ANNEX II

Air quality in the Czech Republic during emergencies

Due to the spread of the SARS-CoV-2 coronavirus infection and the associated COVID-19 disease, a state of emergency was repeatedly declared in the CR in 2020 and a number of measures were associated with it, which more or less limited various activities. **Some of them had an impact on the amount of pollutant emissions and thus on air quality**, which was the subject of a number of studies abroad (Gkatzelis 2021).

The state of emergency was declared for the first time in the CR in 2020 on 12 March 2020 and lasted 66 days until 17 May 2020. Another state of emergency was declared during the escalation of the second wave of the epidemic on 5 October 2020. It lasted until 11 April 2021

For the sake of completeness, the values from the first months of 2021 were also evaluated within this chapter of the yearbook for 2020, to allow analysing the emergency period as a whole. At the same time, however, it is to be noted, that all data for the first months of 2021 are only operational and, after complete verification, the final values may differ.

From the point of view of air quality, three categories of measures were essential:

- **restrictions on movement and social contacts** – significant restrictions on travel, commuting, business trips, etc.
- **longer time spent in households**
- **operation restrictions for industrial plants**.

In the CR, the situation was not such that the operation of industrial facilities would significantly be reduced, as was the case in some other countries. There was therefore no significant reduction in emissions from industry. On the contrary, **the decrease in traffic intensity was noticeable throughout the territory and this was also related to the decrease in emissions of pollutants from transport, especially NO_x. More time spent in households may have affected the amount of emissions from heating**, especially during the heating season. Heating is currently the most significant source of emissions of suspended PM particles and carcinogenic BaP bound to them in the CR.

Assessing the impact of an emergency on air quality is rather complicated, as **a number of other factors** come into play, which act completely independently of human activities and which can have a significant impact in some situations. The most important in this respect are **meteorological conditions**, in particular air temperature (determining the domestic heating

Fig. 1 Transportation mobility of population in the Czech Republic since the beginning of 2020 until the second half of May 2021. Values express the percentage of deviation from the long-term average (data sources: Google 2021; Waze 2021; Apple 2021).

intensity), the amount of precipitation (precipitation due to the process of wet deposition washes out air pollutants), wind speed and thermal stratification of the atmosphere (main factors determining the dispersion situation, that is how well substances in the ground layer of the atmosphere are dispersed).

In the context of the impact of anti-epidemic measures on air quality, attention is paid mainly to nitrogen oxides, i.e. nitrogen dioxide (NO_2) and nitric oxide (NO), the main source of which in the CR is transport. The relationship between traffic intensity and emissions is not linear, it depends, for example, on the flow of traffic or type of vehicles and air temperature. Linearity also does not apply in the relationship between amount of emissions and measured concentrations due to other factors such as meteorological conditions. The analysis of the spring period from 16 March to 19 April 2020 (CHMI 2020) showed that the average NO_2 concentration from all observing stations for the evaluated period was the lowest for the last 6 years. Compared to the 5-year average 2015–2019, it was lower by 2.5 $\mu g.m^{-3}$, corresponding to 13%. The most significant decrease was at traffic stations.

It is possible to demonstrate a decrease in traffic intensity in several ways, namely using traffic counters, analysing the amount of fuel pumped or, for example, using anonymized geolocation data of mobile phone users (either through SIM card data or from operating systems or shared traffic applications). Absolute values cannot be compared with each other because they are calculated differently by each source. However, particularly important are trends. The calculation of population mobility is based on Google data and represents the movement of users of the Android operating systems. Daily deviation values express the degree of transportation mobility compared to the long-term average. Values above the 0% threshold therefore show an above-average condition, values below 0%, on the other hand, show a below-average condition. The largest drop occurred after the declaration of the first state of emergency in mid-March (Fig. 1). Later, the situation gradually returned to normal and reached more or less normal values by the end of June. A gradual decline, although less dramatic, was observed again from the beginning of October, roughly correlating with the declaration of the second state of emergency. In March, the decline was even more than 60%, in October only about 40%. A more significant decline was subsequently recorded at the end of the year, which was mainly related to the stay of the population in their homes between holidays. In addition, travel options were very limited. At the beginning of March 2021, a travel ban outside the district boundaries was issued.

CHMI operates a traffic counter at the Ústí n. L.-Všebořická (hot-spot) traffic station. Data from this station confirm that while the traffic intensity in the first two months of the year was rather slightly above average compared to the 2016–2019 average, in the 12th week (corresponding to the beginning of the state of emergency in the spring) there was a decrease of about 25–30% (Fig. 2). Another decrease from about the 40th week (September 28, 2020) was gradual, only by about 15 to 20%. Given the identical measures throughout the country, it can be assumed that the situation was similar in other towns and villages. This corresponds to the fact that the demand for fuels decreased by approximately 30% in April (Loula 2021).

An attempt to make an estimate of the rate of influence of the individual factors is very complicated and due to the vast number of various factors more or less unrealistic. One way to at least roughly estimate the change in traffic emissions and the degree of improvement due to an emergency is to compare the relative concentrations observed at traffic and background stations that are close to each other. We assume that the meteorological conditions in the site location of both stations are similar. We can therefore compare the long-term ratio of individual pollutants between the traffic and background station nearby and assess whether this ra-

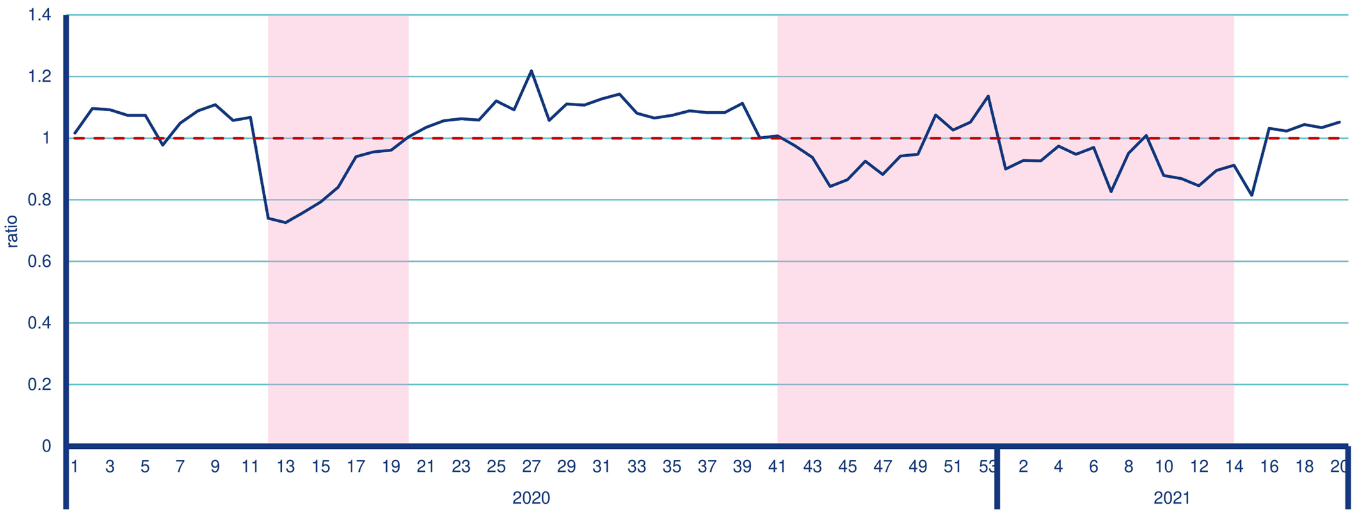

Fig. 2 The ratio of the number of vehicles in individual weeks related to the long-term average 2016–2019 for a given week from the vehicle counting sensor in the Ústí n. L.-Všebořická locality. The emergency period is marked in pink, the red dashed line indicates a ratio of 1.

tio differed during the emergency period. If the decrease in traffic is to have a positive effect on air quality, it can be expected that the situation at traffic stations will be relatively better compared to the long-term average than at background stations, where NO_X emissions from transport have a minor effect.

The state of emergency could also have an effect on the concentrations of PM_{10} suspended particles, but in this case a negative one. Geolocation data from Android users show that the time people spent at home increased during both states of emergency (Fig. 3). At the beginning of the emergency state in the spring, the increase was around 20–25%, in the autumn around 10–15%, and during Christmas time up to about 30%. Another visible increase occurred after the announcement of a travel ban between districts.

The weather during the second half of March and the beginning of April was very cold and the heating rate during the beginning of the first emergency state was therefore relatively high. The second state of emergency was declared already at the time of the beginning of the heating season. Although PM_{10} concentrations are also affected by transport, the areal effect of meteorological conditions and heating on the territory of the whole republic as such is significantly higher. The CHMI report of June 2020 on the impact of the state of emergency on air quality (CHMI 2020) already showed that PM_{10} concentrations during the first weeks of the state of emergency were the highest within the assessment period (last 6 years). In addition, other factors may have come into play, such as the long-range transport of sand from the desert in Turkmenistan in the first weeks of the March 2020 emergency, which worsened PM_{10} concentrations very significantly and across a large area.

The graphs in Figures 4a and 4b are an example of a comparison including a transport and background station – specifically the Brno-Úvoz (hot spot) traffic station and the Brno-Tuřany suburban background station. Both stations are less than 10 km apart, so it can be expected that the meteorological and dispersion conditions there would be very similar in the long run. Two graphs were prepared – one for NO_X and the other for PM_{10}. Each graph shows the average ratio of concentrations at the Brno-Úvoz and Brno-Tuřany stations (Brno-Úvoz/Brno-Tuřany), as an average of 2016 to 2019 and further for the years 2020 and 2021. The graphs also indicate the state of emergency period and the period of the ban on travel outside districts. Apart from the difference to the long-term average, which can largely originate from meteorological and dispersion conditions, we are more interested in the differences between the two graphs – situations where values of the ratio to the long-term average for one pollutant are higher, while lower for the other pollutant.

The first graph (Fig. 4a) for NO_X shows a significantly higher ratio in February 2020. The probable cause of this significantly higher ratio is the fact that, as already mentioned, February 2020 was exceptional in terms of meteorological conditions. There are higher emissions from traffic at the traffic station, so meteorological conditions have a smaller effect there than at the suburban background station. This is also apparent in the second graph for PM_{10} (Fig. 4b), where a significantly higher ratio between concentrations in February 2020 is visible. In both graphs, the ratio is therefore higher than the long-term average. After declaring a state of emergency in March 2020, it can be seen that there has indeed been a change, but this time the opposite – the ratio was significantly lower than the 2016–2019 average. The probable explanation here is the decrease in emissions. This is also confirmed by the fact that such a decline in 2020 is not observed in the second graph for PM_{10}. A very similar decline is evident, for example, in March 2021, with the announcement of the ban on travel outside districts. This decrease in the ratio in 2021 compared to the 2016–2019 average is also evident only in the graph for NO_X, not for PM_{10}.

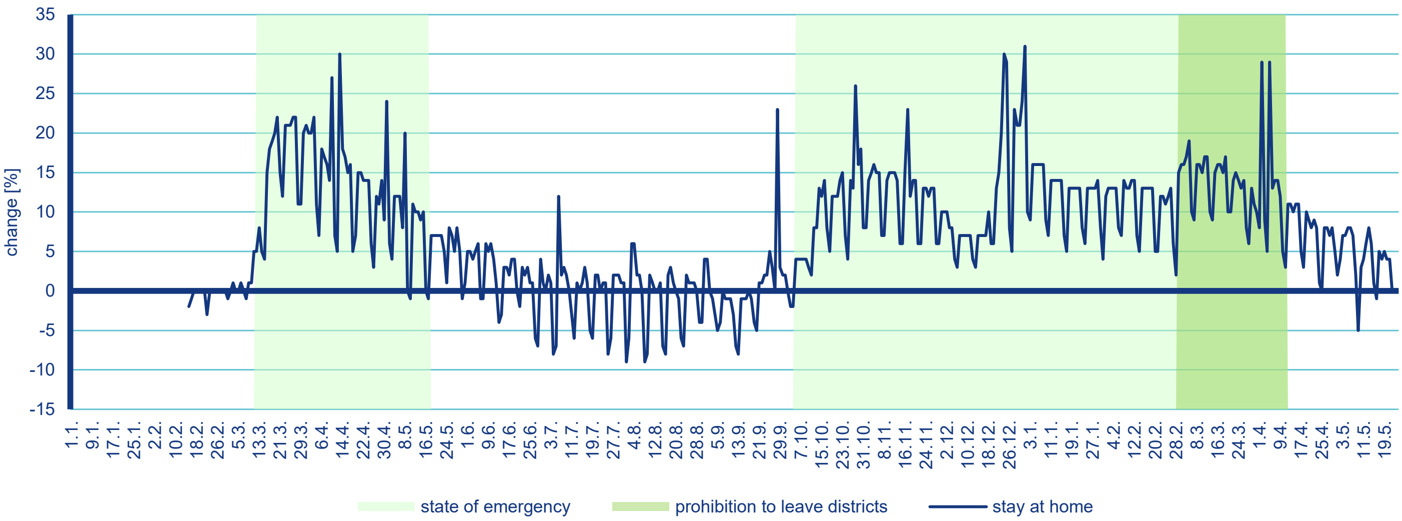

Fig. 3 Length of staying at home in the CR since the beginning of 2020 until the second half of May 2021. Values express the percentage of deviation from the long-term average (data source: Google 2021).

The graphs in Figures 5 and 6 show the ratio of NO_x and PM_{10} concentrations in 2020 and 2021 for the individual weeks in a year compared to the average of 2016–2019 for a given week and station.

Again, we assume that the effect of meteorological and dispersion conditions was similar for both stations. It is apparent that the trends of the conditions at both stations differ in the 12th week of 2020 – the values at the Brno-Tuřany station are higher relative to the long-term average than at the Brno-Úvoz traffic station. This again suggests that the decrease in NO_x emissions was distinct and it can be said that, in the absence of the emergency state, the values at the traffic station would be higher, independently of the absolute values of the concentrations. Another significant deviation is evident around the 9th week of 2021 – just at the time when the ban on travel outside districts was issued.

The graph in Fig. 6 is identical to the graph in Fig. 5, but this time it is made for PM_{10}. However, it is clear there that the conditions at both stations are very similar throughout the period. This again confirms that the emergency state had a minimal effect on PM_{10} concentrations and, if any, it rather led to an increase in concentrations, especially in places with a high proportion of solid fuel heating. In the vicinity of both analysed stations, the heating is predominantly central, so the effect of heating and a longer stay in homes is not very clear, however, this graph proves that the conditions at both stations are generally similar.

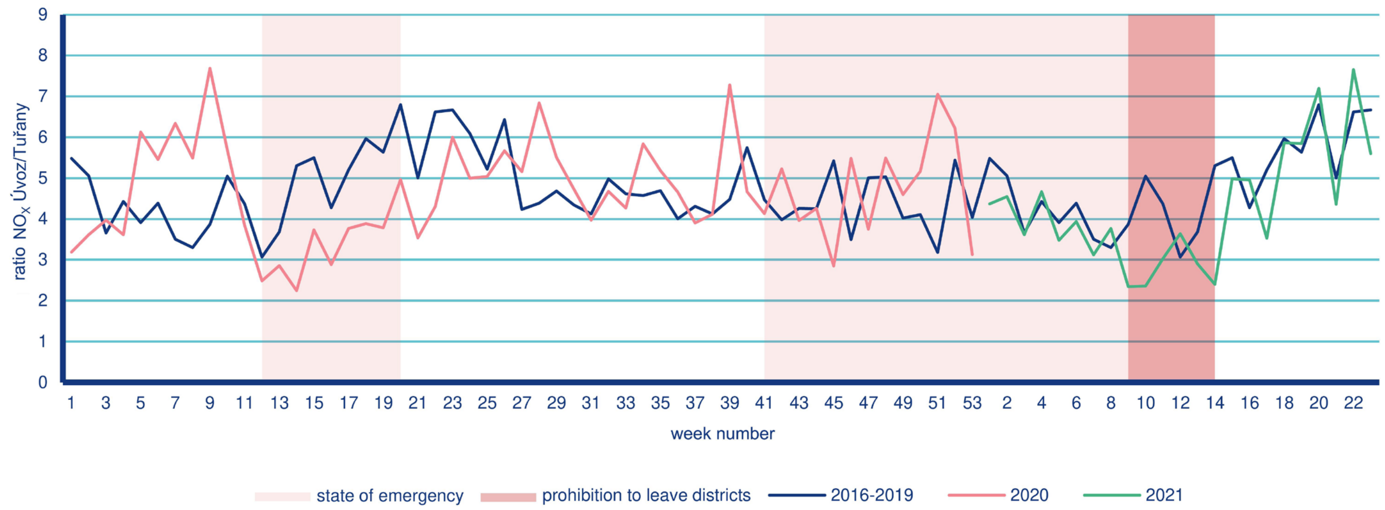

Fig. 4a The ratio between NO_x concentrations at the Brno-Úvoz and Brno-Tuřany stations (Brno-Úvoz/Brno-Tuřany) in individual weeks of the year. The average relates to the 2016–2019 period and values to the years 2020 and 2021. The periods of the state of emergency and travel ban outside districts are also indicated.

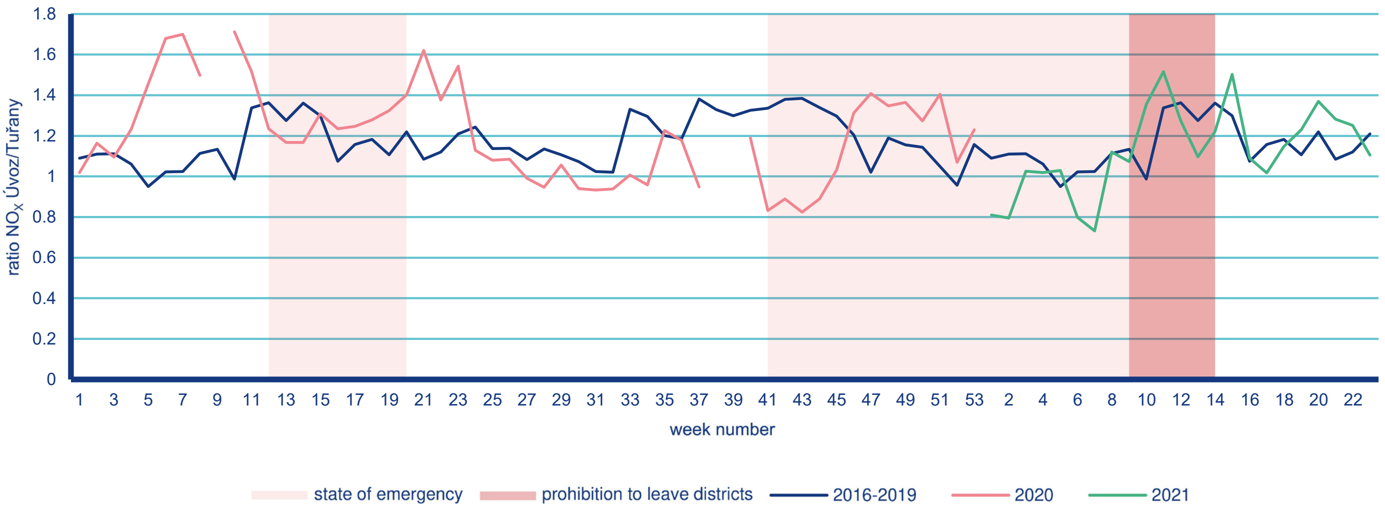

Fig. 4b The ratio between PM_{10} concentrations at the Brno-Úvoz and Brno-Tuřany stations (Brno-Úvoz/Brno-Tuřany) in individual weeks of the year. The average relates to the 2016–2019 period and values to the years 2020 and 2021. The periods of the state of emergency and travel ban outside districts are also indicated.

With regard to measures taken and the main categories of air pollution sources in the CR, we can say that the impact of the emergency state on air quality was relatively small, compared to some other countries in Europe and elsewhere in the world (EEA 2020).

In other countries, where transport and industry contribute more significantly towards the total pollution, measures to reduce these two categories of sources could have a very significant effect on pollutant concentrations. In addition, there are places in Europe where NO_x concentrations are higher in the long-term than in the CR due to very high traffic load, or industry (Benelux, northern Italy, etc.). In these places, therefore, there is a much higher potential for a decrease in concentrations than in places where the values are lower in the long run.

The conclusions of the European Environment Agency (EEA 2020) report also confirm that the impact of anti-epidemic measures in the CR was rather minor. The box plots for PM_{10} (Fig. 7a) and nitrogen dioxide (Fig. 7b) indicate an estimate of the relative change (in percentage) of the concentrations of these substances as a result of the measures – the data in these graphs are adjusted in order to eliminate the effect of meteorological and other factors.

In addition to absolute values, measures against the spread of the pandemic could also have affected some other aspects in air quality monitoring – one being, for example, the time variation of concentrations. The curfew after 9 pm significantly affected concentrations during the New Year celebrations at the turn of 2020 and 2021, when, on average, the concentrations were rather simi-

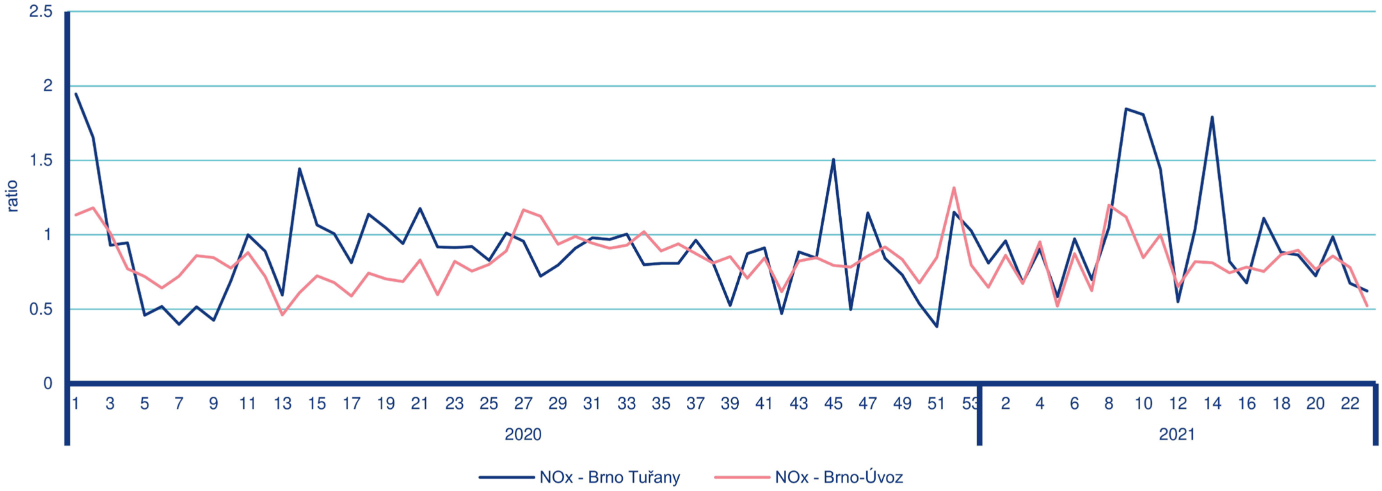

Fig. 5 The average ratio of NO_x concentrations at the Brno-Úvoz traffic station and the Brno-Tuřany background station. Values express the ratio of the average concentration in a given week in 2020 or 2021 to the average of 2016–2019 for a given week in the year.

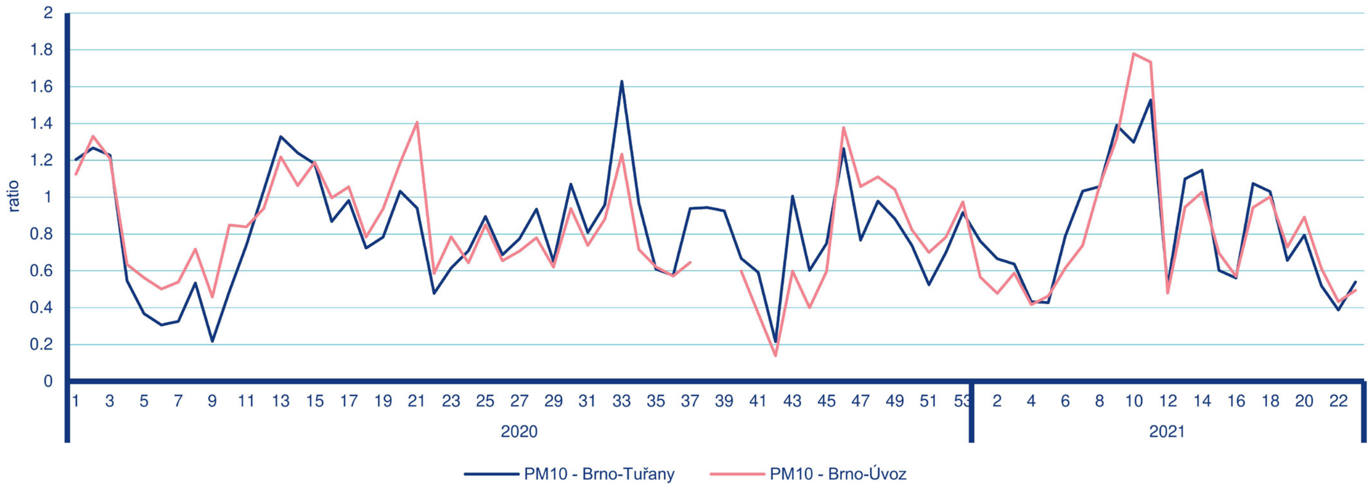

Fig. 6 The average ratio of PM_{10} concentrations at the Brno-Úvoz traffic station and the Brno-Tuřany background station. Values express the ratio of the average concentration in a given week in 2020 or 2021 to the average of 2016–2019 for a given week in the year.

lar to those of other years, however, fireworks and the associated significant increase of suspended particulate matter concentrations occurred much earlier than in the past, and, on the contrary, the peak around New Year's midnight in a number of cities was completely missing (Brzezina 2021).

In this respect, it is certain that measures against the spread of the coronavirus pandemic have had an impact on air quality, but the situation in this case is not unambiguous and it is not possible to say whether positively or negatively. The impact differed significantly depending on the specific pollutant evaluated. At the same time, it is very difficult to separate the influence of the individual sources and thus determine the exact consequences of specific measures. Meteorological conditions play an important role here, which can affect air quality quite fundamentally.

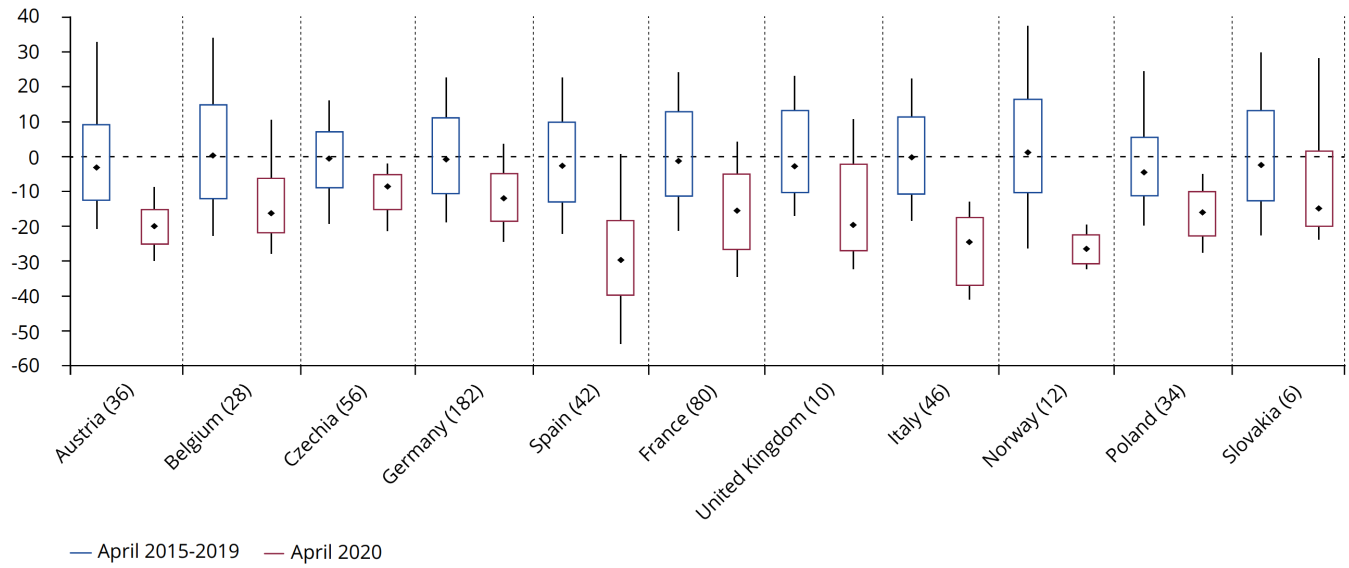

Fig. 7a Relative changes (%) in PM_{10} concentrations in individual European countries during April 2020 based on the GAM model estimate with elimination of meteorological factors (difference between measured concentrations and the model estimate reflecting the ordinary situation). The decrease for the Czech Republic is rather small compared to other countries (source: EEA 2020).

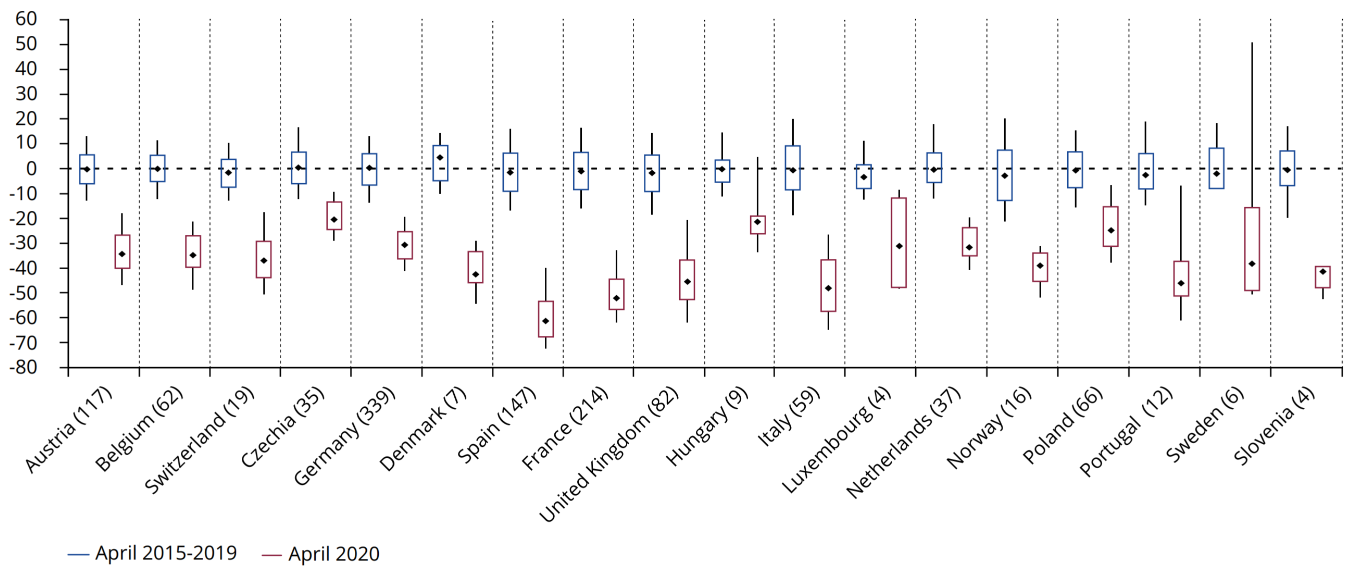

Fig. 7b Relative changes (%) in NO_2 concentrations in individual European countries during April 2020 based on the GAM model estimate with elimination of meteorological factors (difference between measured concentrations and the model estimate reflecting the ordinary situation). The decrease for the Czech Republic is rather small compared to other countries (source: EEA 2020).