Long-Term Development of Air Quality (Edition 2018)

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 exceedings of limit or target values) since measuring began in 1975.

This air quality archive contains the results of data gathering for particular parameters and measurement stations over a period of more than 40 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. § 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 (PM_{10}, $PM_{2.5}$) 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 (PM_{10}, $PM_{2.5}$) 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 (SO_2) emissions are no longer shown, since SO_2 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 PM_{10} 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 updating the Clean Air Plan, 2011-2017, 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 **EU Air Quality Directives** contain specific immissions values as limit or threshold values, 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. 3).

The EU Air Quality Directive has been implemented into national law in Germany as the **Federal Immission Protection Law** (BImSchG), under § 44 - 46a, 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 (PM_{10} and $PM_{2.5}$), nitrogen dioxide (NO_2), nitrogen oxide (NO_x), sulphur dioxide (SO_2), carbon monoxide (CO), benzene and ozone (O_3). For most of these atmospheric parameters, there are limit values and supplementary tolerance margins (i.e., a sliding scale of annual steps towards attainment of the limit). If these limits are not complied with, special measures must be taken to reduce immission concentrations. This includes the above mentioned **Clean Air Plan 2011-2017** (only in German) in particular, which details the required measures.

Special attention is to be paid to all polluters and emissions, which contribute to a considerable degree to exceeding the immissions values.

To summarise, these immisions 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,
- the tracing 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 § 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) of the Senate Department for the Environment, Transport and Climate Protection. Currently (as of September 2016), the network consists of 16 fixed measurement stations for air pollutants, supplemented by one meteorological station and one mobile measurement unit, the “measurement bus”. Every five minutes, each station measures all air pollutants and transfers the results to the Control Centre on Brückenstrasse (borough of Mitte); from this, 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 street lamps (soot and benzene immission collectors = RUBIS) and passive collectors, especially in areas with high traffic volumes lacking the space to operate measuring containers. The elemental carbon and nitrogen oxide loads are thus assessed every two weeks at 23 additional points in the Berlin city area (as of September 2018). Further information and monthly updates are published in addition to the annual updates of the Environmental Atlas Map. For this purpose, a separate website “Berliner Luftgütemessnetz” (Berlin

Clean Air Measurement Network) has been set up, providing access to both current and archived data, which may be viewed or used further.

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, Transport and Climate Protection.

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. PM_{10} 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 NOx (cf. AVISO 2016, p.23).

Table 1: Types and numbers of plants and auxiliary plants requiring a permit in Berlin, 1989 to 2016

Type of plant	Number							
	1989	1992	1996	2000	2004	2008	2012	2016
Heat production, mining, energy	954	356	324	243	100	123	105	100
Bricks and clay, glass, ceramics, construction materials	55	40	37	60	47	29	28	28
Steel, iron and other metals, incl. processing	124	86	74	53	49	65	48	28
Chemical products, medicines, oil refinery & processing	58	38	32	28	25	12	10	4
Surface treatment with organic materials	70	28	13	13	18	31	29	14
Wood, cellulose	3	1	1	2	3	4	4	1
Food, beverages, feed	98	84	88	76	16	10	6	6
Recycling and removal of waste materials	17	9	15	71	90	46	23	17
Storage and loading/unloading of materials	61	61	68	57	33	37	23	21
Other	73	159	82	17	17	30	27	35
Total	**1513**	**862**	**734**	**620**	**398**	**387**	**303**	**254**

Tab.1: Types and numbers of plants and auxiliary plants requiring a permit in Berlin, 1989 to 2016

- 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 (SO_2). 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 NOx, PM_{10} 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 2: 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
Traffic (other)	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
Traffic (other)	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
Traffic (other)	4000	3500	3100	2945	2950	861
Other sources	5000	10000	12000	11400	11000	3214
Particulate matter (PM_{10})	**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
Traffic (other)	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
Traffic (other)				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
Traffic (other)	3000	2000	1710	1590	1200	226

Tab. 2: 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 2000-2015 (cf. also the analysis of Map 03.12.1, Station 174).

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 category “other sources”. Motor vehicle traffic, including abrasion and resuspension, accounted for a share of 24 % of the PM_{10} emissions in Berlin in 2015, while the 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 km^2, is relatively high. Especially here, the problems of space utilization and competition for a growing road traffic volume will increase, if current trend 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 were measured at all **measurement stations** (using the chemiluminescence procedure), dust of the PM_{10} fraction at eleven stations (by measuring the scattering of light by dust particles, ozone at seven stations (through absorption of UV radiation), carbon monoxide at two stations (through absorption of infrared radiation), benzene at four stations (through gas chromatography) and sulphur dioxide at two stations (through UV fluorescence). Heavy metals and benzo(a)pyrene were additionally determined in the PM_{10} fraction at three or four measurement stations, respectively.

The stations are distributed around the city in such a way that various spatial effect factors can be ascertained. Of the 16 stations, six are located along heavily travelled streets, five are in inner-city areas (both residential and commercial) and five are at the periphery of the city or in forest areas. Three stations are equipped with devices for measuring benzene and toluene.

Every weekday at 12 midday the **measured values** of the previous day are sent to several newspapers and radio and TV stations for public broadcast. Additionally, the values are published on the Internet, and can be accessed there under Tageswerte des BLUME-Messnetz (“Daily values of the BLUME measurement network”; only in German). In the case of increased ozone concentrations in the city, this information is broadcast to the public by some radio stations. As mentioned above, the separate website “Berliner Luftgütemessnetz” (Berlin Air Quality Measurement Network) 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).

Since 1997, the network has been expanded by initially 20, and now 23 small, low cost sampling devices installed at the streets, the samples of which are analyzed in the laboratory (RUBIS Measurement Network, as of September 2018). With these miniaturized devices, weekly samples of benzene and soot have been collected. In addition, passive collectors have been installed at these sites to ascertain nitrogen oxide values. These devices collect samples for periods of 14 days, which are then analyzed in the laboratory. These manually generated data are, due to the time lag necessary for analysis between measurement and generation of results, and also due to their minimal temporal resolution, only published as annual mean values in the annual reports.

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 PM_{10}, the situation has improved significantly compared to the years at the beginning of this century. However, the PM_{10} 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 PM_{10} 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. In the years with worse exchange conditions, such as 2009-2011 and also 2014, the annual mean PM_{10} concentrations were slightly higher, whereas in the years with better exchange conditions, such as 2007 and 2008 as well as 2012, 2013, 2015, 2016 and 2017, they were correspondingly lower. The annual mean concentrations of PM_{10} for 2017 detected at the stations of the automatic monitoring network were 16-18 µg/m³ in the suburbs, 20-22 µg/m³ in inner-city areas and 23-28 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 RUBIS measurements for 2017 did not find evidence of limit exceedances for PM_{10} in urban canyons. Also, the short-term limit value for PM_{10} (the daily mean must not exceed the value of 50 µg/m³ more than 35 times a year) was not exceeded at any measuring point in 2017.
- However, there are still substances which regularly exceed the limits values, in particular areas with road influences. Especially nitrogen dioxide NO_2, whose measurements in 2017 were between 41 and 49 µg/m³ near roads. The limit of the 39th BImSchV (40 µg/m³) effective since 2010 was thus exceeded at all six automatic measuring points near roads, although at station 174 (Frankfurter Allee) only barely with 41 µg/m³. The values for near-ground ozone (only in German) also frequently exceed the EU's long-term 8-hour target at several sites during the summer months. In Berlin, limit values were exceeded on up to 8 days in the summer of 2017 in peripheral and inner-city areas. The EU-wide target for 2010 of a maximum of 25 days per calendar year averaged over the last 3 years, was fulfilled in 2017, as only 15-24 exceedances were detected. Since January 1, 2010, this target value is to be kept as far as possible.
- Improvements of the air quality have to do with many components. The de-industrialization of Berlin, the modernization of plants, the use of catalytic converters in vehicles, and the changeover to more low-emission heating fuels had an impact.

The detailed, always current 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 cannot be only local, but rather must also investigate the immission of pollutants from outside, including cross-border transportation (cf. again Berlin Clean Air Plan 2011-2017).

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 **40 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 **187 measurement stations** are presented, of which 39 are still in operation (16 BLUME measurement containers, and 23 RUBIS measurement points, as of September 2018).

For the graphic representation of the development of the parameters total dust, particulate matter (PM_{10}), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), nitrogen monoxide (NO), carbon monoxide (CO), benzene and ozone (O_3), 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/m³ **PM_{10}** 35 exceedings/year	since 01/01/2005
1 year	40 µg/m³ **PM_{10}**	since 01/01/2005
Indicator for mean $PM_{2.5}$ exposition,1 year	20 µg/m³ **$PM_{2.5}$**	since 01/01/2015
Limit value for health protection stage 1, 1 year	25 µg/m³ **$PM_{2.5}$**	since 01/01/2015
Limit value for health protection stage 2, 1 year	20 µg/m³ **$PM_{2.5}$**	as of 01/01/2020
1 h	350 µg/m³ **SO_2** 24 exceedings/year	since 01/01/2005
24 h	125 µg/m³ **SO_2** 3 exceedings/year	since 01/01/2005
mean value, October - March (for the protection of ecosystems)	30 µg/m³ **SO_2** 3 exceedings/year	since 01/01/2005
1 h	200 µg/m³ **NO_2** 18 exceedings/year	since 01/01/2010
1 year	40 µg/m³ **NO_2**	since 01/01/2010
1 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 year	5 µg/m³ **benzene**	since 01/01/2010
8 h (target value)	120 µg/m³ **ozone** top 8-h mean of a day	since 01/01/2010

	25 exceedings/ 3-year mean	
1 year (calendar year)	6 ng/m³ **arsenic (part of PM_{10})** (target value)	since 31/12/2012
1 year (calendar year)	5 ng/m³ **cadmium (part of PM_{10})** (target value)	since 31/12/2012
1 year (calendar year)	20 ng/m³ **nickel (part of PM_{10})** (target value)	since 31/12/2012
1 year (calendar year)	1 ng/m³ **benzo(a)pyrene (part of PM_{10})** (target value)	since 31/12/2012
1 year (calendar year)	0.5 µg/m³ **lead (part of PM_{10})** (limit value)	since 01/01/2005

Tab. 3: Limit and target values for selected air pollutants (PM_{10}, $PM_{2.5}$, SO_2, NO_2, NO_x, CO, benzene and ozone, cadmium, nickel, benzo(a)pyrene and lead)

The average exposure indicator (AEI) was defined to measure the population's 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. 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. Therefore, the AEI 2020 (average from 2018 to 2020) must not exceed 13.9 µg/m³.

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

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