note that meteorological variability has a considerable impact on year-to-year changes in ambient air concentrations of air pollutants (EEA, 2020), and the last year (2021) is based on UTD data, while the previous years are based on officially reported validated data.
Note: It is important to note that the figure is not based on a consistent set of stations. The number, location and classification of the stations included may vary from year to year.
4 Status of ozone ambient air concentrations

Data for O$_3$ were reported from 1885 stations for the calculation of EU standards, from 1885 stations in relation to the short-term WHO AQG, and from 1754 stations for the long-term WHO AQG. These stations were located in all the reporting countries shown in Figure 1.

16 countries in EU-27 and 4 other reporting countries registered concentrations above the O$_3$ target value (120 µg/m$^3$) more than 25 times (Figure 17). In total, 9 % of all stations reporting O$_3$ showed concentrations above the target value for the protection of human health. In addition, only 20 % (367) of all stations fulfilled the long-term objective (120 µg/m$^3$). 86 % of the stations with values above the long-term objective were background stations.

8 % (150) of all stations and only 20 of the 484 reported rural background stations had values below the short-term WHO AQG value for O$_3$ (100 µg/m$^3$) (Figure 20), set for the protection of human health. The long-term (peak season) WHO AQG level (60 µg/m$^3$) was exceeded in 98 % (1726) of all stations located in 26 countries in EU-27 and 7 other reporting countries. Only 0 of the 469 reported rural background stations had values below this AQG level (Figure 23).
Figure 17: UTD Map and boxplot of O₃ concentrations in 2021

Note: Observed concentrations of O₃ in 2021. The map shows the 93.2 percentile of the O₃ maximum daily 8-hour mean, representing the 26th highest value in a complete series. It is related to the O₃ target value. At sites marked with the last two colour categories, the 26th highest daily O₃ concentrations were above the 120 µg/m³ threshold, implying an exceedance of the target value threshold. Please note that the legal definition of the target value considers not only 1 year but the average over 3 years. Only stations with more than 75 % of valid data have been included in the map.

Note: The graph is based, for each country, on the 93.2 percentile of the maximum daily 8-hour mean concentration values, corresponding to the 26th highest daily maximum of the running 8-hour mean. For each country, the number of stations considered (in brackets), the lowest, highest and average values (in µg/m³) recorded at its stations are given. The rectangles mark the 25th and 75th percentiles. At 25 % of the stations, levels are below the lower percentile; at 25 % of the stations, concentrations are above the upper percentile. The target value threshold set by the EU legislation is marked by the horizontal line. Please note that the legal definition of the target value considers not only 1 year but the average over 3 years. The graph should be read in relation to the above map, as a country's situation depends on the number of stations considered.
Figure 18 shows the maps of the observed 93.2 percentile of the O₃ maximum daily 8-hour mean concentrations (O₃ target value) for the last four years. In this way, any significant change in the spatial distribution of the values above the set thresholds in the legends can be observed. Note that only the last year’s map (2021) is based on UTD data, while the previous three years are based on officially reported validated data (CDR).

Figure 18: Maps of O₃ concentrations (related to the target value) for the last 4 years

Heatmaps with the evolution from 2000 of the mean (top) and the maximum (bottom) O₃ concentrations (93.2 percentile of the maximum daily 8-hour mean concentration, target value) at country level are shown in figure 19. In this way, the evolution along years of the average and maximum measured concentration levels can be seen for each country. Note that meteorological variability has a considerable impact on year-to-year changes in ambient air concentrations of air pollutants (EEA, 2020), especially for O₃ as higher atmospheric temperature leads to
enhanced photochemical reactions and $O_3$ formation. The last year (2021) is based on UTD data, while the previous years are based on officially reported validated data.
Figure 19: Evolution of mean (top) and maximum (bottom) O$_3$ concentrations (93.2 percentile of the maximum daily 8-hour mean concentration, related to the target value) per country from 2000

Note: It is important to note that the figure is not based on a consistent set of stations. The number, location and classification of the stations included may vary from year to year.
Figure 20: UTD Map of $O_3$ concentrations in 2021 - short-term WHO AQG level

Note: Observed concentrations of $O_3$ in 2021. The map shows the 99 percentile of the $O_3$ maximum daily 8-hour mean concentrations, equivalent to 3–4 exceedance days per year, according to the definition of the short-term WHO AQG (100 µg/m³).

The first colour category indicates stations with concentrations below this AQG level.

Only stations with more than 75 % of valid data have been included in the map.
Figure 21 shows the maps of the 99 percentile of the O₃ maximum daily 8-hour mean concentrations (equivalent to the short-term WHO AQG level) for the last four years. In this way, any significant change in the spatial distribution of the values above the set thresholds in the legends can be observed. Note that only the last year’s map (2021) is based on UTD data, while the previous three years are based on officially reported validated data (CDR).

**Figure 21: Maps of O₃ concentrations (short-term WHO AQG level) for the last 4 years**

Heatmaps with the evolution from 2013 of the mean (top) and the maximum (bottom) 99 percentile of the O₃ maximum daily 8-hour mean concentrations at country level are shown in figure 22. In this way, the evolution along years of the average and maximum measured concentration levels can be seen for each country. Note that meteorological variability has a considerable impact on year-to-year changes in ambient air concentrations of air pollutants (EEA, 2020), and the last year (2021) is based on UTD data, while the previous years are based on officially reported validated data.
Figure 22: Evolution of mean (top) and maximum (bottom) 99 percentile of the O₃ maximum daily 8-hour mean concentrations per country from 2013

Note: It is important to note that the figure is not based on a consistent set of stations. The number, location and classification of the stations included may vary from year to year.
Figure 23: UTD Map of peak season O₃ concentrations in 2021

Note: Observed concentrations of O₃ in 2021. The map shows the average of the daily maximum 8-hour mean O₃ concentration in the six consecutive months with the highest six-month running-average O₃ concentration. The first colour category represents stations fulfilling the peak season O₃ AQG level. Only stations with more than 75 % of valid data have been included in the map.
Figure 24 shows the maps of the peak season $O_3$ concentrations (equivalent to the long-term WHO AQG level) for the last four years. In this way, any significant change in the spatial distribution of the values above the set thresholds in the legends can be observed. Note that only the last year’s map (2021) is based on UTD data, while the previous three years are based on officially reported validated data (CDR).

**Figure 24: Maps of peak season $O_3$ concentrations for the last 4 years**

Heatmaps with the evolution from 2013 of the mean (top) and the maximum (bottom) peak season $O_3$ concentrations at country level are shown in figure 25. In this way, the evolution along years of the average and maximum measured concentration levels can be seen for each country. Note that meteorological variability has a considerable impact on year-to-year changes in ambient air concentrations of air pollutants (EEA, 2020), and the last year (2021) is based on UTD data, while the previous years are based on officially reported validated data.
Figure 25: Evolution of mean (top) and maximum (bottom) peak season O₃ concentrations per country from 2013

Note: It is important to note that the figure is not based on a consistent set of stations. The number, location and classification of the stations included may vary from year to year.
5 Status of nitrogen dioxide ambient air concentrations

The reporting countries shown in Figure 1 submitted NO\textsubscript{2} data from 2702 stations for the annual limit value, 2697 stations for the hourly limit value, and 2694 stations for the daily WHO AQG level.

7 of the countries in EU-27 and 1 other reporting countries (Figure 26) recorded concentrations above the annual limit value (40 µg/m\textsuperscript{3}). This happened in 1 % of all the stations measuring NO\textsubscript{2}. On the contrary, 73 % of stations, located in 27 of the countries in EU-27 and 8 other reporting countries reported concentrations above the WHO AQG level of 10 µg/m\textsuperscript{3}. Figure 26 shows the measured annual mean NO\textsubscript{2} concentrations.

100 % of all values above the annual limit value were observed at traffic stations. Furthermore, 100 % of the stations with concentrations above the annual limit value were located in urban or suburban areas.

Concentrations above the hourly limit value (200 µg/m\textsuperscript{3}) were observed in 0.2 % (5 stations) of all reporting stations, mostly at urban traffic stations. They were observed in four countries (number stations): Italy (two), Serbia (one), Spain (one) and Sweden (one).

Finally, concentrations above the daily NO\textsubscript{2} WHO AQG level (25 µg/m\textsuperscript{3}) were registered in 78 % (2109 stations) of all the reporting stations in 27 of the countries in EU-27 and 8 other reporting countries (Figure 29).
**Figure 26: UTD Map and boxplot of NO\textsubscript{2} concentrations in 2021**

Note: Observed concentrations of NO\textsubscript{2} in 2021. The last two colour categories correspond to values above the EU annual limit value (40 µg/m\textsuperscript{3}), while the first colour category indicates stations reporting values below the WHO AQG for NO\textsubscript{2} (10 µg/m\textsuperscript{3}). Only stations with more than 75 % of valid data have been included in the map.

The graphic represents the annual mean NO\textsubscript{2} concentrations across European countries. The map uses a color scale to indicate concentration levels, with categories for different ranges of concentrations and a legend indicating the number of stations reporting data. The boxplot graph below the map provides a more detailed statistical analysis of NO\textsubscript{2} concentrations for each country, showing the lowest, highest, and average values recorded, as well as the distribution of data points within each country.

Note: The graph is based on the annual mean concentration values. For each country, the number of stations considered (in brackets) and the lowest, highest and average values (in µg/m\textsuperscript{3}) recorded at its stations are given. The rectangles mark the 25th and 75th percentiles. At 25 % of the stations, levels are below the lower percentile; at 25 % of the stations, concentrations are above the upper percentile. The limit value set by EU legislation is marked by the horizontal line. The WHO AQG level is marked by the lower dashed horizontal line.

The graphic should be read in relation to the above map, as a country’s situation depends on the number of stations considered.
Figure 27 shows the maps of the observed NO₂ annual mean concentrations for the last four years. In this way, any significant change in the spatial distribution of the values above the set thresholds in the legends can be observed. Note that only the last year’s map (2021) is based on UTD data, while the previous three years are based on officially reported validated data (CDR).

Figure 27: Map of NO₂ concentrations (annual mean) for the last 4 years

Maps for years before 2020 are different to the ones published in previous reports because the bands in the legend have been modified to accommodate the 2021 WHO AQG level.

Heatmaps with the evolution from 2000 of the mean (top) and the maximum (bottom) NO₂ annual mean concentrations at country level are shown in figure 28. In this way, the evolution along years of the average and maximum measured concentration levels can be seen for each country. Note that meteorological variability has a considerable impact on year-to-year changes in ambient air concentrations of air pollutants (EEA, 2020), and the last year (2021) is based on UTD data, while the previous years are based on officially reported validated data.
Note: It is important to note that the figure is not based on a consistent set of stations. The number, location and classification of the stations included may vary from year to year.
Figure 29: UTD Map of NO₂ concentrations in 2021 - daily WHO AQG level

Note: Observed concentrations of NO₂ in 2021. The map shows the 99 percentile of the NO₂ daily mean concentrations, equivalent to 3–4 exceedance days per year, according to the definition of the daily WHO AQG level (25 µg/m³). The first colour category indicates stations with concentrations below this AQG level. Only stations with more than 75 % of valid data have been included in the map.
Figure 30 shows the maps of the 99 percentile of NO$_2$ daily mean concentrations (equivalent to the WHO AQG for NO$_2$ daily mean level) for the last four years. In this way, any significant change in the spatial distribution of the values above the set thresholds in the legends can be observed. Note that only the last year’s map (2021) is based on UTD data, while the previous three years are based on officially reported validated data (CDR).

Figure 30: Maps of NO$_2$ concentrations (daily WHO AQG level) for the last 4 years

Heatmaps with the evolution from 2013 of the mean (top) and the maximum (bottom) 99 percentile of NO$_2$ daily mean concentrations at country level are shown in figure 31. In this way, the evolution along years of the average and maximum measured concentration levels can be seen for each country. Note that meteorological variability has a considerable impact on year-to-year changes in ambient air concentrations of air pollutants (EEA, 2020), and the last year (2021) is based on UTD data, while the previous years are based on officially reported validated data.
Figure 31: Evolution of mean (top) and maximum (bottom) 99 percentile of NO$_2$ daily mean concentrations (daily WHO AQG level) per country from 2013

Note: It is important to note that the figure is not based on a consistent set of stations. The number, location and classification of the stations included may vary from year to year.
6 Status of sulphur dioxide ambient air concentrations

The reporting countries shown in Figure 1 reported measurements of SO\textsubscript{2} from 1179 stations for the hourly limit value and 1178 stations for the daily limit value. 14 stations (\textsuperscript{4}) registered concentrations above the hourly limit value (350 μg/m\textsuperscript{3}); and 14 stations (\textsuperscript{5}) registered concentrations above the daily limit of 125 μg/m\textsuperscript{3} for SO\textsubscript{2} (Figure 32).

On the contrary, 53 (4 \%) of all the stations reporting SO\textsubscript{2} levels, located in 13 reporting countries (\textsuperscript{6}), measured SO\textsubscript{2} concentrations above the WHO AQG of 40 μg/m\textsuperscript{3} for daily mean concentrations (\textsuperscript{7}).

\textsuperscript{4}Bosnia and Herzegovina (eleven), Bulgaria (one), Italy (one) and Poland (one).
\textsuperscript{5}Bosnia and Herzegovina (eleven), Italy (two) and Poland (one).
\textsuperscript{6}All reporting countries except Andorra, Austria, Croatia, Cyprus, Denmark, Estonia, Finland, Greece, Hungary, Ireland, Kosovo, Lithuania, Luxembourg, Malta, Netherlands, North Macedonia, Portugal, Slovakia, Slovenia and Switzerland.
\textsuperscript{7}Although the WHO AQG level for daily means refers to the percentile 99 (3-4 exceedance days), here we have used the percentile 99.18 (3 exceedance days), so the daily WHO AQG level can be directly compared with the EU daily LV.
Figure 32: Map of SO$_2$ daily concentrations in 2021

Note: Observed concentrations of SO$_2$ in 2021. The map shows the percentile 99 of SO$_2$ daily means, indicating 3 exceedance days. It relates to the EU daily limit value (125 µg/m$^3$) and to the WHO daily AQG level (40 µg/m$^3$). Only stations with more than 75 % of valid data have been included in the map.
Figure 33 shows the maps of the observed SO\textsubscript{2} daily mean concentrations for the last four years. In this way, any significant change in the spatial distribution of the values above the set thresholds in the legends can be observed. Note that only the last year’s map (2021) is based on UTD data, while the previous three years are based on officially reported validated data (CDR).

Heatmaps with the evolution from 2000 of the mean (top) and the maximum (bottom) SO\textsubscript{2} daily mean concentrations at country level are shown in figure 34. In this way, the evolution along years of the average and maximum measured concentration levels can be seen for each country. Note that meteorological variability has a considerable impact on year-to-year changes in ambient air concentrations of air pollutants (EEA, 2020), and the last year (2021) is based on UTD data, while the previous years are based on officially reported validated data.
Figure 34: Evolution of mean (top) and maximum (bottom) SO₂ 99.18 percentile of daily mean concentrations (EU LV (125 µg/m³) and WHO AQG level (40 µg/m³)) per country from 2000

Note: It is important to note that the figure is not based on a consistent set of stations. The number, location and classification of the stations included may vary from year to year.

Note: It is important to note that the figure is not based on a consistent set of stations. The number, location and classification of the stations included may vary from year to year.
7 Abbreviations, units and symbols

µg/m³: microgram(s) per cubic metre

AQG: Air quality guideline

CDR: Central data repository

EEA: European Environment Agency

ETC HE: European Topic Centre on Human health and the Environment

EU: European Union

LV: limit value

NO₂: Nitrogen dioxide

O₃: Ozone

PM: Particulate matter

PM₂.₅: Particulate matter with a diameter of 2.5 µm or less

PM₁₀: Particulate matter with a diameter of 10 µm or less

RL: Reference level

SO₂: Sulphur dioxide

TV: target value

UTD: up-to-date

WHO: World Health Organization
8 Annex

Data included in this report was received by 24 March 2022 from the reporting countries. By that date the number of stations by country reporting each pollutant is summarized in Table 3:

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Table 3: Reporting status of 2021 air quality data by 24 March 2022 (continued)

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References


The European Topic Centre on Human health and the environment (ETC-HE) is a consortium of European institutes under contract of the European Environment Agency.