



Long-Term Development of Air Quality

03.12.1 Immissions /

03.12.2 Emissions

Overview

For a detailed and complete representation of the long-term development of air pollution in Berlin, numerous separate maps are presented, which

- both evaluate the findings of the **Emissions Register** since 1989 (in a grid of 1x1 km),
- and display all available measurements of the Berlin Clean Air Measurement Network **BLUME** for selected parameters (annual mean values, and/or exceedance of limit or target values) since measuring began in 1975. This includes both the data of automatic stations and the measurements of the small sampling devices (soot and benzene immission collectors (RUBIS) or passive collectors) that were put into operation later.

This air quality archive contains the results of data gathering for particular parameters and measurement stations over a period of more than 45 years.

The Emissions Register for industry, domestic heating and transport, which was developed in 2015, unites the previously separate presentations of the individual polluter groups in one map. This map, titled "Emissions 2015", is available in the Geoportal (cf. Map view).

Emissions

In order to comply with air pollution limits, suitable measures for reducing air pollution permanently should be taken. These measures should address any polluters that contribute to exceeding the immissions limits, based on the principle of proportionality and the pollution share. This requires detailed knowledge of all Berlin emissions. Article 46 of the BImSchG thus stipulates the keeping of an emissions register.

Dispersion calculations based on this register are used to determine the share of the individual polluter groups contributing to the measured air pollution.

The emissions of the relevant pollutants **nitrogen oxide** (NO_x) and particulate matters (PM₁₀, PM_{2.5}) are determined for the following polluter groups for the period 1989 to 2015:

- plants requiring a permit (**industrial plants**)
- heating systems not requiring a permit (**domestic heating, small business**)
- **motor vehicle traffic**

On the basis of the emissions data for the two air parameters nitrogen oxide (NO_x) and particulate matters (PM₁₀, PM_{2.5}) comparably available on all polluter groups, the present maps illustrate the development since 1989. In order to do justice to current developments, the following changes have been taken into account for the survey year 2008/2009:

- First, sulphur dioxide (SO₂) emissions are no longer shown, since SO₂ has for years stagnated at a low level, and is no longer relevant for clean air.
- Second, observation series have been initiated in the Environmental Atlas with regard to the emissions of PM₁₀ and PM_{2.5}. This is called for by their great relevance for public health, and the fact that air quality limit values have been exceeded.

The data from the 2015 Emissions Register also served as the basis for the second update of the [Air Quality Plan](#), which describes the additional measures to further improve air quality and to reduce as far as possible the period and extent of exceedance of the limit values.

Immissions

The European guidelines for air quality list a large number of substances which burden the atmosphere especially strongly due to increased anthropogenic production. Throughout the EU, it is necessary to monitor and decrease this extensive phenomenon, and to restrict the environmental damage it causes. The **Ambient Air Quality Directive 2008/50/EC** contain specific immissions values as limits or thresholds, and also target values which are to be attained within a certain period. These values are oriented toward those of the World Health Organisation (WHO), to limit the impairment to human and animal health, and to protect the flora and fauna from environmental hazards (cf. Tab. 2).

The EU Air Quality Directive has been implemented into national law in Germany as the **Federal Immission Protection Law** (BImSchG) and the 39th Ordinance for the Implementation of the Federal Immission Protection Law. Pursuant to Articles 44 - 46a of the BImSchG, under which Berlin is mandated to measure and to publish the measurement results for all atmospheric parameters which may be dangerous for human beings and/or nature. These include: particulate matters (PM₁₀ and PM_{2.5}), nitrogen dioxide (NO₂), nitrogen oxide (NO_x), carbon monoxide (CO), and ozone (O₃). For most of these atmospheric parameters, there are limit values and supplementary tolerance margins (i.e., a sliding scale of annual steps towards the limit). If these limits are exceeded, measures must be taken to reduce immission concentrations. This includes the above mentioned second update of the [Air Quality Plan](#) in particular, which details the required measures.

Special attention must be paid to all polluters and emissions, which contribute (significantly) to immissions values being exceeded.

To summarise, these immissions values calculated for the Berlin air provide a basis for:

- the calculation of statistical values of the atmospheric pollution load for evaluating the air quality by means of limit and target values,
- the determination of the pollutant load for permit procedures under the Technical Instructions on Air Quality Control (TA Luft),
- investigation into the causes of atmospheric pollution load,
- investigation of the effectiveness of measures to clean the air, and,
- providing information for the public.

Statistical Base / Methodology

The German Federal States are mandated to record their air pollution continuously and to reduce emissions sustainably under Article 44 Para. 1 of the Federal Immission Protection Law (BImSchG) and the 39th BImSchV. Berlin meets these requirements comprehensively, both in terms of recording and evaluating emissions and in terms of monitoring air pollutants.

Since 1975, the **atmospheric pollution load** in Berlin has been monitored continuously with the aid of the [Berlin Clean Air Measurement Network](#) (BLUME, only in German) of the Senate Department for the Environment, Urban Mobility, Consumer Protection and Climate Action. Currently (as of December 2022), the measurement network consists of 17 fixed measurement stations which measure air pollutants for air quality assessment purposes. In addition, a separate station for internal investigations is in operation. Every five minutes, each station measures all air pollutants and transfers the results to the Control Centre on Brückenstrasse (borough of Mitte); from this, characteristic values incl. half-hourly, hourly and daily values are calculated forming the basis for further analyses.

The [Report on the Emissions Register 2015](#) (pdf, 8 MB, only in German) details the statistical bases and methods for updating **emissions** in the State of Berlin. There is therefore no reason to repeat them here. All measuring and gathering of data on immissions is performed by the Berlin Clean Air Measurement Network (BLUME).

Since road traffic for most pollutants accounts for a considerable proportion of the immission load, the automatic monitoring network has been supplemented with additional measurements since the mid-90s. These involve small sampling devices attached to streetlamps (soot and benzene immission collectors

= RUBIS) and passive collectors, especially in areas with high traffic volumes lacking the space to operate measuring containers. These are additionally used to estimate the elemental and organic carbon (EC and OC) pollution at 23 locations in the Berlin city area every two weeks; the nitrogen oxide pollution is gauged at more than 30 locations (as of December 2022). Further information and [monthly updates](#) are published in addition to the annual updates of the Environmental Atlas Map. A separate website "[Berliner Luftgütemessnetz](#)" (Berlin Clean Air Measurement Network, only in German) was set up in addition, providing access to both current and archived data, which may be viewed or used further. The automatically collected data may also be accessed [via the app](#).

Map Description

Emissions

A single map consolidates all data collected by the **Emissions Register** since 1989, resulting in a detailed and complete representation of the long-term development of emissions in Berlin. During emissions calculations in 2015, the analysis of relevant polluters was extended significantly. This limits the comparability of emissions by heating systems with those measured in previous years. A new emissions report was drawn up to calculate emissions in 2015. In addition to the previous analysis of statistical parameters, this report includes a survey and considers a multitude of stakeholders. The [final report](#) (only in German) is available on the website of the Senate Department for the Environment, Urban Mobility, Consumer Protection and Climate Action.

The individual layers of Map [03.12.2 Long-Term Development of Air Quality – Emissions](#), grouped into pollutants and polluter groups, illustrate which polluters account for the largest share of emissions of each parameter and in which areas of Berlin.

Analysis of the long-term development of air quality

- Since 1989, all emissions have been greatly reduced, with reductions of between 73 % for nitrogen oxide and 96 % for sulphur dioxide. PM₁₀ emissions dropped by 86 % over this period.
- The total amount of all **industrial plants** requiring a permit has decreased significantly since 1989. This decrease can be explained by plant closures based on the changed political and economic situation and by a change in legal regulations regarding mandatory permits for many of the smaller plants. The emissions of these plants have since then either been assigned the domestic heating or small business source group. Regarding plants requiring a permit (industry) in the State of Berlin, both heat and energy production, and the food and beverages industries are main causes of NO_x emissions (cf. AVISO 2016, p.23).
- In the area of **domestic heating**, which covers not only apartments, but also small business incl. doctors' practices, lawyers' offices etc., an impressive decrease in emissions has been achieved, thanks to an increase in pipeline-based energy sources, instead of the formerly predominant brown coal. This is especially obvious with regard to the former lead parameter for air pollution, sulphur dioxide (SO₂). The energy-oriented rehabilitation of the old building stock, sponsored by the State of Berlin since 1990 in an exemplary manner, has contributed to this considerably. With regard to the spatial distribution structure of the emissions from heating systems not requiring a permit (domestic heating, small business), a similar picture emerges for the pollutants NO_x, PM₁₀ and PM_{2.5}: the highest emission densities occur in Berlin's city centre, i.e. in the boroughs of Charlottenburg-Wilmersdorf, Tempelhof-Schöneberg, Friedrichshain-Kreuzberg and Pankow (cf. AVISO 2016, p.81).
- Meanwhile, **traffic** is the main cause of nitrogen oxide. In 2015, road traffic alone accounted for more than 37 % of the nitrogen oxide emissions in Berlin, while industrial plants caused less than 36 % of the total of these emissions. Since the pollution emitted by road traffic enters the atmosphere close to the ground (or "close to the nose"), it contributes greatly to air pollution (further information: [nitrogen dioxide](#), only in German).

Table 1: Emissions in Berlin by polluter groups, 1989 to 2015

	Data in tonnes per year (t/a)					
	1989	1994	2002	2005	2009	2015
Sulphur dioxide	70801	17590	7158	4666	3838	2997

Plants requiring a permit	60470	10870	4433	2899	2319	2372
Domestic heating, commerce, trade, services	8601	4960	2460	1563	1339	590
Traffic (only motor vehicles)	1440	1400	55	16	13	13
Other traffic (rail, waterways, air)	140	140	75	68	54	17
Other sources	150	220	135	120	113	5
Nitrogen oxide	70369	42333	22043	19787	18718	18223
Plants requiring a permit	43531	16169	6494	6035	6590	6088
Domestic heating, commerce, trade, services	3904	3820	3045	3105	2934	1994
Traffic (only motor vehicles)	20034	18944	10590	9032	7613	7077
Other traffic (rail, waterways, air)	1400	1300	900	652	641	1596
Other sources	1500	2100	1014	963	940	1468
Carbon monoxide	293705	203948	76133	69701	57463	36510
Plants requiring a permit	32443	3888	1581	1521	1637	1726
Domestic heating, commerce, trade, services	70212	42360	8193	6068	5823	11276
Traffic (only motor vehicles)	182050	144200	51259	47767	36053	19433
Other traffic (rail, waterways, air)	4000	3500	3100	2945	2950	861
Other sources	5000	10000	12000	11400	11000	3214
Particulate matter (PM₁₀)	17580	8804	4199	3854	3135	2526
Plants requiring a permit	9563	3161	650	384	152	142
Domestic heating, commerce, trade, services	2943	1368	285	245	353	241
Traffic (only motor vehicles, exhaust)	1736	1135	394	355	225	110
Abrasion and resuspension caused by traffic	1200	1150	1050	1099	680	516
Other traffic (rail, waterways, air)	238	190	130	123	119	250
Other sources	1900	1800	1690	1648	1606	1267
Particulate matter (PM_{2.5})				2363	1834	1216
Plants requiring a permit				211	88	78
Domestic heating, commerce, trade, services				206	283	228
Traffic (only motor vehicles, exhaust)				337	225	110
Abrasion and resuspension caused by traffic				714	366	203
Other traffic (rail, waterways, air)				71	69	51
Other sources				824	803	546
Organic gases	103351	73703	26590	24033	22427	25620
Plants requiring a permit	11801	3473	1966	1596	824	576
Domestic heating, commerce, trade, services households, and other sources	38750	34340	14914	13547	13478	21058
Traffic (only motor vehicles)	49800	33890	8000	7300	6925	3760
Other traffic (rail, waterways, air)	3000	2000	1710	1590	1200	226

Tab. 1: Emissions in Berlin by polluter groups, 1989 to 2015

The particulate emissions from the exhausts of motor vehicles, which are a health hazard, have decreased by more than 90% between 1989 and 2015. One reason for this was the introduction of the environmental zone that included particulate filters, which resulted in a reduction in soot particles. This figure matches the diesel exhaust particulates measured in urban canyons, the main component of particulate emissions from exhausts. The measured concentration of diesel exhaust particulates at Measuring Container 174 of the Berlin Clean Air Measurement Network BLUME on Frankfurter Allee in the borough of Friedrichshain hence dropped by more than 50% during the period from 2000 to 2015 (cf. also the analysis of Map 03.12.1, [Station MC174](#), only in German).

However, since particulate emissions from tyre abrasion and resuspension caused by road traffic have been reduced far less over these 20 years than emissions caused by combustion processes, motor

vehicle traffic remains the second most important source of particulate emissions in Berlin, surpassed only by the “other sources” category. “Motor vehicle traffic”, including abrasion and resuspension, accounted for a share of 24 % of the PM₁₀ emissions in Berlin in 2015, while “other sources” accounted for 50 %. In the case of PM_{2.5}, the figures were 26 % and 45 %, respectively.

The atmospheric pollution load caused by road traffic in the inner-city area, where some 1 million inhabitants live in an area of approx. 100 km², is relatively high. Especially here, the demand and competition for space from a growing road traffic volume will increase, if current conditions continue. Particularly, road transport of goods will, given unchanged conditions, meet increasing capacity limits in road space.

For further information on the different types of emission, click [here](#) (only in German).

Immissions

Nitrogen monoxide and nitrogen dioxide are measured at all **measurement stations** (using the chemiluminescence procedure), dust of the PM₁₀ and PM_{2.5} fraction at twelve stations (by measuring the scattering of light by dust particles, ozone at eight stations (through absorption of UV radiation), carbon monoxide at two stations (through absorption of infrared radiation) and benzene at two stations (through gas chromatography). As of June 1, 2020, SO₂ is no longer measured using the reference method, as SO₂ levels have decreased dramatically over the last 30 years and the levels recorded in the last few years were below the detection limit of the reference measurement method to a large extent. According to the 39th BImSchV, the obligation to measure SO₂ does therefore no longer apply. Heavy metals and benzo(a)pyrene were additionally determined in the PM₁₀ fraction at two or four measurement stations, respectively.

The stations are distributed throughout the city in such a way that various spatial influencing factors can be ascertained. Of the 17 stations at which air pollutants are measured to assess the quality of the air, seven are located along heavily travelled streets, five in inner-city areas (both residential and commercial) and five at the periphery of the city or in forest areas. Additionally, special measurements are recorded along the A100 motorway, which are not used to monitor limits.

The staff of the Berlin Air Quality Monitoring Network analyse the samples collected at the 23 RUBIS sites at a laboratory and determine the benzene and soot levels. In addition, passive collectors are used at more than 30 locations in total to determine nitrogen dioxide levels and, in some cases, nitrogen oxide levels. Samples are collected over a sampling period of 14 days, which are then analysed at a laboratory. This manually generated laboratory data is only published upon completion of all quality assurance measures as an annual data set (incl. 2-week values, available in the [air data archive](#), only in German) and annual means in the annual mean reports, due to the delay between measurements and results caused by analysis, as well as long measurement intervals.

Every weekday around 11am, the **measured values** of the previous day, which are automatically determined by the measurement containers, are sent to several newspapers and radio and TV stations for public broadcast. Additionally, the data is published hourly or daily on the Internet, and may be accessed there, for example, under [Tageswerte des BLUME-Messnetzes](#) (“Daily values of the BLUME measurement network”; only in German). In the case of increased ozone concentrations in the city, this information is also broadcast to the public by some radio stations. As mentioned above, the “[Berliner Luftgütemessnetz](#)” (Berlin Air Quality Measurement Network) website offers a comprehensive range of data and analyses.

[Monthly and annual reports](#), which, in addition to an evaluation of the preceding measurement period, also contain site tables of the measurement stations and an overview of limit and target values, are also available online (only in German).

The results of the measurements of the last years allow the following conclusions to be drawn:

- Compared with the 1970s and '80s, the atmospheric burden of most air pollutants has been reduced by orders of magnitude. Thus, for example, sulphur dioxide concentrations have been reduced by > 90 %, and under no circumstances exceed the EU limit values for immissions. With regard to PM₁₀, the situation has improved significantly compared to the years at the beginning of this century. However, the PM₁₀ burden strongly depends on the meteorological conditions of propagation. In particular, high pressure conditions in winter with low southerly to easterly winds lead to a high accumulation of PM₁₀ particulates in the air in the Berlin area, some of which are brought to Berlin by long-distance transport and some of which originate from sources within the city, primarily road traffic and domestic heating. In the years with worse exchange conditions, such as 2009-2011 and also 2014, the annual mean PM₁₀ concentrations were slightly higher, whereas in the years with better exchange conditions, such as 2007 and

2008 as well as 2012, 2013, 2015, 2016, 2017 and 2019, they were correspondingly lower. The annual mean concentrations of PM₁₀ for 2021 detected at the stations of the automatic monitoring network were 15-17 µg/m³ in the suburbs, 16-19 µg/m³ in inner-city areas and 21-28 µg/m³ along heavily travelled streets. Therefore, the annual mean limit was not exceeded even at the measuring point with the highest load. Also, the short-term limit value for PM₁₀ (the daily mean must not exceed the value of 50 µg/m³ more than 35 times a year per measurement station) was not exceeded at any measuring point in 2021.

- As in the previous year, the annual mean limit of the 39th BImSchV (40 µg/m³) for NO₂, effective since 2010, was also complied with throughout Berlin. At the automatic measurement stations, the annual mean along streets ranged between 23 and 35 µg/m³ in 2021. All sites with passive collectors that meet the site criteria according to the 39th BImSchV also complied with the limit, albeit only narrowly in some cases with 40 µg/m³.
- Target values for [near-ground ozone](#) (only in German) were not exceeded at any station in 2021. The EU-wide target of a maximum of 25 days per calendar year with a maximum 8-hour value of above 120 µg/m³, averaged over the last 3 years, applies here. Since January 1, 2010, this target has to be met as far as possible.
- Improvements of the air quality have to do with many components. The deindustrialisation of Berlin, the modernisation of plants, the use of catalytic converters in vehicles, and the changeover to more low-emission heating fuels had an impact.

The detailed overview and compilation of the quality of Berlin's air is provided online [here](#) (only in German).

But since immissions are also influenced by supra-regional effects and weather events, an analysis of causes should not be carried out locally only, but should rather also investigate the immission of pollutants from outside, including cross-border transportation (cf. [Air Quality Plan, 2nd Update](#)).

For the present Map [03.12.1 Long-Term Development of Air Quality – Immissions](#), all available data collected in the measurement programmes described over the past **45 years** was compiled and prepared statistically and graphically with regard to the measurement year. For spatial distribution of current and former measurement stations and measurement points, the following data can be accessed for each station:

- address
- type of station
- description of neighbourhood (including photos)
- coordinates
- measurement parameters
- period of measurement
- measured values (as diagrams and as EXCEL tables).

The **stations** are divided into the categories traffic, residential area, industrial, suburban, and meteorological stations.

A total of **201 measurement stations** are presented, of which 58 were in operation in 2021 (17 BLUME measurement containers, one special measurement station, 23 RUBIS measurement points and 17 additional locations with passive collectors).

For the graphic representation of the development of the parameters total dust, particulate matter (PM₁₀), sulphur dioxide (SO₂), nitrogen dioxide (NO₂), nitrogen monoxide (NO), carbon monoxide (CO), benzene and ozone (O₃), the following limit and target values were referred to, which serve the purposes of health protection, unless otherwise stated:

Mean value for	Limit value	Compliance date
24 h	50 µg/m ³ PM ₁₀ 35 exceedances/year	since 01/01/2005
1 calendar year	40 µg/m ³ PM ₁₀	since 01/01/2005

1 calendar year	25 µg/m³ PM_{2.5}	since 01/01/2015
1 h	350 µg/m³ SO₂ 24 exceedances/year	since 01/01/2005
24 h	125 µg/m³ SO₂ 3 exceedances/year	since 01/01/2005
mean value, October - March (for the protection of ecosystems)	30 µg/m³ SO₂ 3 exceedances/year	since 01/01/2005
1 h	200 µg/m³ NO₂ 18 exceedances/year	since 01/01/2010
1 calendar year	40 µg/m³ NO₂	since 01/01/2010
1 calendar year (for the protection of ecosystems)	30 µg/m³ NO_x	since 01/01/2002
8 h	10 µg/m³ CO maximum 8-h mean of a day	since 01/01/2005
1 calendar year	5 µg/m³ benzene	since 01/01/2010
8 h (target value)	120 µg/m³ ozone maximum 8-h mean of a day 25 exceedances/ 3-year mean	since 01/01/2010
1 calendar year	6 ng/m³ arsenic (part of PM₁₀) (target value)	since 31/12/2012
1 calendar year	5 ng/m³ cadmium (part of PM₁₀) (target value)	since 31/12/2012
1 calendar year	20 ng/m³ nickel (part of PM₁₀) (target value)	since 31/12/2012
1 calendar year	1 ng/m³ benzo(a)pyrene (part of PM₁₀) (target value)	since 31/12/2012
1 calendar year	0.5 µg/m³ lead (part of PM₁₀) (limit value)	since 01/01/2005

Tab. 2: Limit and target values for selected air pollutants (PM₁₀, PM_{2.5}, SO₂, NO₂, NO_x, CO, benzene and ozone, cadmium, nickel, benzo(a)pyrene and lead)

The average exposure indicator (AEI) is an indicator of the population's average exposure to PM_{2.5} in the urban background. Based on PM_{2.5} levels recorded at relevant measurement stations over a three-year period, the indicator is calculated for each EU member state individually yielding an annual moving average. The average spanning the years 2008 to 2010 was defined as the AEI for 2010 (reference year), which was 16.4 µg/m³ for the whole of Germany. Based on the AEI 2010, a national target to reduce PM_{2.5} by 15 % by 2020 has been set in accordance with the 39th BImSchV. Since 2020, the AEI must therefore not exceed 13.9 µg/m³. Berlin's AEI 2021 (mean between 2019 and 2021) is 12.5 µg/m³.

This [overview](#) provides further statutory limit and target values for air quality (only in German).

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