BACKGROUND // JANUARY 2018

Air Quality 2017

Preliminary Evaluation

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The information presented in this brochure reflects the level of research at the time of publication. The definitive data is presented on the UBA website from the middle of the year onwards:

for PM_{10} and $PM_{2.5}$:
www.umweltbundesamt.de/en/topics/air/particulate-matter-pm10

for NO_2:
www.umweltbundesamt.de/en/topics/air/nitrogen-dioxide

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UBA air monitoring station Waldhof in the Luneburg Heath.

I Air Quality in 2017: Data basis and evaluation methodology

1 Air quality and air pollutants

Air quality, or expressed otherwise, the condition of the air, is monitored throughout Germany by the individual federal states and the UBA (German Environment Agency/*Umweltbundesamt – UBA*). In this respect, air quality is determined on the basis of the amount of air pollutants it contains, which means substances which have a harmful impact on human health and/or the environment. These include, primarily, particulate matter, nitrogen dioxide and ozone.

The pollutant concentrations in the air are measured several times a day at over 650 air monitoring stations throughout Germany.

For the Germany-wide assessment of the air quality, the data gathered by the federal states is collected and evaluated at the UBA.

The evaluation and assessment of the air quality takes place in terms of the limit and target values as defined by the Directive on Ambient Air Quality and Cleaner Air for Europe[1]. The results are also compared with the considerably stricter recommendations of the World Health Organisation (WHO).

2 Provisional nature of the information

This evaluation of air quality in Germany in the year 2017 is based on preliminary data which has not yet been conclusively audited from the air monitoring networks of the federal states and the UBA, valid on 23rd January 2018. Due to the comprehensive quality assurance within the monitoring networks, the final data will only be available in mid-2018.

1 EU Directive 2008/50/EC, which became German law with the 39th Ordinance Implementing the Federal Immission Control Act (Ordinance on Air Quality Standards and Emission Ceilings – 39. BImSchV)

Particulate matter (PM_{10}, $PM_{2.5}$)
is defined as particles which pass through the size-selective air inlet of a monitoring device, which demonstrates a 50 % efficiency cut-off for an aerodynamic diameter of 10 (PM_{10}) and 2.5 ($PM_{2.5}$) micrometres (µm) respectively. Above all, particulate matter is propagated by combustion processes in motor vehicles, power stations and small-scale furnaces and during the production of metals and steel. It is also propagated by soil erosion and precursors such as sulphur dioxide, nitrogen oxides and ammonia. Particulate matter has been proven to have a negative impact on human health.

Nitrogen dioxide (NO_2)
is a reactive nitrogen compound which occurs in the form of a by-product during combustion processes, particularly in motor vehicles, and can have several negative effects on the environment and health. Nitrogen dioxide affects the respiratory mucous membrane, influences the respiratory function and can lead to a Bronchoconstriction, which may be worsened by the impact of allergens.

Ozone (O_3)
is a colourless and toxic gas which forms a natural layer in the upper atmosphere (stratosphere) and protects the earth from the harmful ultraviolet radiation from the sun (the ozone layer). During intense sunlight, however, it also arises at ground-level due to complex photochemical processes between ozone precursors – primarily nitrogen oxides and volatile organic compounds. High concentrations of ozone can cause people to suffer coughs, headaches and respiratory tract irritations.

The currently available data allows for a general assessment of the past year. The following pollutants were subject to consideration: particulate matter (PM_{10} and $PM_{2.5}$), nitrogen dioxide (NO_2) and ozone (O_3), since, the limit and target values for the protection of human health are still exceeded for such substances.

3 Causes of air pollution

The primary sources of the air pollutants are road traffic and combustion processes in industry, the energy sector and households. Agriculture also contributes to particulate matter emissions due to the development of what are known as "secondary particles", which are particles that arise from complex chemical reactions between gaseous substances. The degree of the pollution level is also influenced by the weather conditions. In cold weather, emissions usually increase because heating systems go into increased use. High-pressure weather during the winter, which is often characterised by low wind speeds and a limited vertical exchange of air, means that air pollutants become concentrated in the lower atmospheric strata. High-pressure weather in the summer, with intense sunlight and high temperatures, acts to boost the formation of ground-level ozone. At high wind speeds and under positive mixing conditions, the levels of pollution fall, however. Inter-year variations in the levels of air pollution are primarily caused by different weather conditions of this kind. They therefore affect the influence of the more long-term development of the emissions.

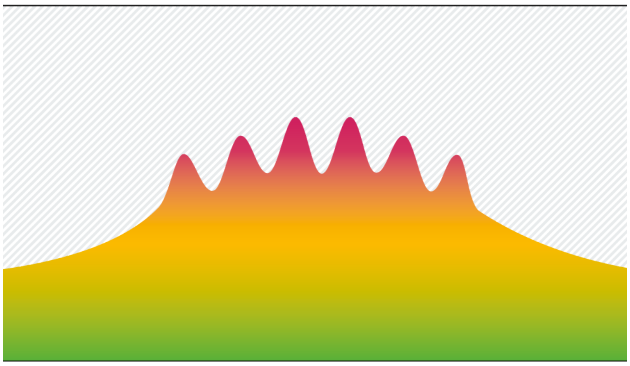
4 Influence of environmental conditions

In the following sections, the concentration values recorded at the individual air monitoring stations are summarised in the form of what are referred to as »pollution regimes«. Pollution regimes group air monitoring stations together with similar environmental conditions. The »rural background« regime relates to areas in which the air quality is largely uninfluenced by local emissions. The air monitoring stations in this regime therefore represent the regional pollution level, which is also referred to as the regional background. The »urban background« regime is characterised by areas in which the measured pollutant concentrations can be seen as being typical for the air quality in the city. In this respect, the pollution results from emissions in the city itself (road traffic, heating systems, industry, etc.) and that in the regional background. The air monitoring stations in the »urban traffic« regime are typically located on busy roads. As a result of this, the urban background pollution is joined by a contribution which arises due to the direct road traffic emissions. Figure 1 provides a diagrammatic representation of the contributions by the individual pollution regimes, although it only provides the approximate proportions.

Figure 1

Diagrammatic presentation of the pollution regime for particulate matter and nitrogen dioxide

Modified according to Lenschow*



rural background | urban background | urban traffic

* Lenschow et. al., Some ideas about the sources of PM_{10}, Atmospheric Environment 35 (2001) p.23–p.33

II Particulate matter: Low pollution – but no all-clear for health

1 PM_{10} – 24-hour values

In 2017, the level of particulate matter pollution was lower in comparison with 2005–2016. In 2017, one of the lowest levels of pollution was recorded. The legal limit was only exceeded at the "Am Neckartor" air monitoring station in Stuttgart, with 45 daily values of over 50 µg/m³ – only 35 such days are permitted. In the previous years, the exceeding of the limits occurred almost exclusively at urban traffic air monitoring stations, as shown in figure 2 (red bars). The recommendations of the World Health Organisation (WHO[2]) were not complied with at 87 percent of all air monitoring stations.

EU limit value

The 24-hour PM_{10} value must not exceed 50 µg/m³ more than 35 times per year.

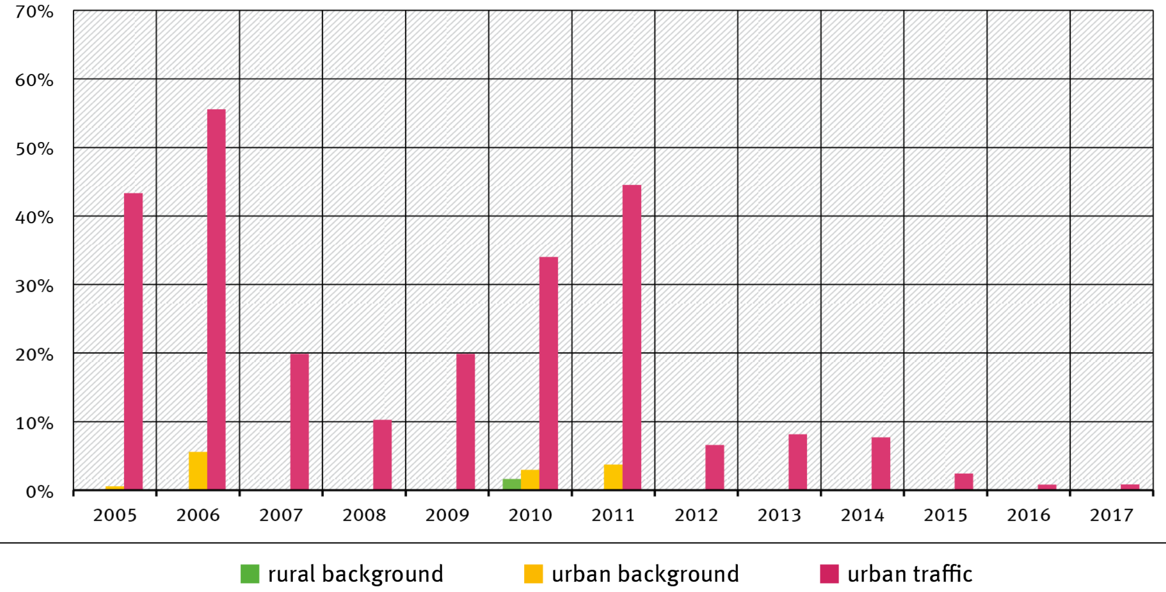
WHO recommendation

The 24-hour PM_{10} value should not exceed 50 µg/m³ more than 3 times per year.

Figure 2

Percentage share of air monitoring stations exceeding the PM_{10} limit value

for the 24-hour values in the corresponding pollution regime, time frame 2000–2017



Source: German Environment Agency (UBA) 2018

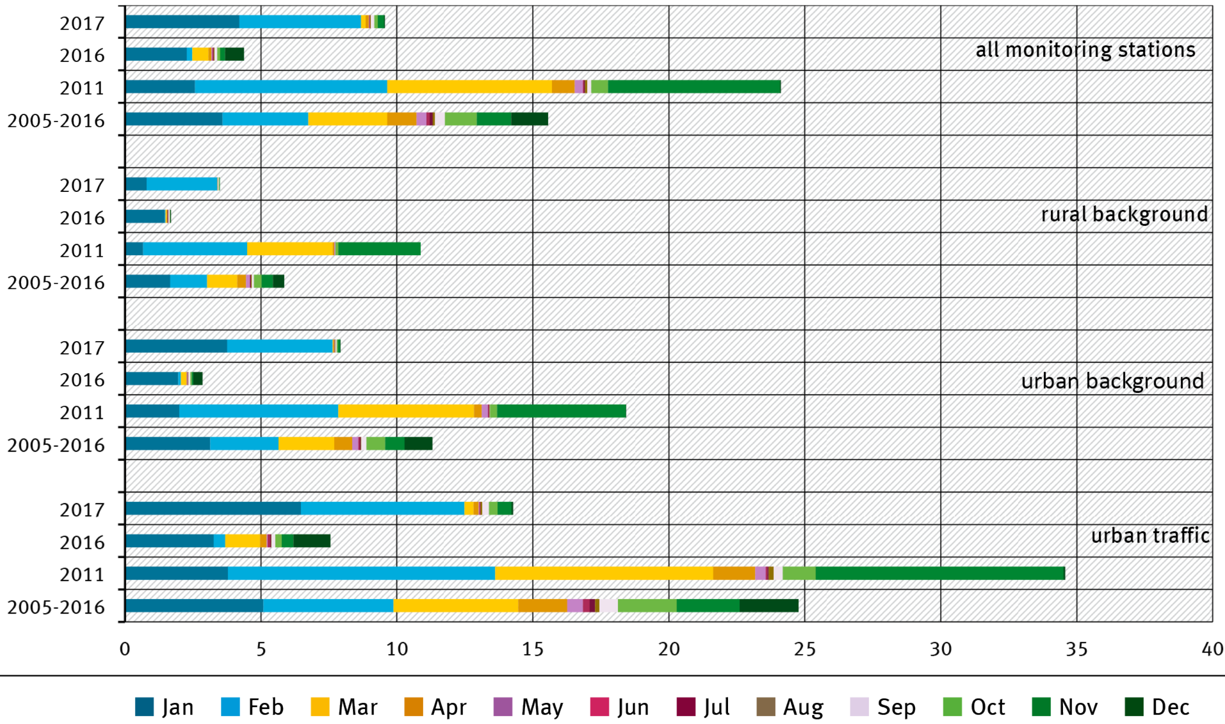
Figure 3 shows how many days were recorded on which the limits were exceeded, on average, per month. In this case, 2017 is compared with 2011, in which the levels of pollution were high due to the frequent occurrence of cold, stable high-pressure weather conditions, with the previous year and an extended reference period (2005–2016). It can be seen that in January and February there was an above-average number of days on which the limits were exceeded. From March onwards the levels of particulate matter pollution were very low, so that the year 2017 can be characterized as lowly polluted.

2 WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulphur dioxide, Global update 2005
http://www.euro.who.int/en/what-we-do/health-topics/environment-and-health/air-quality/publications/pre2009/air-quality-guidelines.-global-update-2005.-particulate-matter,-ozone,-nitrogen-dioxide-and-sulfur-dioxide

Figure 3

Average number of days on which the PM_{10} limit was exceeded (24-hour values > 50µg/m³)

per month in the corresponding pollution regime. Shown for the years 2017, 2016, 2011 and the period 2005–2016

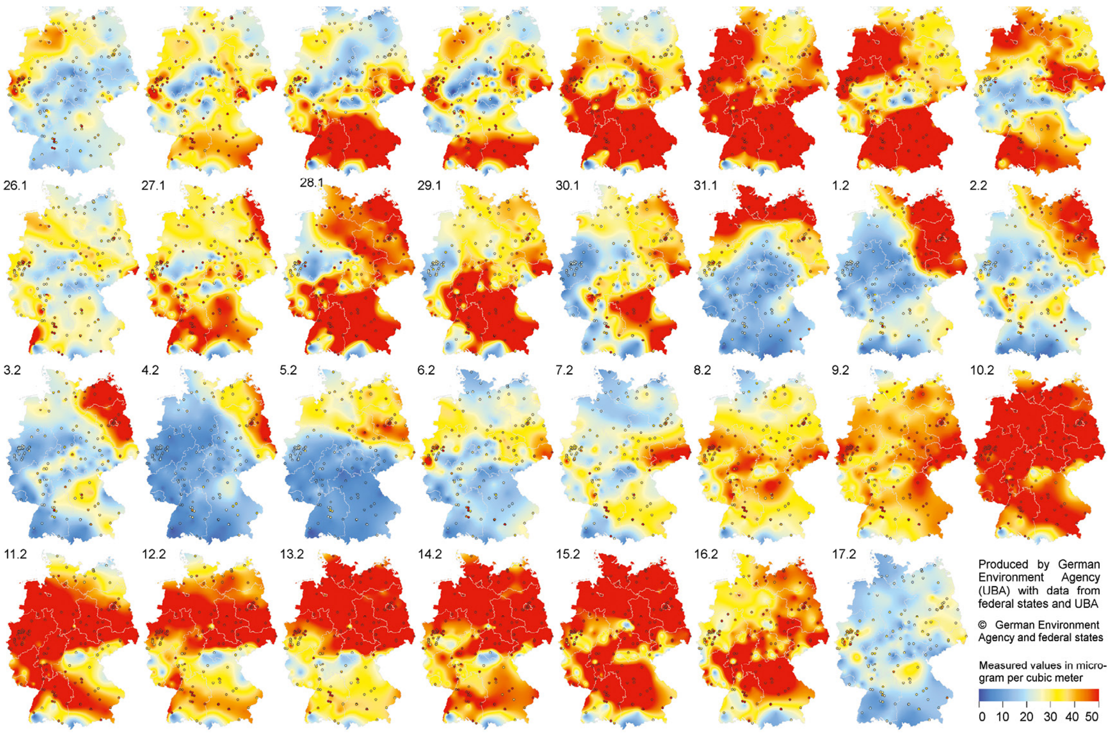


Source: German Environment Agency (UBA) 2018

Figure 4

Daily means of PM_{10} concentrations from 18 January until 17 February 2017

concentrations above 50 µg/m³ in red



Source: German Environment Agency (UBA) 2018

In middle of January an episode of high PM_{10} values started and continued for four weeks. Such episodes of high PM_{10} values typically occur within the winter months. Cold, continental air masses, mostly from easterly directions and local (temperature-affected high) emissions combined with high-pressure weather conditions can lead to extensively high PM_{10} concentrations. Because of the enhanced nocturnal cooling caused by the missing cloud cover, the temperature in the boundary layer air does not decrease with increasing height as it normally does. Now it increases, which means that the cold, heavier air is layered under the warm, lighter air. In this very stable atmospheric conditions with low winds, pollutants can accumulate beneath this "covering" over a period of several days.

Caused by many days with high-pressure weather conditions, the January of 2017 was dry-cold and very sunny. In the middle of January, Germany became affected from three high-pressure systems that caused very low temperatures, especially in southern Germany: Followed by Baden-Württemberg, Bavaria was the coldest and sunniest federal state and experienced the coldest January since 1987. The first half of February was characterised by continental, cold air from Eastern Europe. Low-pressure troughs transported mild, maritime air to the south and west, but were not able to prevail over the high pressure over Eastern Europe. In the middle of February the cold period expired when the blockading high pressure system moved back and the whole of Germany was affected by a westerly airstream which was rich in precipitation.[3]

Because of those high PM_{10} values in January and February, in 2017 more exceedance days were recorded than in the previous year.

2 PM_{10} – Annual mean values

In 2017, the PM_{10} limit of 40 µg/m³ as the annual mean value was complied with throughout Germany. 21 percent of the air monitoring stations recorded values that infringed the air quality guidelines proposed by WHO, however. The vast majority of these air monitoring stations were in urban traffic locations.

Accompanied by the regional falls in the PM_{10} emissions, the annual mean PM_{10} values also show a clear fall in all pollution regimes throughout the entire period of observation from 2000 to 2017. This is shown by Figure 5, for which only air monitoring stations were selected that conducted measurements over an extended period. The progression is also characterised by strong inter-year variations, however, particularly due to the different weather conditions.

As in 2016, the average concentrations in 2017 are on a very low level compared to the considered period.

EU limit value

The annual mean PM_{10} value must not exceed 40 µg/m³.

WHO recommendation

The annual mean PM_{10} value should not exceed 20 µg/m³.

3 $PM_{2.5}$ – Annual mean values and AEI

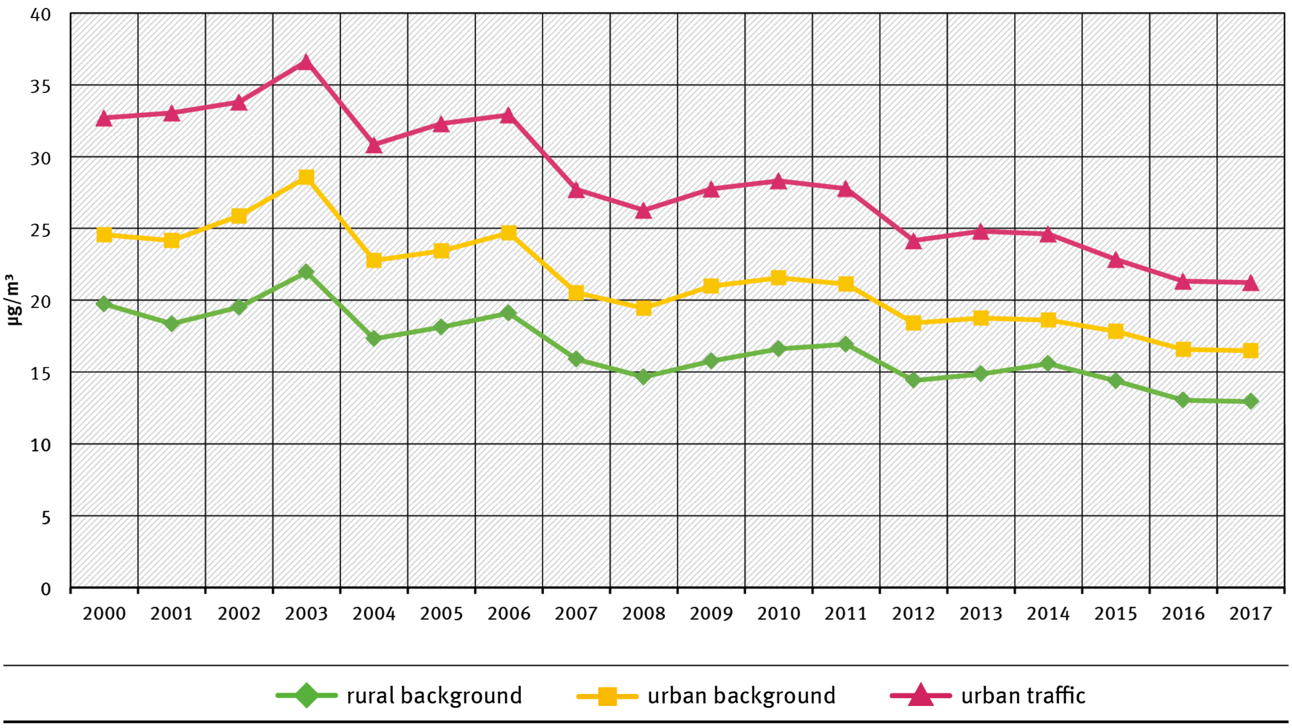
From 1st January 2015, for the smaller fraction of particulate matter which only contains particles with a maximum diameter of 2.5 micrometres (µm), an annual mean limit of 25 µg/m³ applies throughout Europe. In Germany, in 2017, as in the previous year, this value was not exceeded at any air monitoring station.

The EU Air Quality Directive also requires the average exposure of the population to $PM_{2.5}$ to be reduced until the year 2020. For this purpose, the Average Exposure Indicator (AEI) was developed. As the initial value for Germany for 2010, an AEI of 16.4 µg/m³ was calculated as the average value of the years 2008 to 2010. According to the requirements of the EU Directive, this results in a national reduction goal of 15 percent until 2020. Accordingly, the AEI calculated for 2020 (average value of the years 2018, 2019 and 2020) may not exceed the value of 13.9 µg/m³. In 2017 (average value of the years 2015, 2016, 2017), the AEI totalled 12.6 µg/m³ (estimation, because not for all measuring stations data are already available) and therefore was complied with for the second time, together with the 2016's AEI. Even if

3 Source: Press releases of the German weather service DWD; https://www.dwd.de/DE/presse/pressemitteilungen/pressemitteilungen_archiv_2017_node.html

Figure 5

Development of the annual mean PM_{10} values via selected air monitoring stations
in the corresponding pollution regime, time frame 2000–2017



Source: German Environment Agency (UBA) 2018

the future compliance seems to be ensured right now, calculations made clear, that for the 3 year average two lowly polluted years like we had in the last years are not enough to compensate one highly polluted year like 2011. Therefore it is not definitely sure that the national reduction goal for 2020 can be reached.

In addition, from 1st January 2015 onwards, the AEI is not permitted to exceed a value of 20 µg/m³. This value has not been exceeded in Germany since the start of the measurements in 2008.

Exposure
The contact of an organism with chemical, biological or physical influences is known as "exposure". A person is "exposed" to particulate matter, for example.

How is the Average Exposure Indicator (AEI) calculated?
The average exposure indicator is determined as an average value over a period of 3 years from the individual annual mean $PM_{2.5}$ values of selected air monitoring stations with an urban background. This results in a value which is expressed in µg/m³ for each 3-year period.

III Nitrogen dioxide: Half of the urban traffic air monitoring stations exceed the limit value

1 NO_2 – Annual mean values

According to the current data, 41 percent of air monitoring stations in urban traffic locations exceeded the statutory limit and/or the WHO air quality guidelines. But only values of stations with automatic measurements are included. The NO_2 concentrations measured by passive collectors, primarily at highly polluted urban traffic locations, are not yet available for this preliminary evaluation. On the basis of a projection derived from the previous years' data, we estimate the proportion of all air monitoring stations in urban traffic locations that exceeded the limit in 2017 to be approx. 46 percent (figure 6, red bars).

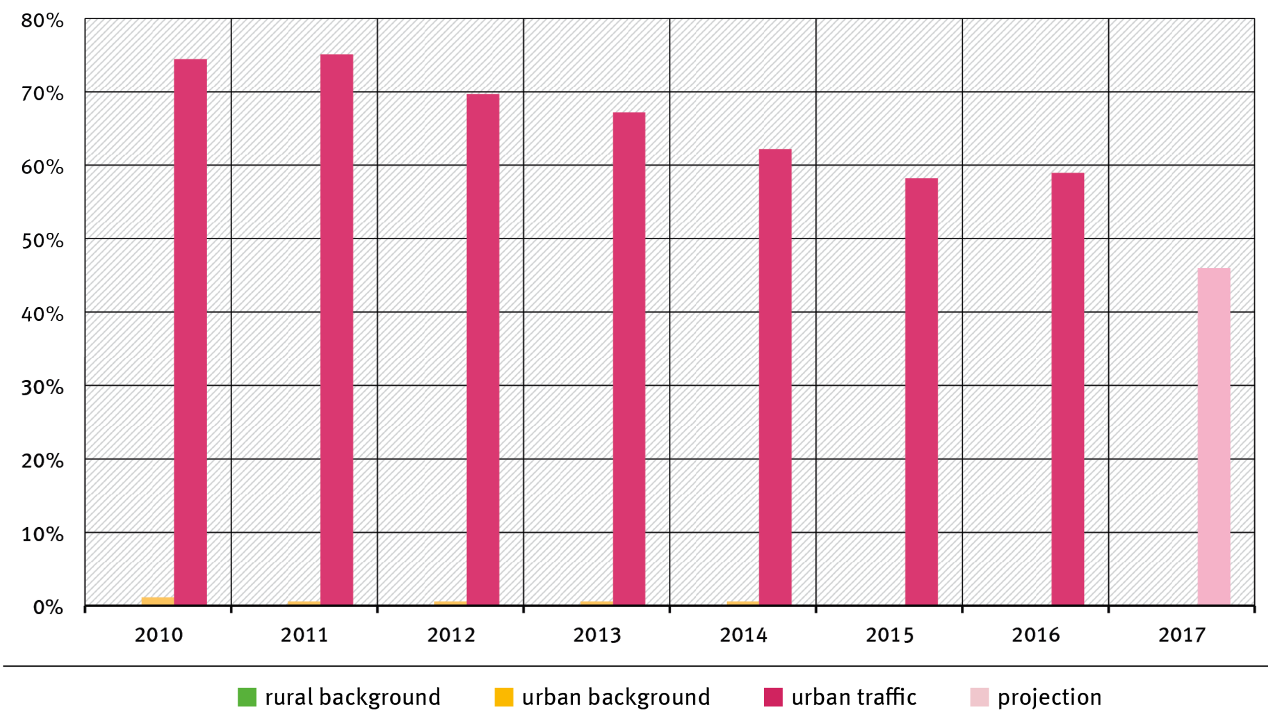
The nitrogen dioxide pollution shows a fall in the last ten years (figure 7). In order to minimize the influence of the closure or opening of stations on the development of the average NO_2 values only air monitoring stations were selected that conducted measurements over an extended period. The levels of pollution are

Passive collector: A passive collector is a small monitoring device which operates without electrical power and in which several detection tubes absorb the pollutants from the air. The detection tubes are regularly removed and their contents evaluated in the laboratory.

Figure 6

Percentage share of air monitoring stations exceeding the NO_2 limit value for the annual mean

in the corresponding pollution regime, time frame 2000–2017

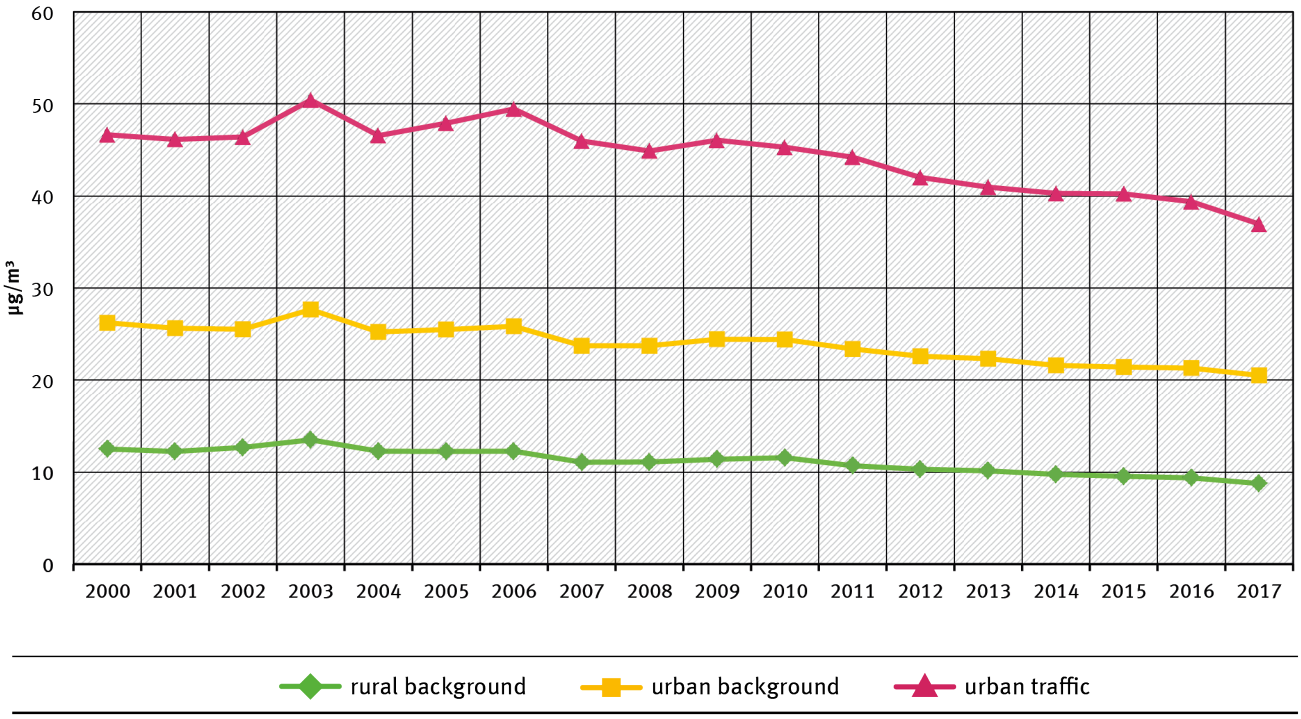


Source: German Environment Agency (UBA) 2018

Figure 7

Development of the annual mean NO_2 values via selected air monitoring stations

in the corresponding pollution regime, time frame 2000–2017



Source: German Environment Agency (UBA) 2018

primarily determined by local emission sources – particularly the traffic in urban conurbations – and only show limited inter-year variations.

In rural areas, which are a long way from the major sources of NO_2, from 2000–2017, the average annual concentration for all the air monitoring stations only amounted to 10 µg/m³ (figure 7, green curve). At the air monitoring stations with an urban background, the values were well below the limit of 40 µg/m³ (figure 7, yellow curve).

Like in the previous year, the average NO_2 concentration at urban traffic air monitoring stations fell below 40 µg/m³. With values of 45 µg/m³ the average NO_2 value at urban traffic locations between 2000–2011 (figure 7, red curve) exceeded the limit with which compliance has been required since 2010 by approx. 5 µg/m³.

But that is not an all-clear signal, because annual mean values of over 40 µg/m³ were measured at many air monitoring stations and cases in which the limits were exceeded were therefore recorded.

Figure 8 shows the NO_2 annual values of all air monitoring stations in urban traffic locations in descending order. The gaps result from the missing data of the passive collectors, arranged in order of the 2016's data. It becomes clear that there are big differences between the monitoring stations: Some stations exceed the limit value of 40 µg/m³ slightly, whereas other stations exceed nearly twice the limit value.

EU limit values

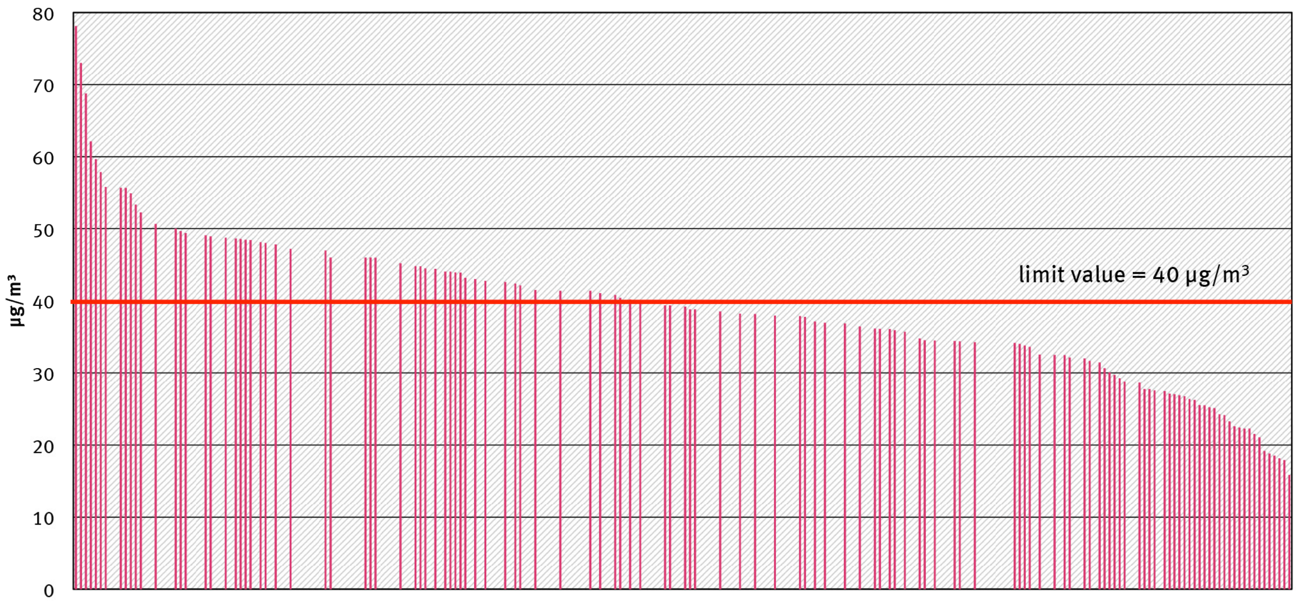
The annual mean NO_2 value must not exceed 40 µg/m³.

WHO recommendation

The WHO recommendation is equivalent to the EU limit value.

Figure 8

NO_2 annual mean values 2017
of all urban traffic monitoring stations



Source: German Environment Agency (UBA) 2018

2 NO_2 – One hour values

Since 2010, one hour NO_2 values exceeding 200 µg/m³ are only permitted a maximum of 18 times per year. In 2017, this value was not exceeded for the first time. In the previous years there used to be several exceedances at urban traffic stations.

13 percent of all air monitoring stations in urban traffic locations failed to comply with the WHO recommendation.

EU limit value
The one hour NO_2 values must not exceed 200 µg/m³ more than 18 times per year.

WHO recommendation
The one hour NO_2 values should never exceed 200 µg/m³.

IV Ground-level ozone: The clean air policy is taking effect – but no all-clear

1 O_3 – Target value for the protection of human health

After a dry period at the beginning of the summer, the weather was characterised by abundant rainfall and thunderstorms. The lack of sustained periods of high pressure led to an absence of periods with high concentrations of ozone. Anyhow, in contrast to the moderately warm north of Germany, it became very hot in the south.

In comparison with the last 20 years, the concentrations were quite low.

A 3-year period is monitored for the target value for the protection of human health: on average, an 8-hour average value of 120 µg/m³ may only be exceeded on 25 days. In the most recent averaging period of 2015 to 2017, however, 17 percent of the air monitoring stations exceeded this value. Figure 9 shows that most cases in which the target values were exceeded occurred in rural areas – in contrast to pollutants such as particulate matter and nitrogen dioxide, which have the highest concentrations in the vicinity of roads, the ozone values in the vicinity of roads are a lot lower. Therefore, ozone is rarely measured at air monitoring stations in urban traffic locations.

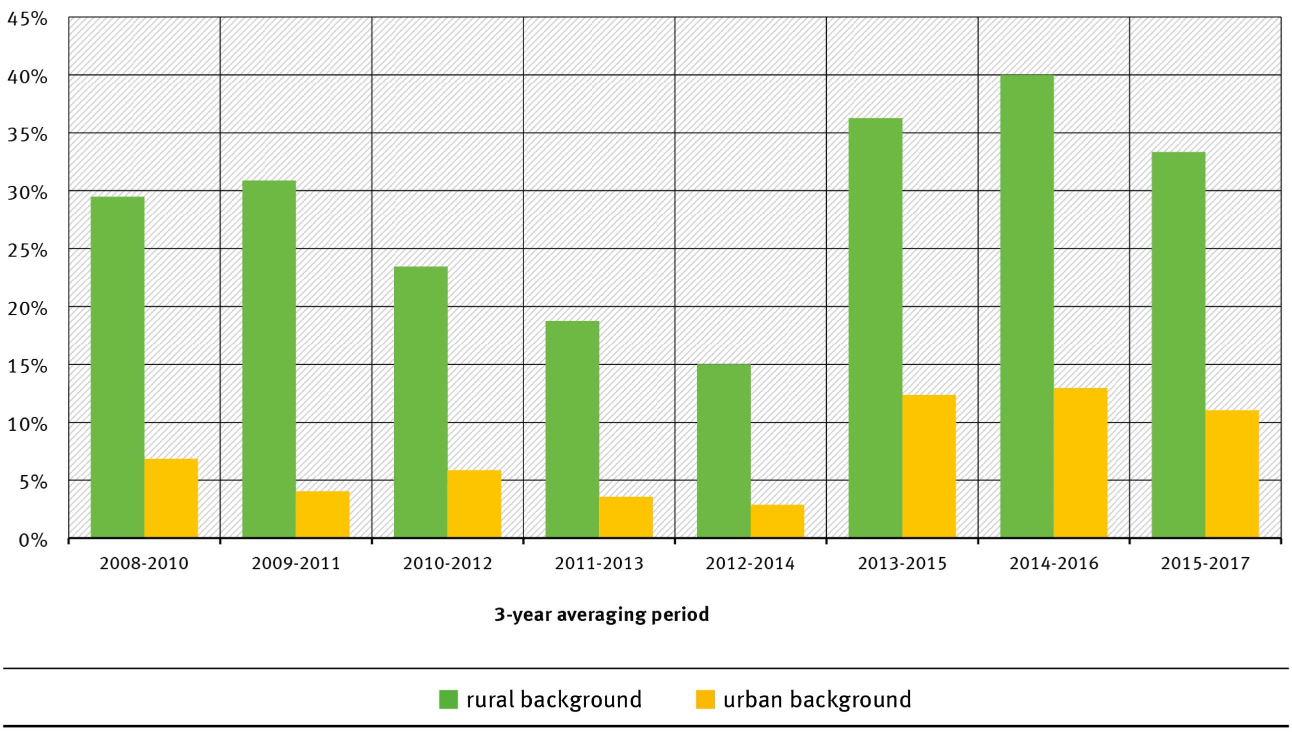
2 O_3 – Information and alert threshold

The highest 1-hour average value amounted to 238 µg/m³, therefore the alert threshold of 240 µg/m³ as an average hourly value was not exceeded. The information threshold of 180 µg/m³ was exceeded on 7 days. This means that the summer of 2017 was one of those with the lowest of levels of ozone pollution.

Figure 10 shows that the exceedances of the information threshold vary in a wide range, the record-breaking summer of 2003 sticks out clearly. But also the year 2015 was characterised by a higher ozone pollution

Figure 9

Percentage share of air monitoring stations recording an exceedance of the target value
for the protection of human health, time frame 2010–2017 (in each case, 1-year moving average over 3 years)



Source: German Environment Agency (UBA) 2018

than 2017. The reason for this variation is the high dependency on the weather conditions. In contrast to particulate matter and NO_2, ozone is not emitted directly but formed from specific precursors and with intensive solar radiation. When there are several days of summery high-pressure weather conditions, ozone can be accumulated in the lower atmospheric layers which leads to high concentrations.

By the year 2016 in comparison with 1990, the emissions of ozone precursors such as nitrogen oxides (i.e. from road traffic and furnaces) fell by 58 percent and volatile organic compounds (i.e. from paints, varnishes and cleaning agents) fell by 69 percent in Germany.

3 O_3 – Long-term objective

The efforts made by Germany to further reduce the emissions of ozone precursors must nevertheless be continued, because the long-term objective for the protection of human health (120 µg/m³ as 8-hour average value) is not complied with throughout Germany. In 2017, 8-hour average values of over 120 µg/m³ were measured at 241 air monitoring stations (= 95 percent).

Figure 11 shows the average number of days with exceedances of the long-term objective. Rural areas are slightly more affected than urban areas. For this development only air monitoring stations were selected that conducted measurements over an extended period. The recommendation of WHO that the 8-hour average values should not exceed the value of 100 µg/m³ was missed.

4 O_3 – Protection of the vegetation

According to the EU Air Quality Directive, to determine the target values for the protection of the vegetation (AOT40), only the data from the around 160 air monitoring stations in non-urban locations is considered. For the target value (which has been mandatory since 2010), an averaging over a five-year period is required. The target value (18,000 µg/m³ h obtained from May to July) for the most recent averaging period of 2013 to 2017 was exceeded at 20 air monitoring stations (= 12 %, previous year: 12 air monitoring stations = 7 %). Over the last ten years, only few exceendances have been recorded. This improvement does not mean that risks to vegetation no longer occur, however. According to the currently valid methodology, the critical threshold for adverse effects on vegetation amounts to the sum of the average target value (6,000 µg/m³ h, obtained from May to July), which was exceeded at 139 of the 159 air monitoring stations in 2017 (= 87 %; previous year: 98 %). The methods of the impact evaluation of ozone are currently undergoing development in Europe. In this respect, it isn't just the concentration of ozone, but the meteorological conditions, the opening characteristics of the stomata of the plants and therefore the ozone flux into the plants, which are taken into account (PODy method, Phytotoxic Ozone Dose).

Information threshold
With ozone values of over 180 µg/m³ (1-hour average value), the general public is notified by the media of the presence of a health risk for particularly sensitive sections of the population.

Alert threshold
With ozone values of over 240 µg/m³ (1-hour average value), the general public is warned by the media of the presence of a general risk to human health.

Target values for the protection of human health
Ozone values of over 120 µg/m³ (highest daily 8-hour average value) are only permitted to occur on a maximum of 25 days per calendar year, averaged over 3 years. Over the long term, the 8-hour average values should never exceed 120 µg/m³ (long-term objective).

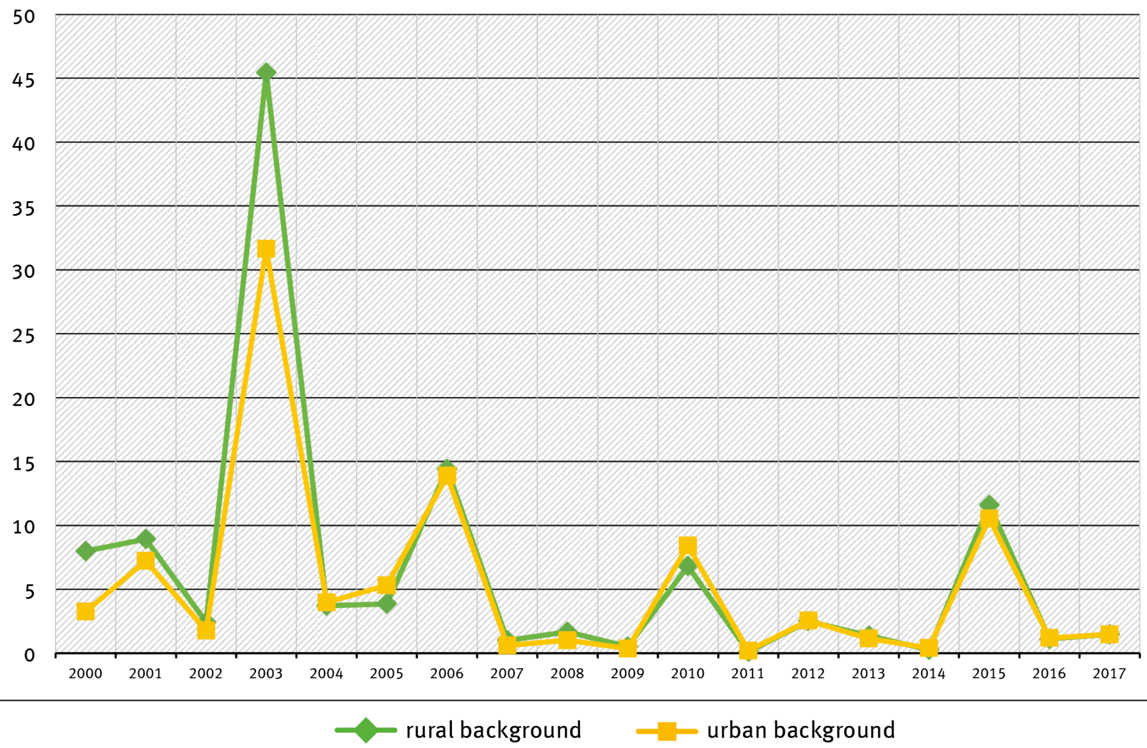
WHO recommendation
The 8-hour average values should never exceed 100 µg/m³.

Target values for the protection of vegetation (AOT40)
The term AOT40 (Accumulated Ozone exposure over a Threshold of 40 parts per billion) designates the total sum of the differences between the 1-hour average values exceeding 80 µg/m³ (=40 ppb) and the value 80 µg/m³ between 8am and 8pm in the months of May to July. Since 2010, as 5-year average, the AOT40 target value should not exceed a value of 18,000 µg/m³ – i.e. 9,000 ppb h and/or 9 ppm h. Over the long term, the value should not exceed a maximum value of 6,000 µg/m³ in one year – i.e. 3,000 ppb h and/or 3 ppm h.

Figure 10

Hours during which the information threshold (180 µg/m³) for ozone was exceeded

Average over selected monitoring stations

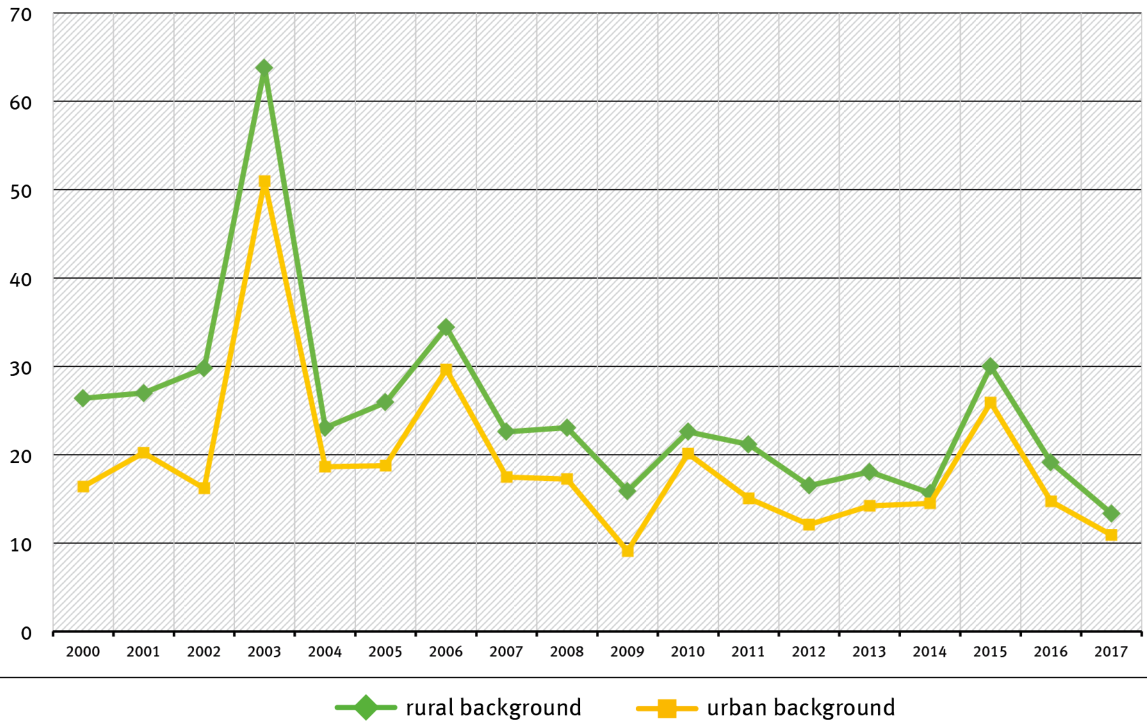


Source: German Environment Agency (UBA) 2018

Figure 11

Days during which the long-term objective (120 µg/m³ as 8-hour average value) was exceeded

Average over selected monitoring stations



Source: German Environment Agency (UBA) 2018

V Nitrogen dioxide pollution in urban areas and measures for its reduction

According to the evaluation of the measurement data on air quality for 2017, in many German cities, the limit value for nitrogen dioxide (NO_2) was exceeded. The cases of exceedance are exclusively concentrated in areas that are located in the vicinity of road traffic. For this reason, the measures for NO_2 reduction are related to this category of emissions.

1 Total nitrogen oxide emissions in Germany

Nitrogen oxides (NO_x) largely originate from combustion processes which are caused by human activities. The temporal development in figure 12 shows that there has been a decrease in total national emissions in the last 25 years. Amounting to 40 %, the primary cause of nitrogen oxides is road traffic. Another key source is the energy sector. Smaller amounts of nitrogen oxides are also emitted by industry and agriculture.

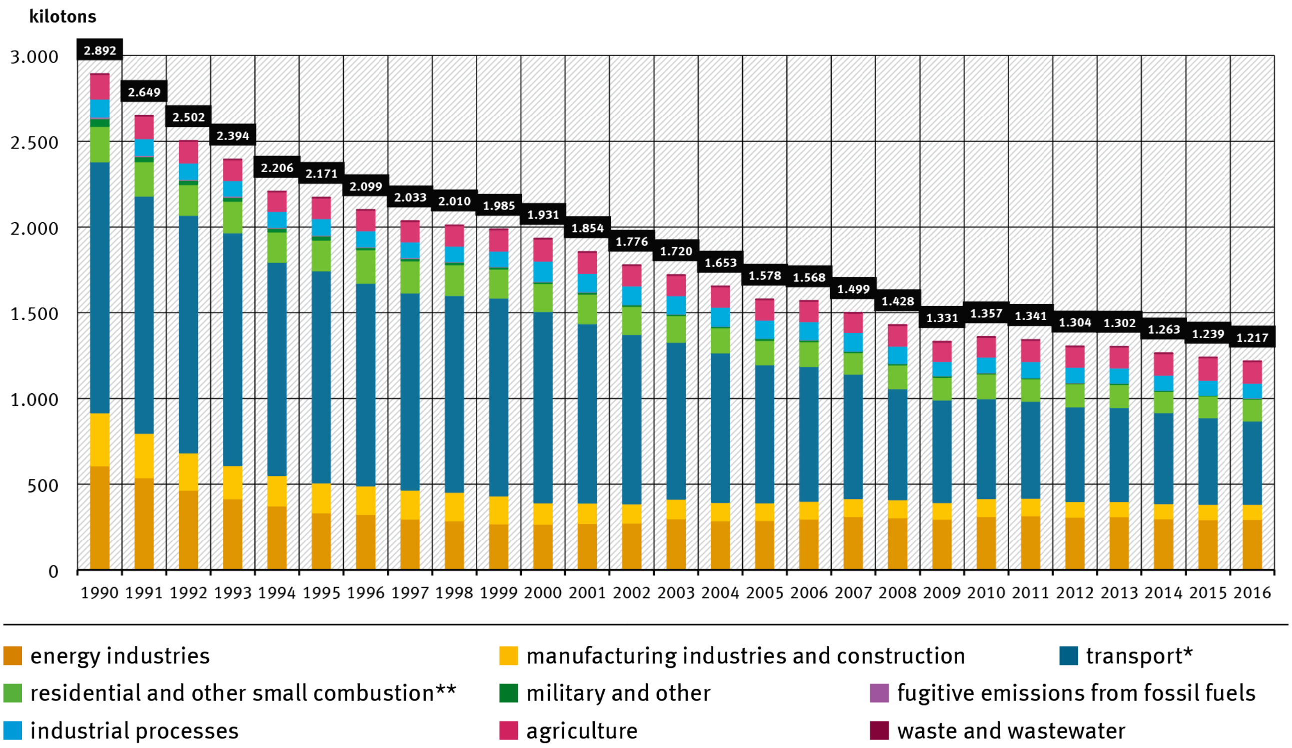
The cases in which the NO_2 limit value is exceeded at heavily used roads can therefore be primarily attributed to road traffic. Nitrogen oxides are released as NO or directly as NO_2. Within the source group of "road traffic", different categories of vehicles also contribute to the nitrogen oxide emissions to a different extent. In figure 13, it is evident that in 2016 half of the emissions can be attributed to diesel passenger cars. Depending on the fleet composition, this can vary strongly from one region to another.

Within the category of diesel passenger cars, vehicles with different emission standards also make very different contributions to the emissions of nitrogen oxide. Detailed information is available in the *Handbuch für Emissionsfaktoren* [Handbook Emission Factors] (HBEFA). Accordingly, the highest emissions of nitrogen oxides were from diesel passenger cars with the Euro 5 emission standard. Emissions from

Figure 12

Development of total nitrogen oxide emissions in Germany over the last 27 years

The contributions of the different sources are highlighted in colour

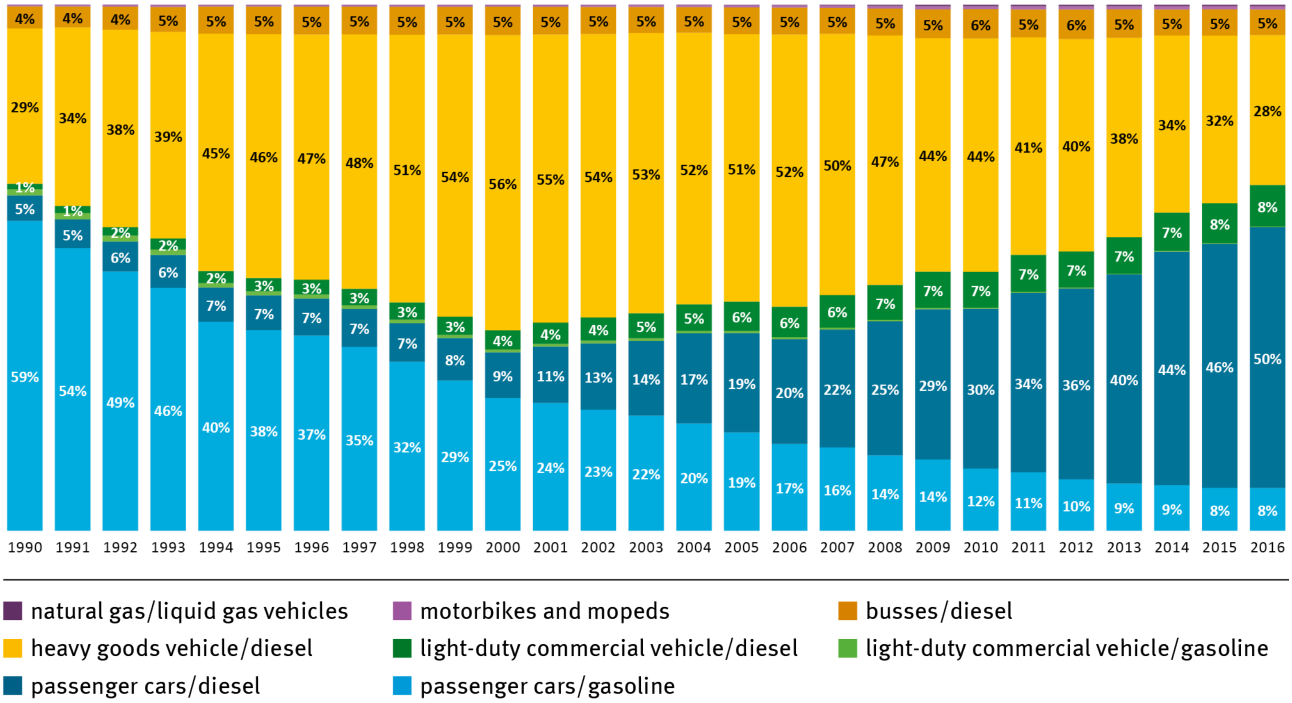


* excluding agricultural and forestry transport
** including agricultural and forestry transport

Source: German Environment Agency, National Trend Tables for the German, national trend tables for the German reporting of atmospheric emissions since 1990, emission trends 1990 to 2016 (as of 01/2018)

Figure 13

Contributions of different vehicle groups to NO_x emissions from road traffic



Source: German Environment Agency (UBA) 2018

the newer Euro 6 diesel passenger cars are somewhat lower, but with no substantial improvement. It is expected that the emissions of nitrogen oxides will only record substantial decreases with the introduction of the Euro 6d standard in two stages, in which the emissions tests also take place under real driving conditions (RDE). Since 1st September 2017, according to the Euro 6d Standard which has been valid from that date, new diesel passenger cars must comply with the emissions limit value of 168 mg/km under real driving conditions (Euro 6d-TEMP emission standard) for their successful registration. From January 2020 onwards, this value will be reduced to just 120 mg/km (Euro 6d emission standard).

2 Distribution of the NO_2 concentration in urban areas

Immediately after being released, nitrogen oxides are involved in a variety of chemical reactions in the atmosphere. Together with volatile hydrocarbons, they are responsible for the formation of ozone during the summer and also contribute to fine particulate matter pollution.

The distribution of the concentration in the urban background can be calculated with chemical transport models (CTM) which take several chemical conversion processes in the atmosphere into consideration. In this modelling approach, the area under consideration is divided into grid cells with edge lengths as low as a few kilometres.

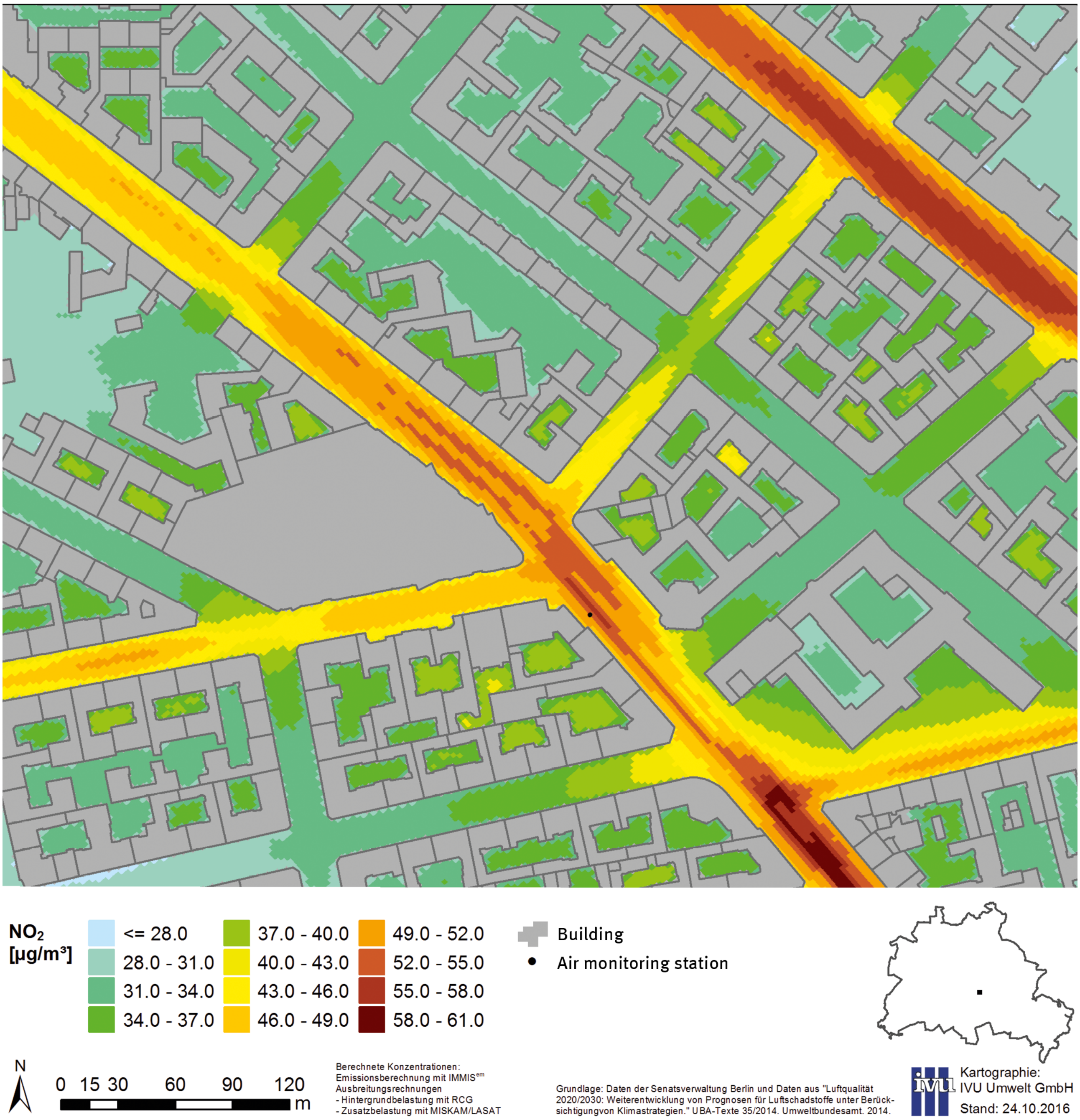
To be able to assess the concentrations of NO_2 in the immediate vicinity of a road in an urban area, it is necessary to apply a modelling approach with a much higher resolution. The concentration distribution within a 500 m x 500 m sized model area in Berlin is shown in figure 14. These calculations were carried out for the year 2010 as part of the research project of Pfäfflin et al. (2017)[4]. In this case, the model area was also divided into grid cells, but with a grid size of just 2.2 m x 2.2 m. To simulate the transport of the pollutant within this small area, the MISKAM-LASAT model combination was used. Due to the shorter transport times from the source to the receptor in the area of the road, with detailed calculations of this kind, it is normally the case that only a limited set of the chemical transformation processes are considered. However, with such a model-based approach, it is also possible

4 F. Pfäfflin, V. Diegmann, L. Neunhäuserer, E. Reimer, R. Stern (2017): Urbane NO_2- und PM_{10}-Konzentrationen: Grundlagen für die Entwicklung einer modellgestützten und flächenbezogenen Beurteilung der Luftqualität, FKZ 3715 51 200

Figure 14

Average NO_2 concentration at the Karl-Marx-Straße in Berlin

for the year 2010 with a grid width of 2.2 m x 2.2 m



Source: F. Pfäfflin, V. Diegmann, L. Neunhäuserer, E. Reimer, R. Stern (2017): Urbane NO_2- und PM_{10}-Konzentrationen: Grundlagen für die Entwicklung einer modellgestützten und flächenbezogenen Beurteilung der Luftqualität, FKZ 3715 51 200

to detect the hotspots in which the limit values are exceeded in urban areas.

2.1 Estimation of roadside NO_2 pollution

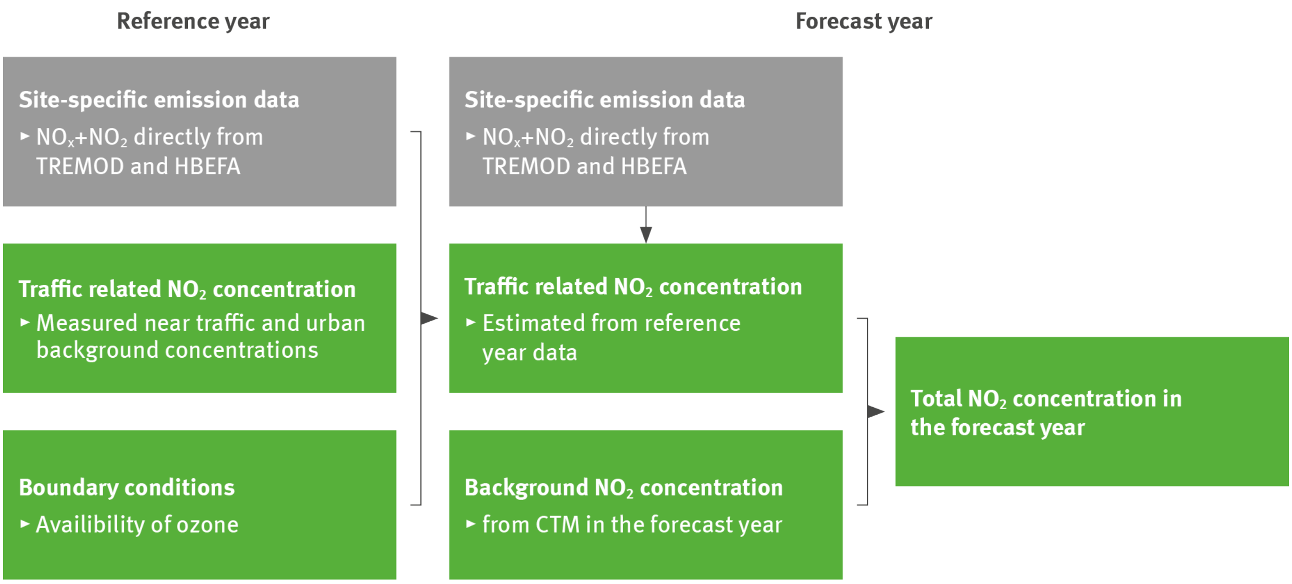
Since detailed models are very complex from a computational point of view, approaches are often chosen in which the relationship between the emissions and the NO_2 concentration is simplified. An approach of this kind was used to estimate roadside NO_2 pollution in the study by Stern (2013)[5]. The objective of this study was to forecast the concentrations of NO_2 at differing heavily used roads in Germany.

5 R. Stern (2013): Prognose der Luftqualität und Abschätzung von Grenzwertüberschreitungen in Deutschland für die Referenzjahre 2010, 2015 und 2020

Figure 15

Schematic presentation of the methodology according to Stern (2013)

for estimating roadside NO_2 concentrations for a specific forecast year



Source: German Environment Agency (UBA) 2018

A schematic presentation of the methodology is provided in figure 15. The key input data are NO_x and direct NO_2 emissions from road traffic at the road section under consideration and in the reference year. These are estimated from the traffic counts, the fleet composition and the emission factors from HBEFA. These emissions lead to a road traffic-related proportion of airborne NO_2, which is also known as the traffic increment. This increment therefore consists of the NO_2 which is released directly by vehicles and the proportion which is formed from NO due to chemical reactions in the atmosphere. Since this proportion from the atmospheric chemical reaction also depends on the ozone concentration, data from this pollutant are also taken into consideration.

As in the reference year, for the forecast year estimations of the expected emissions in the road section are also required. For this purpose, data regarding the development of the future emissions and road traffic from the TREMOD (Transport Emission Model) approach are applied to the road section. With the information from the reference year, it is then possible to estimate the additional NO_2 concentration increment due to road traffic in the forecast year. Finally, to be able to estimate the future overall concentration in the road section, the forecast for NO_2 background concentration is also required. This can be taken from regional model calculations with CTM for the forecast year.

3 Evaluation of the effectiveness of actions to reduce the NO_2 concentration

The methodology described in 2.1 was used to estimate the change in the roadside concentration of NO_2 on the basis of the decisions of the National Diesel Forum in August 2017. These decisions aim to achieve a reduction in the road traffic emissions. To investigate the effects of these decisions on the future NO_2 concentration, UBA considered two scenarios of emission reduction. These scenarios relate to the software updates of Euro 5 and Euro 6 diesel passenger cars and the exchange of diesel passenger cars with the Euro 4 emission standard or older for new diesel or petrol passenger cars. Estimations of the emissions and immisions were carried out for a location with an exceptionally high NO_2 concentration (the Landshuter Allee in Munich, annual mean value in 2016: 80 µg/m³), and for a location with a somewhat lesser average NO_2 concentration (the Parcusstraße in Mainz, annual mean value in 2016: 53 µg/m³).

3.1 Emission scenarios

The NO_x and NO_2 emissions for each location, the Landshuter Allee in Munich and the Parcusstraße in Mainz, were calculated on the basis of the HBEFA (v3.3) using the local road traffic counts, the fleet composition and the driving situations. The proportion of vehicles with different emission standards were adopted from TREMOD. At the Landshuter Allee, a total of 130,025 motor vehicles per day was taken as the basis. At the Parcusstraße in Mainz, a total of 21,685 motor vehicles per day was applied. Using these input data, the emissions for the actual situation were then derived.

The impact of the scenarios for the year 2020 was considered in the second step. On this basis, it was assumed that until 2020, no changes will occur to the driving situations or the traffic counts. TREMOD provides the development of the proportions in the different vehicles and emission standards on the basis of the Germany-wide average. To depict the scenarios on the software update and the exchange of old diesel passenger cars, the composition of the fleet in the different vehicle categories as well as the emission factors were modified.

The fact that the exchange of old diesel passenger cars has seen buyers bringing their purchasing decisions forwards – and therefore the registration of fewer Euro 6d TEMP vehicles – was also taken into consideration. The background to this is that EURO 6 a/b/c vehicles are now being purchased that would otherwise have been bought at a later date as EURO6d-TEMP. A summary of all the scenarios observed is provided

Tab. 1

Description of the software updates (SU) and exchange (R) scenarios and their combination

Summary of the emission scenarios regarding the software update (SU) with the number of vehicles and the assumed impact of the update in terms of emission reduction. The scenarios on the exchange of old diesel passenger cars (R) are also listed with the proportion of vehicles to be replaced by the Euro 6 a/b/c, Euro 6 petrol vehicles or Euro 6d-TEMP.

SU1	**5 million** (3.5 million Euro 5; 1.5 million Euro 6)	**25 %**		
SU2	**3.75 million** (3 million Euro 5; 0.75 million Euro 6)	**15 %**		
R1			**75 % of diesel Euro 1–4**	**by diesel** Euro 6a/b/c
R1_2			**75 % of diesel Euro 1–4**	**by diesel** Euro 6d-TEMP
R2			**25 % of diesel Euro 1–4**	**by diesel** Euro 6a/b/c
R2_2			**25 % of diesel Euro 1–4**	**by diesel** Euro 6d-TEMP
R3			**25 % of diesel Euro 1–4**	**by diesel** Euro 6a/b/c & gasoline Euro 6
SU1R3	**5 million** (3.5 million Euro 5; 1.5 million Euro 6)	**25 %**	**25 % of diesel Euro 1–4**	**by diesel** Euro 6a/b/c & gasoline Euro 6
SU2R2	**3.75 million** (3 million Euro 5; 0.75 million Euro 6)	**15 %**	**25 % of Diesel Euro 1–4**	**by Diesel** Euro 6a/b/c

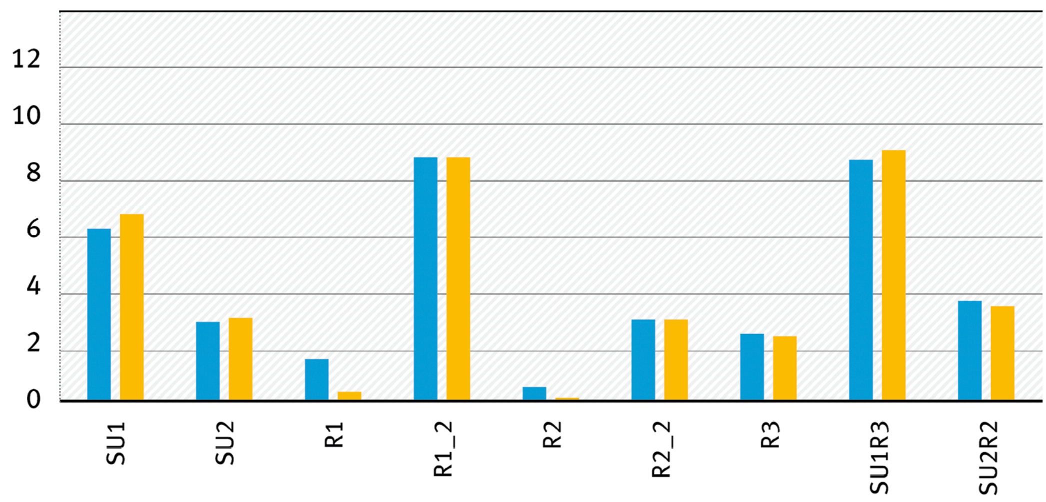
in Table 1. As an example, for the SU1 scenario, it is assumed that throughout Germany, some 3.5 million Euro 5 and 1.5 million Euro 6 vehicles receive an update, which leads to a 25 % reduction in emissions. This is equivalent to half of the current fleet of Euro 5 and the Euro 6 diesel passenger cars in Germany.

The percentage reductions in emissions for the scenarios from table 1 are shown in figure 16. The results only show limited differences between the locations in Mainz and Munich. The calculated effect of the software updates totals up to 7 % (SU1). The effect is considerably diminished if the owners decline the updates (e.g. only 3.75 million instead of 5 million), or the emission reduction due to the update is smaller (15 % instead of 25 %).

The impact of the exchange of old diesel passenger cars is estimated to be lower than that of the software update, particularly in cases in which the replacement is not a low emissions vehicle. For example, if a changeover to a newer diesel passenger car with emission standard Euro 6 a/b/c takes place for 75 % of old diesel passenger cars, this results in a maximum emission reduction of 3 % (R1). However, if it were possible for 75 % of Euro 4 diesels to be replaced by 6d TEMP diesels, the biggest reduction in emissions would be achieved, totalling up to 9 % (R1_2). A combination of optimistic assumptions regarding the software updates and an exchange for petrol vehicles (SU1R3) achieves a similarly strong reduction.

Figure 16

Percentage NO_x reduction of the software updates (SU) and exchange (R) scenarios and their combination* compared to the reference scenario



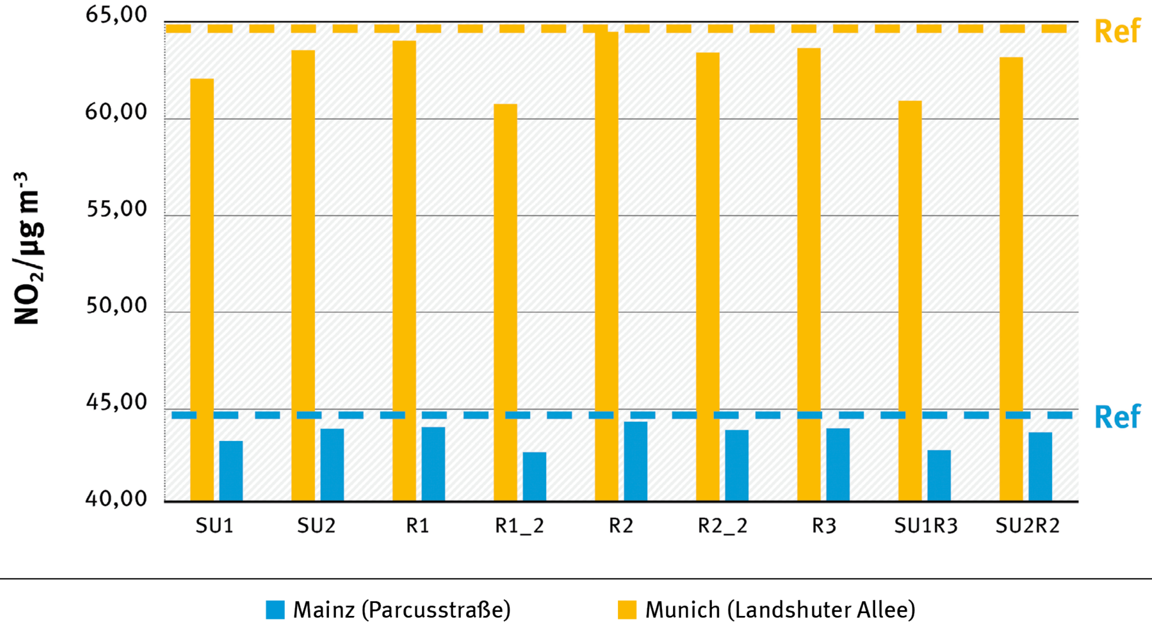
* For a detailed description of the scenarios see Table 1

Source: German Environment Agency (UBA) 2018

Figure 17

Estimated NO_2 concentration in the year 2020 with software updates (SU) and exchange (R) scenarios and their combination*

Reference scenario (without measures) as dashed line



* For a detailed description of the scenarios see Table 1

Source: German Environment Agency (UBA) 2018

3.2 Roadside NO_2 concentration

In the year 2016, the average concentration at the Parcusstraße in Mainz amounted to 53 µg/m³, while the same figure at the Landshuter Allee in Munich amounted to 80 µg/m³. The model calculations with the methodology described in section 2.1 show that in the reference case scenario – i.e. without the measures resulting from the diesel forum – the concentration at the Landshuter Allee in the year 2020 will still amount to 65 µg/m³, and that at the Parcusstraße to 44 µg/m³ (figure 17).

The estimation of the impact of the reductions in the emissions demonstrated that with the software update (SU1), the concentration at the Landshuter Allee can be reduced by an additional approx. 3 µg/m³ to 62 µg/m³. In the case of the exchange scenarios changing to Euro 6a/b/c or to Euro 6a/b/c and petrol passenger car, a very limited impact is evident, with a reduction of roughly 1 µg/m³ at the Landshuter Allee. At the Parcusstraße in Mainz, the absolute reduction of NO_2 is even lower.

If, as is the case in scenario R1_2, a large proportion of the old diesel passenger cars are exchanged for Euro 6d-TEMP diesel, this results in the biggest potential reduction, of approx. 5 µg/m³ at the Landshuter Allee and 2 µg/m³ at the Parcusstraße. A similar reduction potential can be expected from the combination of software updates with 75 % of the Euro 5 and Euro 6 diesel passenger cars and the exchanging of 25 % of the older diesel passenger cars in the SU1R3 scenario. In summary, it can be concluded that the expected reductions in concentration are rather low when compared with the level to which the limit values are exceeded. In this case, it would not be possible to comply with the NO_2 limit value of 40 µg/m³ for any of the scenarios in the year 2020 either at the Parcusstraße in Mainz or at the Landshuter Allee in Munich.

Further information on the topic

Current air quality data:
https://www.umweltbundesamt.de/en/data/current-concentrations-of-air-pollutants-in-germany#/start?_k=rkzblq

Air and air pollution control website:
https://www.umweltbundesamt.de/en/topics/air

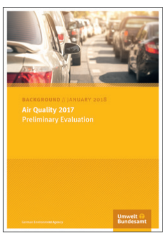
UBA map service on air pollutants:
http://gis.uba.de/Website/luft/index.html

Development of air quality in Germany:
http://www.umweltbundesamt.de/luft/entwicklung.htm

Information on the air pollutant PM_{10}:
https://www.umweltbundesamt.de/en/topics/air/particulate-matter-pm10

Information on the air pollutant NO_2:
https://www.umweltbundesamt.de/en/topics/air/nitrogen-dioxide

Information on the air pollutant ozone:
https://www.umweltbundesamt.de/en/topics/air/ozone



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