

03.11.1 Traffic-Related Emissions (Edition 2017)

Overview

Original situation

Ground-level emissions from motor vehicle traffic is the most influential factor in the assessment of traffic-related air pollution. Causes and effects are therefore presented in two maps that are closely related:

- Traffic-Related Emissions (Environmental Atlas 03.11.1) and
- Traffic-Related Air Pollution (Environmental Atlas 03.11.2).

The original situation is identical in both maps, a description of which may be found in the [relevant section of Map 03.11.2](#).

Effects

Nitrogen oxides are acidifiers. They are harmful to human health, cause damage to plants, buildings, and monuments, and contribute significantly to the excessive formation of ground-level ozone and various noxious oxidants during summer heat waves.

Nitrogen oxides, especially nitrogen dioxide, lead to irritation of the mucus membranes of the respiratory passages in people and animals, and can increase the risk of infection (cf. Kühling 1986). Cell mutations have also been observed (BMUNR 1987). Various epidemiological studies have shown a correlation between the deterioration of the functions of the lungs, respiratory tract symptoms, and increased nitrogen dioxide levels (see Nowak et al. 1994).

Diesel soot is a major component of **particulate matter (PM₁₀)** in motor vehicle exhaust. It is a carrier for polycyclic aromatic hydrocarbons (PAH), a carcinogen, but also on its own, it is a possible cause of lung and bladder cancer (see Kalker 1993). Moreover, such ultra-fine particulate as diesel soot, smaller than 0.1 µm, is suspected to increase the risk of cardiovascular disease.

Legal stipulations and limit values

An evaluation of air pollution from motor vehicle traffic has only become concretely possible for immission control authorities since 1985, since the European Community, in the Directive of the Council of 7 March 1985 on Air Quality Standards for Nitrogen Dioxide (Directive 85/203/EEC), specified limits and goals for this pollutant. In addition, it stipulated that measurements be taken of concentrations of nitrogen dioxide on "urban canyons" and major intersections.

In 1996, due to a multiplicity of new findings regarding this and other air pollutants, "Directive 96/62/EC on Ambient Air Quality Assessment and Management (the so-called "Framework Directive") was drafted and brought into force.

In this Directive, the Commission is called upon to submit, within a specified time period, so-called "subsidiary directives" stipulating limits and details for the measurement and assessment of a specified list of components.

Since then, four subsidiary directives have come into force:

- as of July 19, 1999, Directive 99/30/EV, with limits for sulphur dioxide, particulate matter (PM₁₀), nitrogen dioxide and lead
- as of December 13, 2000, Directive 2000/69/EC, with limits for benzene and carbon monoxide

- as of February 9, 2002, Directive 2002/3/EC, for comparing ozone at ground level to the data and level of excess over the limits; and
- as of December 15, 2004, Directive 2004/107/EC, with limits for arsenic, cadmium, mercury, nickel and PAH.

Germany had two years to enact the first two subsidiary directives into national law, a deadline it missed substantially, as the Seventh Amendment to the Federal Immissions Protection Law (BImSchG), which addressed the first subsidiary directive, was not enacted until September 2002. The new Ozone Directive has now also been enacted into German law with the new 33rd Ordinance of the BImSchG.

The core elements of the Air Quality Directives are the immission limit values, which are "to be attained within a given period and not to be exceeded once attained". The pollution concentrations, and the time in which the limits must be met, are stipulated in the subsidiary directives, and in the 22nd Ordinance of the BImSchG (22nd BImSchV).

Table 1 shows the corresponding values for the air pollutants which pose the greatest potential problem for Berlin: PM_{2.5}, PM₁₀ and nitrogen dioxide.

Table 1: EU-wide immission limit values and deadlines for particulate matters PM_{2.5}, PM₁₀ and nitrogen dioxide (NO₂)			
Substance	Mean value for	Limit value	Compliance date
Particulate matter PM _{2.5}	Target value, 1 year	25 µg/m ³	since Jan. 1, 2010
	Limit value, stage 1, 1 year	25 µg/m ³	since Jan. 1, 2015
	Limit value, stage 2, 1 year	20 µg/m ³	since Jan. 1, 2020
Particulate matter PM ₁₀	24 h	50 µg/m ³ 35 exceedances/year	since Jan. 1, 2005
	1 year	40 µg/m ³	since Jan. 1, 2005
NO ₂	1 h	200 µg/m ³ 18 exceedances/year	since Jan. 1, 2010
	1 year	40 µg/m ³	since Jan. 1, 2010

Table 1: EU-wide immission limit values and deadlines for PM_{2.5}, PM₁₀ and nitrogen dioxide (NO₂), as per the 39th BImSchV

At the European level, EU Directive 2008/50 governs the assessment of air quality based on established limit and target values for all relevant pollutants, including the establishment of common methods and criteria. For the first time, air quality values have been established for the particularly harmful small particulate matter (diam. < 2.5 micrometres; PM_{2.5}).

At the national level, the 39th Federal Immissions Protection Ordinance (BImSchV) on air quality standards and emissions limits governs the implementation of EU Air Quality Directive 2008/50/EC. At the same time, the Ordinance on Immission Values for Atmospheric Pollutants (22 BImSchV) and the Regulation for the Reduction of Summer Smog, Acidification and Nutrient Inputs (33 BImSchV) have been superseded by the 39th BImSchV.

Under §11 of the 39th BImSchV, Berlin is a metropolitan area in which the air quality must be evaluated annually and, if necessary, measures must be taken to comply with the limits. The entire city was designated as a planning area for the possible establishment of a plan to preserve air quality. Exceeding of the limits occurs throughout the city, especially on primary roads. It therefore makes no sense to limit the planning area to parts of the city, or to divide the city into several planning areas.

Problems in applying Directive 99/30/EC and the 39th BImSchV, using the example of PM₁₀ pollution in the city

In the proximity of high pollution immission, such as on urban canyons, high concentrations of immission occur. Unlike in most industrial areas, there are many people on traffic filled streets, be they residents, customers or workers, who face increased exposure to pollution. In order to meet the EU Directives to comply with emission limits at the locations of the highest concentrations, quantification of harmful pollutants must be as complete as possible. For this purpose, such measurements have in Berlin been supplemented by model calculations for all high-traffic streets in which limits could potentially be exceeded.

However, even on a high-traffic urban canyon, the **existing pollution** produced by other sources in the city, and introduced by the long distance transportation of pollution, is an important factor. Therefore, for the planning of measures to improve air quality in Berlin, a system of models was used, which can calculate the wide-ranging influence of distant sources, as well as the effect of all emitters within the city, even on high-traffic urban canyons. The model uses the levels:

- urban canyon
- city-wide background pollution, and
- regional background pollution.

The simplified diagram shown in Figure 1, which shows the spatial distribution of PM₁₀ concentrations in Berlin and the surrounding area, was developed from these investigations of the source of particulate matter pollution in Berlin.

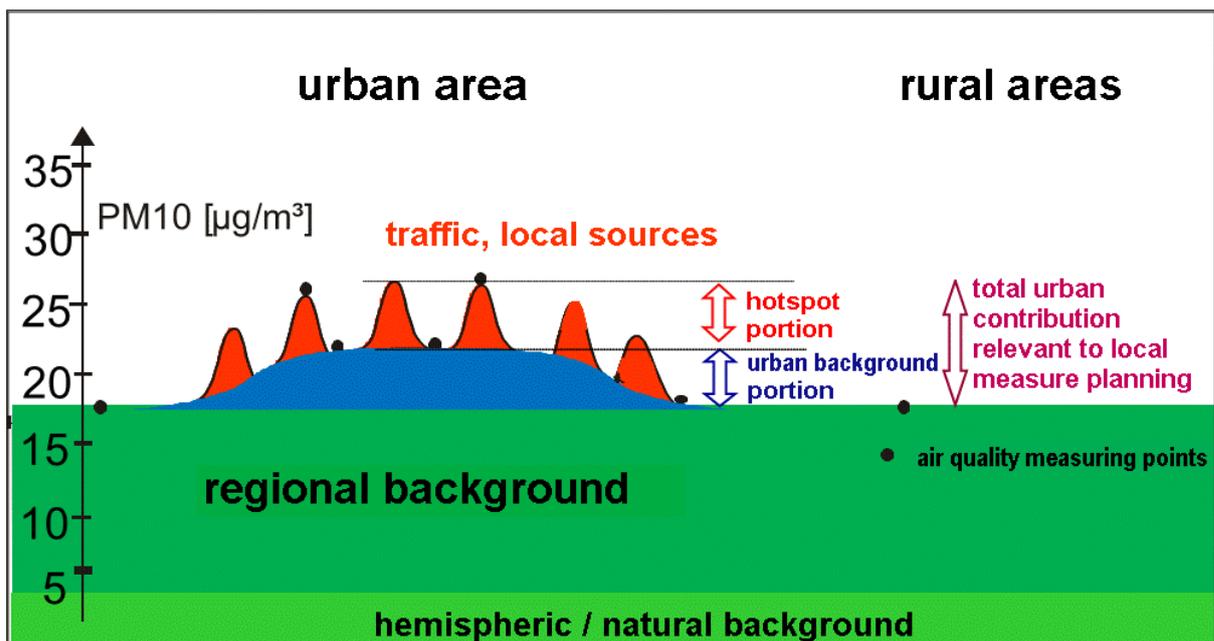


Fig. 1: Diagram showing the pattern of particulate (PM₁₀) pollution in Berlin and the surrounding area (SenUVK 2016a)

There is a broadly distributed background level (green area of chart) which, according to measurements taken at several rural stations in Brandenburg in 2016, amounts to almost 16 µg/m³. The component, known as the "regional background pollution", is distributed relatively evenly outside of the city, as the results of the large-scale model show.

Added to that is the proportion of PM₁₀ pollution caused by local Berlin-based sources. It includes:

- that portion obtained by the combination of all emissions from all Berlin sources: power plants, industry, residential heating (blue area). Together with the regional background, this reflects

the particulate concentrations measured in the residential areas of the city remote from traffic and industry;

- an additional portion caused by local emitters in the immediate area of a source, such as motor vehicle traffic on Frankfurter Allee (red peaks).

In summary for Berlin, more than half of the PM₁₀ pollution measured at stations near traffic in the inner city comes from the regional background and the other locally caused particulate pollution. That portion is in turn equally divided between the amounts produced by local traffic, and those produced by the pollution sources in the remainder of the city. Only this last share can be influenced by local measures in Berlin.

Statistical Base

Motor Vehicle Traffic Emissions Registry

The Motor Vehicle Traffic Emissions Registry was compiled anew on the basis of traffic counts for 2014, because according to experience to date, this category of polluters contributes significantly to particulate and nitrogen oxide pollution. Detectors to count the number of passing motor vehicles have been installed at many locations on the primary roads of Berlin since 2001. This data serves to make the current traffic patterns in Berlin accessible, and to incorporate them into traffic management. This information is evaluated in the [Traffic Control Centre](#) (VKRZ), and is used to inform the population, especially drivers, of current traffic conditions and provide routing recommendations to avoid traffic jams via radio broadcasts, the internet, and centrally located sign boards. With its further development, the VKRZ aims at achieving dynamic traffic management based on current traffic conditions and volumes.

Ascertainment of traffic volume

Since 2002, the data from approx. 400 detectors at about 300 locations within the Berlin primary road network have been available at the *Verkehrslenkung Berlin* (VLB, [Traffic Control](#)). Many of these detectors distinguish between cars and lorries, and can be used for approximate annual traffic counts.

In addition, for 2014, traffic count figures for car, lorries, buses and motorcycles from an official count by trained persons at many intersections ordered approximately every 5 years by the Senate Department for the Environment, Transport and Climate Protection were available. Compared with counts by detectors, this official traffic count has the advantage of being better able to distinguish between lorries of more or less than 3.5 t, respectively, and other motor vehicles. For 2014, therefore, this traffic count was selected as the basis for the **Emissions Survey for Motor Vehicle Traffic 2015, as part of the 2011-2017 update of the Air Quality Plan** as had been the case for the previous Emissions Registers for Motor Vehicle Traffic in 1994, 1999, 2005 and 2009.

The exhaust emissions were then ascertained as follows:

- the extrapolation of the point-related intersection counts to the entire Berlin primary road network with a traffic-flow computational model (VISUM) by the Senate Department for Transport provided the results showing the mean daily traffic figures (DTV) and the proportions of lorries for all major streets.
- the ascertainment of the segment-related pollution of the primary road network with regular bus traffic of the *Berliner Verkehrsbetriebe* (BVG, Berlin Transport Services) was calculated on the basis of the bus schedule data for 2014.
- the calculation of the emissions with the emission factors from the UBA manual for emissions factors (Edition 3.3) with consideration for the type of road and its function, is ascertained with the aid of the programme IMMIS^{em/luft}.

Ascertainment of emissions

The pollution emissions from motor vehicle traffic include exhaust and abrasion emissions from moving traffic, evaporation emissions from standing traffic, and evaporation emissions from fuel stations. Figure 2 provides an overview of the survey system. Emissions at fuel stations are assigned to "small business".

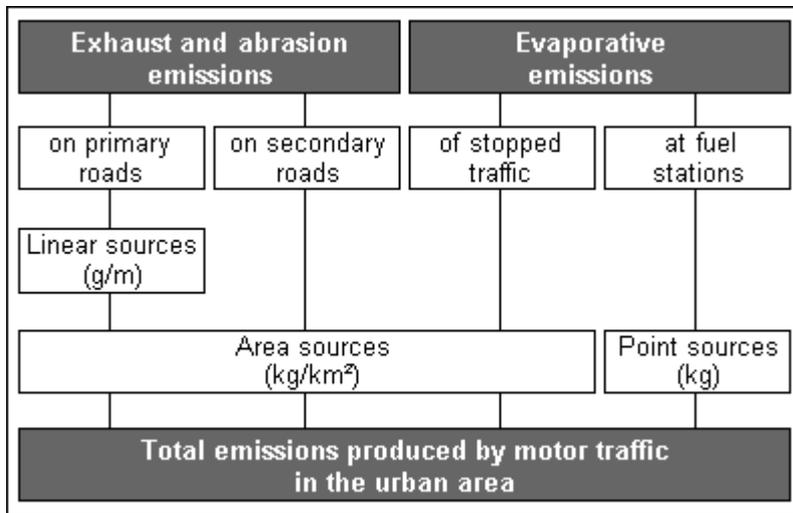


Fig. 2: 2015 survey of emissions of motor vehicle traffic of the 2011-2017 update of the Air Quality Plan

The pollution and CO₂ emissions from linear sources (primary roads) and area sources (secondary road networks and evaporation emissions) are calculated with the aid of emissions models.

The exhaust and abrasion emissions appear as linear sources on primary and secondary roads. However, they are only calculated as linear sources for the primary road network because DTV traffic counts and hourly capacity information are only available for those streets. The emissions from the linear sources are then assigned to the grid network as area sources. The emissions from the secondary road network are, however, derived directly from estimates of traffic volume and lorry shares for each grid.

The primary roads (linear sources) and secondary road networks (area sources) emissions models

Exhaust emissions from motor vehicle traffic depend on factors which can be summarized as traffic-specific and motor vehicle-specific quanta.

Traffic-specific quanta are described by traffic density, i.e. the number of vehicles moving on a given section of a road (source), and their driving style (driving mode). Driving style is determined by street type (city centre street, secondary road, primary road with or without traffic lights, motorway), and function (shopping street, residential street, or access street).

The **motor vehicle-specific quanta**, generally expressed by exhaust emissions, are determined by:

- type of engine (four-stroke, two-stroke or diesel)
- type of carburetion (carburettor or fuel injection for petrol engines)
- type of fuel (two-stroke mixture, gasoline, diesel)
- type of purification system, if any (regulated or unregulated catalytic converter, recycling of exhaust gases, particulate filters, NO_x scrubbers); and
- other factors pertaining to the technical condition of the engine.

Emissions also depend on the driving style (driving mode), and are therefore stated for various driving styles. Cold weather starts, which lead to increased emissions during the warm-up phase of the engine, together with evaporation emissions, are considered important vehicle specific quanta.

The emissions factors are provided in the UBA Emissions Factors Manual (Version 3.3) for each year from 1990 through 2030. It lists the emissions factors for all relevant emitted substances for each vehicle group (passenger cars, light commercial vehicles, motorized two wheeled vehicles, buses, and heavy commercial vehicles), for currently at least six reduction levels (1980s ECE cycle, Euro I/1, Euro II/2, Euro III/3, and Euro IV/4; Euro V/5 and Euro VI/6) and for each type of road.

However, the stricter standard Euro VI for heavy commercial vehicles became effective in January 2013. The Euro 6 for norm for passenger cars started to come into force in September 2014 and has been tightened in stages since September 2017. It will be mandatory as of January 2020. These exhaust standards can be taken into account with the present version of the UBA manual, so that realistic forecasts for motor vehicle emissions are possible.

Ascertainment of emissions from abrasion and resuspension caused by street traffic

With today's knowledge, it is assumed that a large part of traffic related PM_{10} emissions does not originate from vehicle exhaust, but rather from the wind stirring up the particulate matter lying on the street surface, and from tyre and brake abrasion.

The calculations of these emissions with $IMMIS^{em/luft}$ are based on the modified EPA formula from corresponding investigations. This formula was developed in Berlin from measurements taken on Schildhornstraße and on Frankfurter Allee, and is based on the finding that approx. 50 % of the measured additional particulate in urban canyons referring to the year 2001 is not attributable to motor vehicle exhaust, but is rather caused by motor vehicle related abrasion (braking and street/tyre abrasion) and resuspension. Since exhaust emissions have since been further reduced by improved engine technology, the proportion of additional pollution due to non-exhaust-caused emissions is today considerably higher than 50 %.

Figure 3 shows the various output quanta for the calculation of exhaust and abrasion emissions from traffic, such as driving style factors, stop-and-go supplements, cold weather start factors etc., as well as the results.

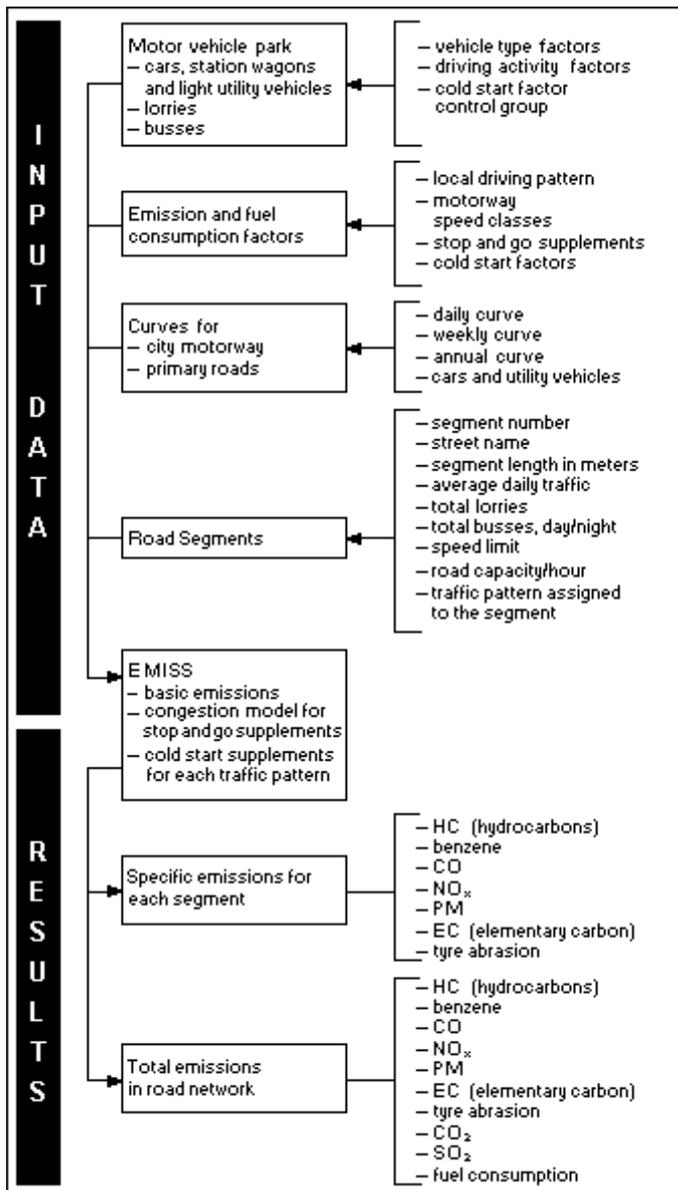


Fig. 3: Emissions model for the calculation of quantities of emitted pollutants on primary roads (Liwicki, Garben 1993)

For areas with distinct orography, the road sections should be arranged in longitudinal categories. In Berlin, this was applied for the first time in the Emissions Register "Traffic 2015".

Emissions model for secondary roads networks (area sources)

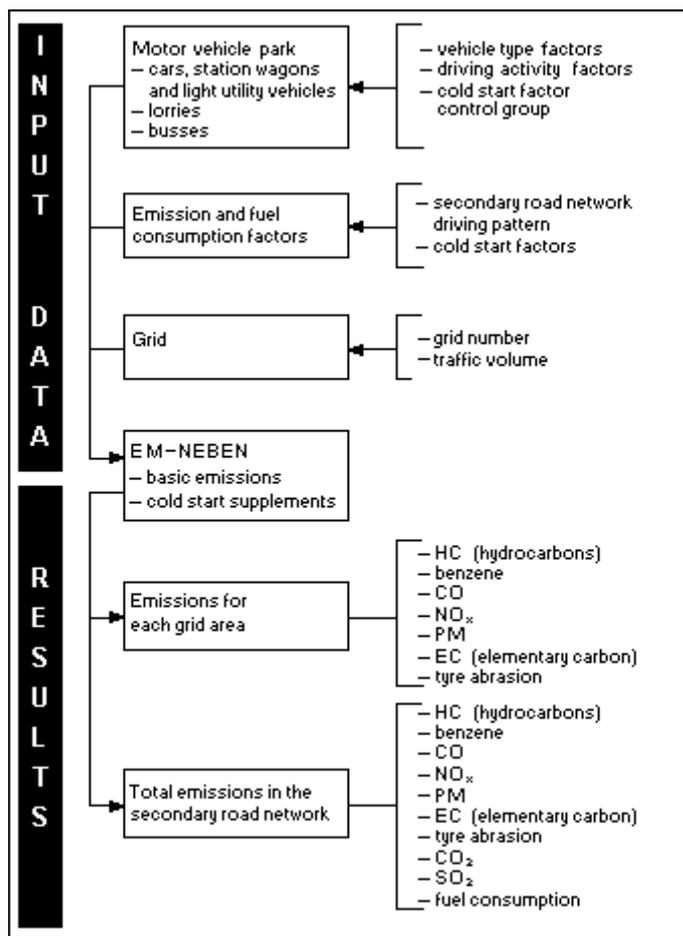


Fig. 4: EM-NEBEN – Emissions model for the secondary road network (area sources) (Liwicki, Garben 1993)

The traffic pollution on secondary roads for 2015 was calculated with the aid of the traffic routing programme VISUM, based on the underlying source-goal relationship. The resulting total driving performance and the proportion of heavy commercial vehicles was assigned to the traffic cells in the city. The emissions in secondary roads from exhausts and from resuspension and abrasion were determined using the IMMIS^{em/luft} emissions module.

In secondary road networks, emissions are not calculated for specified sections of roads, but rather as 1 x 1 km grid squares. The driving performance for the grid squares is determined on the basis of:

- predominate use of the area, as either
 - residential areas in the periphery;
 - commercial and industry; or
 - inner-city and sub-centres
- the number of residents and jobs is categorized as
 - trade and service jobs, or
 - manufacturing
- the source/goal matrices of motor vehicle traffic derived from the above.

Further inputs for determining total emissions of each pollution component for each area correspond to those for the calculations in the primary road network.

Exhaust and abrasion emissions in the city

Table 2 breaks down the driving activity caused by motor vehicle traffic on Berlin's primary roads (millions of vehicle kilometres per year); fuel use (t) and the exhaust and abrasion emissions of vehicle traffic (t/year), by type of vehicle, for the reference year 2015.

Tab. 2: Traffic volume (in millions of vehicle-km/year), fuel consumption (t) and exhaust and abrasion emissions (t/year) by type of vehicle on primary roads, for the reference year 2015							
	Total	Cars and station wagons	Heavy lorries	Light commercial transport	City buses	Travel buses	Motorized two wheelers
Driving activity	10,109.0	8,367.0	354.2	1,031.1	109.2	33.2	214.4
Fuel consumption	703,692.0	511,015.0	63,486.0	65,779.0	46,613.0	11,265.0	5,534.0
of which diesel vehicles	363,991.0						
Carbon dioxide	2,222,136.0	1,609,954.0	201,824.0	209,011.0	148,186.0	35,812.0	17,349.0
of which diesel vehicles	1,157,142.0						
NOx	5,817.0	2,854.3	1,017.2	768.0	916.1	238.6	22.7
of which directly NO ₂	1,445.6	797.3	126.6	242.9	250.1	27.6	1.1
NOx from diesel vehicles	5,109.6						
PM ₁₀	546.2	315.1	111.5	64.8	41.8	13.0	0.0
of which exhaust particles	96.5	47.902	11.747	31.84	2.57	2.437	0
exhaust particles from diesel vehicles	90.2						
of which PM _{2,5}	267.0						
SO ₂	10.7						
CO	13,788.2						
Hydrocarbons (HC)	2,629.8						
HC excl. methane (CH ₄)	2,474.5						
CH ₄	155.4						
Benzo(a)pyrene	7.9						
Benzene	164.4						
Toluene	262.3						
Xylene	244.5						
Dinitrogen monoxide (N ₂ O)	37.2						
Ammonia (NH ₃)	190.0						

Tab. 2: Traffic volume (in millions of vehicle-km/year), fuel consumption (t) and exhaust and abrasion emissions (t/year) on primary roads, by type of vehicle, for the reference year 2015

Emissions from the secondary road network, which account for approx. 18 % of total emissions from road traffic, need to be factored in. An overview of emissions from industry, domestic heating and traffic can be found in [Table 2 of the Environmental Atlas Map "Long-Term Development of Air Quality \(03.12\)"](#).

The new method of measuring emissions for this registry is also a suitable basis for dispersion calculations to determine the extent of pollution at streets. The extensive reorganisation of calculation methods permits only very limited comparisons with previous emissions surveys, because these were based on a much simpler method of calculation.

Immissions – The results of stationary measurements

Street measurement stations are operated to ascertain the pollution caused by motor vehicle traffic, in the framework of the automatic Berlin Clean Air Measurement Network BLUME. In order to comply with EU Directives and the amendments to the BImSchG and the 39th BImSchV of 2010, resulting from those directives, revisions of the Berlin Clean Air Measurement Network are continually being carried out.

Since the concentrations of sulphur dioxide and carbon monoxide have now been reduced to only a fraction of the limit values, the measurement of these substances has been correspondingly reduced. Due to the current issues at hand, more attention is at the same time being directed towards the ascertainment of **particulate matter (PM₁₀)** and **nitrogen dioxide (NO₂)**, particularly in the proximity of traffic.

For a detailed and complete online presentation of the long-term development of air pollution in Berlin, an archive has been established, which can be accessed via the [Environmental Atlas Map "Long-Term Development of Air Quality \(03.12\)"](#).

Measurement of immissions in the city

In 2016, air pollutant measurements were conducted at a total of 16 measurement containers (5 at the outskirts, 5 in the inner-city background and 6 at street locations), and at 23 RUBIS measurement stations. With these miniaturized devices, benzene and soot were collected as weekly samples. In addition, passive samplers were placed at these sites to measure nitrogen oxides. These devices collect samples during a sampling period of 14 days, which are then analyzed in the laboratory. Please refer to Figure 5 for a diagram of the locations of these measurement stations. The exact addresses are listed in the [monthly reports on air-pollution control](#) of the Senate Department for the Environment, Transport and Climate Protection (only in German).

The Geoportal provides information on the location of the automatic measurement containers of the Berlin Clean Air Quality Measurement Network (BLUME) as well as the RUBIS measuring points, including the in part long-term corresponding annual values, which can be accessed via the map and factual data on the "[Long-term Development of Air Quality - Immissions](#)".

For the precise placement of sampling points and the implementation of the measurements, the following provisions of the 39th BImSchV are to be observed as closely as possible:

- The air flow around the measurement intake should not be impeded throughout a radius of at least 270°, and there should be no obstacles that could affect the air flow in the vicinity of the measurement station, i.e., buildings, balconies, trees or other obstacles should be several metres away, and the measurement stations for air quality at the building line must be at least 0.5 meters from the nearest building.
- Generally, the measurement intake should be placed between 1.5 m (breathing zone) and 4 m above the ground. Higher positions (up to 8 m) may be necessary under certain circumstances, e.g. if the measurement station is to be representative of a larger area.
- The measurement intake should not be positioned in the immediate vicinity of any emissions source, so as to avoid the direct intake of emissions which have not been mixed into the ambient air.
- The exhaust outlet pipe must be positioned so that recirculation of exhaust air to the measurement intake is avoided.
- For all traffic-related pollutants, the sampling points should be at least 25 m from the edge of major junctions, and no more than 10 m from the kerbside.

The level of measured concentrations is not solely dependent on the number of motor vehicles and the resulting emissions, but also on the air exchange conditions, which are on the one hand determined by meteorological parameters (e.g. the wind), and on the other by the type and extent of buildings. Thus, there is a high immission impact registered in streets with buildings on both sides (urban canyons), such as on Silbersteinstraße in Neukölln, or Schildhornstraße in Steglitz, while lower pollution concentrations are found at the city motorway, which carries a noticeably higher traffic volume. Figure 5 shows typical pollution distribution in an urban canyon. Such distribution develops if the wind direction (above roof level) leads from the measurement point towards the centre of the road, resulting in the formation of a turbulence in the urban canyon. This blows the motor vehicle emissions to the side of the road where the measurement station is located.

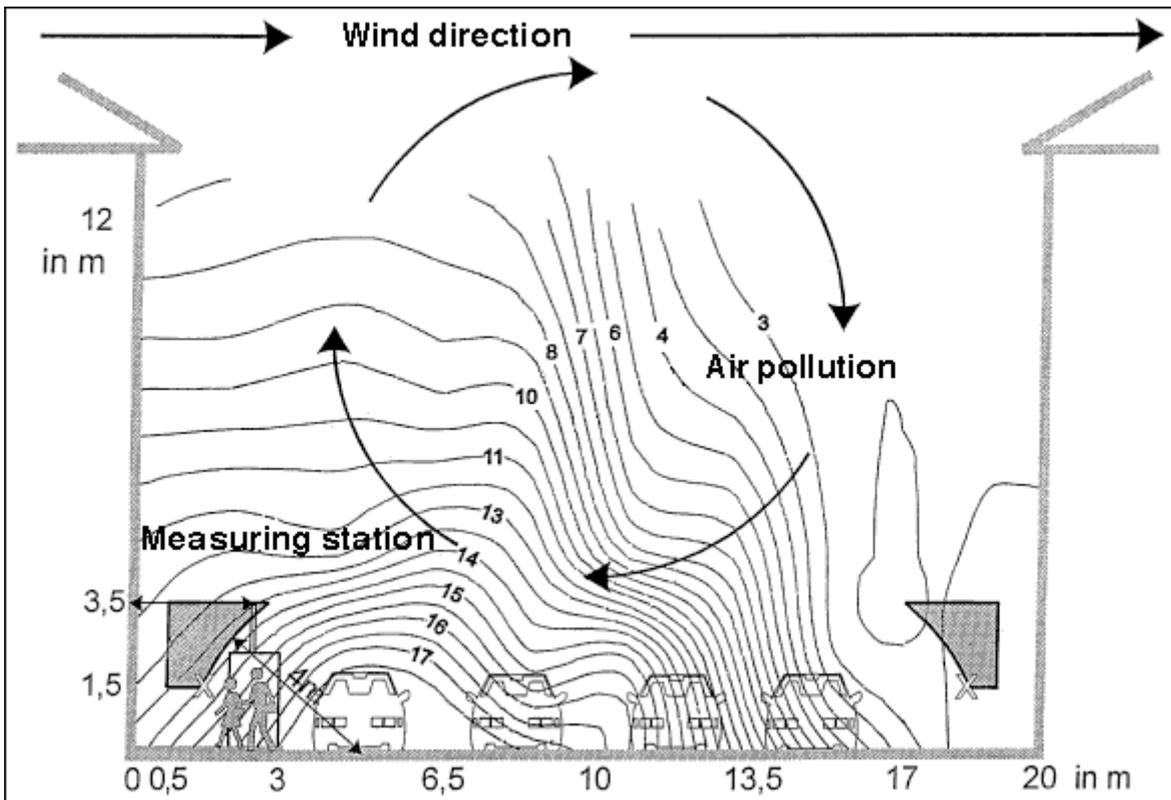


Fig. 5: Pollution distribution on an urban canyon, with the measurement range as per 39th BImSchV, and the receptors used for calculation with the IMMIS^{em/luft} urban canyon model

Long-term trend of NO₂ concentration in the city

The results of the measurements carried out in 2016 throughout Berlin indicate the following long-term trend (cf. Figure 6):

- A clear drop in nitrogen dioxide concentrations was achieved until about 1995 by equipping the Berlin power stations with NO_x scrubbers and by introducing the regulated catalytic converters for petrol vehicles.
- NO₂ pollution has hardly changed at all during the past ten years at any of the three station categories shown. The values of heavily-travelled streets (red curve) are still considerably above the EU annual average limit value of 40 µg/m³.
- The expected reduction in nitrogen oxide emissions due to the improvement in exhaust gas technology in vehicles has not led to any reduction in nitrogen dioxide pollution.

Long-term trend of nitrogen dioxide pollution

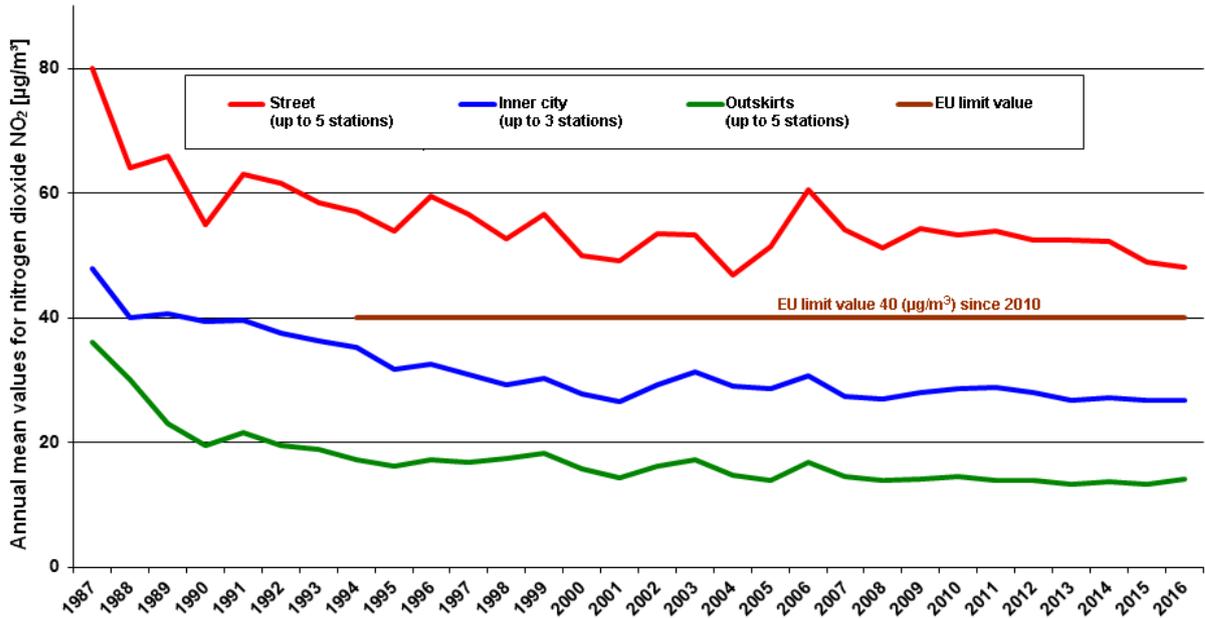


Fig. 6: Long-term trend of nitrogen dioxide values in Berlin (more information provided under [Long-Term Development of Air Quality](#), only in German)

Long-term trend of PM₁₀ concentration in the city

Figure 7 shows the development of PM₁₀ and total particulate concentrations in Berlin and the surrounding areas over approximately the past 30 years (in 1997, the measurement system was changed from overall dust to particulates [PM₁₀]).

The red curve shows pollution at three measurement stations near traffic, while the blue and dark green lines show the mean concentrations at three measurement stations in populated areas of the inner city, and at five measurement points on the outskirts of the city.

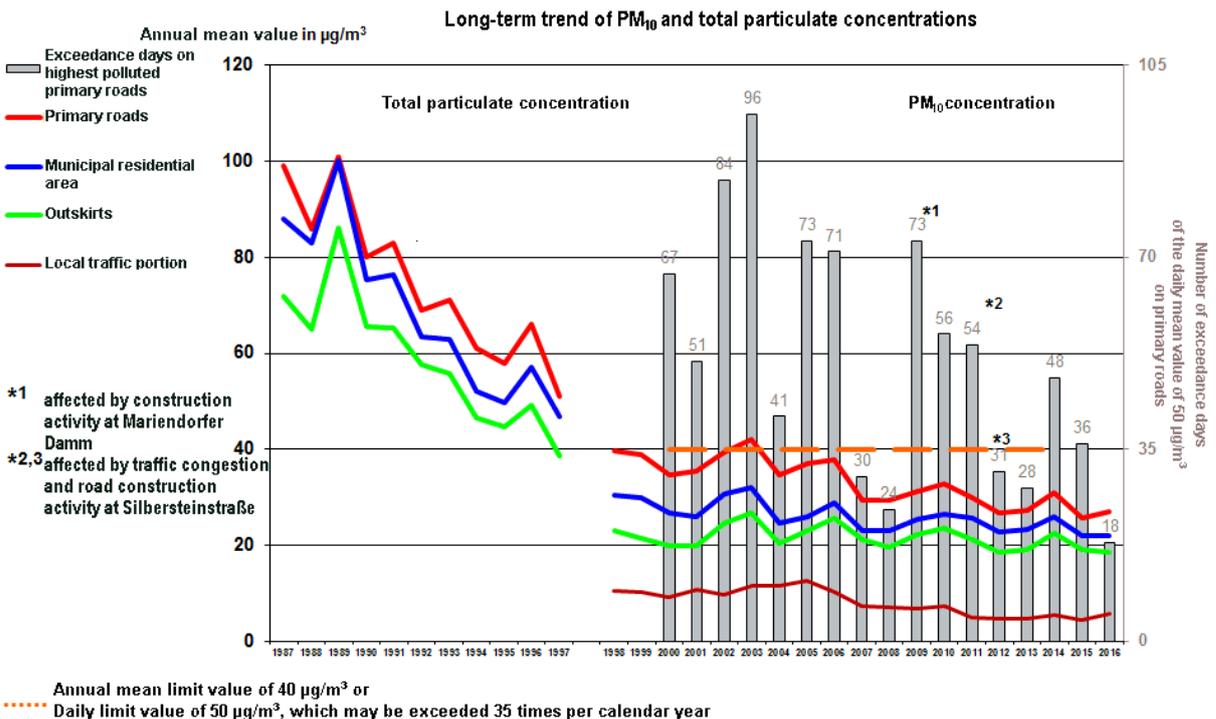


Fig. 7: Long-term trend of PM₁₀ and total particulate concentrations in Berlin, and number of exceedance days (more information is provided under [Long-Term Development of Air Quality](#), only in German)

A comparison of the curves reveals the following:

- The PM₁₀ concentrations on the outskirts of Berlin and in the rural areas of Brandenburg around the city had by 2003 already reached approx. half the PM₁₀ pollution level on major Berlin inner-city streets. By 2016, due to a continual annual mean drop in concentrations in the traffic sector, the ratio between the outskirts and primary roads then settled at approx. 2:3.
- The drop in particulate values which continued throughout the '90s has not continued during the past few years. By contrast, the soot pollution level primary roads declined continuously from 1998 to 2008, by almost 60 % (cf. [Annual mean measurements of soot](#) at [BLUME measuring container 174](#) [in µg/m³]), one cause being the improvements in exhaust gas technology in the vehicles, including those of the bus fleet of the Berlin Transport Services (BVG).
- The annual mean for fine particle pollution near traffic has since 2004 been below the EU limit of 40 µg/m³. However, before 2006 and after 2009, the more stringent 24-hour limit was exceeded on some occasions. The 24-hour limit of 50 µg/m³. is not to be exceeded more than 35 times per calendar year. The decrease in the annual mean value and the number of exceedance days at primary roads is also attributable to favourable meteorological conditions, and to the establishment of the Low-emission Zone. In 2010, the number of exceedance days above 50 µg/m³ would have been higher by about 10 days without the Low-emission Zone.
- The annual variation of PM₁₀ levels is similar at all stations. In particular, the clear resurgence of PM₁₀ levels in 2002, 2003, 2005, 2006 as well as 2010 and 2014 is a phenomenon that occurred at the same time throughout the city, as well as at stations located on the outskirts and areas adjacent to the city. The cause is hence not primarily to be found in Berlin's PM₁₀ emissions; but is rather attributable to unfavourable weather conditions (a large number of wintertime low-exchange southerly and south-easterly wind situations) and the large-scale transport of particulate matter.

Methodology

The basis for the presentation of motor vehicle traffic emissions was provided by the traffic counts on the primary road network in Berlin carried out in 2014. As described in the chapter "Ascertainment of emissions," the traffic-related pollutants for the 2014 count network were calculated on this basis.

Evaluation of emissions quantities

The map shows the spatial distribution of traffic-caused emissions. In order to achieve the classification of the emissions quantities, four emissions classes were established, oriented towards the distribution of absolute emissions in Berlin's primary road network.

To differentiate these classes, the two indicators with a special air-hygienic significance for determination of air quality levels, the pollutants nitrogen oxides (NO_x) and particulate matter (PM₁₀), were used. First, groups of 10 percentage ranges ("deciles") were calculated for each substance separately, on the basis of a sizing of the material and the emission levels per substance and section. In a further step, combined groups were formed for NO_x and PM₁₀, respectively.

The assignment of the decile ranges to groups, with evaluations, are shown in Table 3.

Evaluation of the emission quantities, motor vehicle traffic		
Groups	Evaluation	Delimitation
Group 1	far below average to below average	1 st – 3 rd decile (bottom 30 % of emissions values)

Group 2	average	4 th – 7 th decile (31 - 70 % of emissions values)
Group 3	above average	8 th and 9 th decile (71 - 90 % of emissions values)
Group 4	far above average	10 th decile (top 10 % of emissions values)
		100 % = 10,086 road sections

Tab. 3: Grouping of emissions quantities in the primary road sections, based on the indicators NO_x and PM₁₀

Assignment to one of the four emissions classes does not allow direct conclusions to be drawn regarding the pollution/immissions situation in the respective section. For this purpose, separate calculations for concentrations of major substances are carried out (see [Map 03.11.2 Traffic-Related Air Pollution](#)).

Data display for the Map

The data displayed in the [Geoportal](#) provides detailed information about the road section selected. In addition to the key number of the section, they show the following parameters:

- Length of road section [m]
- Name of road section
- Average daily traffic volume (DTV)
- Number of passenger cars per day
- Number of heavy trucks (> 3.5 t) per day
- Number of light trucks (<3.5 t) per day
- Number of city buses per day
- Number of travel buses per day
- Number of motorcycles per day
- Source of data traffic count, 2014
- Nitrogen dioxide emissions in [g/(m/day)]
- Nitrogen oxides emissions in [g/(m/day)]
- Exhaust particle emissions in [g/(m/day)]
- PM₁₀ particulate emissions in [g/(m/day)]
- PM_{2.5} particulate emissions in [g/(m/day)]
- Benzene emissions in [g/(m/day)]
- Carbon monoxide emissions in [g/(m/day)]
- Carbon dioxide emissions in [g/(m/day)]
- Hydrocarbons emissions in [g/(m/day)]
- Soot emissions in [g/(m/day)]
- Sulphur dioxide emissions in [g/(m/day)]
- Methane emissions in [g/(m/day)]
- Non-methane hydrocarbon emissions in [g/(m/day)]
- Toluene emissions in [g/(m/day)]
- Xylene emissions in [g/(m/day)]
- Ammonia emissions in [g/(m/day)]

- Nitrous oxide emissions in [g/(m/day)]
- Benzo(a)pyrene emissions in [g/(m/day)]
- Evaluation of the emission levels based on NO_x and PM₁₀.

Map Description

Generally, the transport-related emissions are primarily determined by the number and composition of the vehicle fleet, the lorry share, vehicle speed, the susceptibility of a particular road section to congestion, and the average specific emissions of the vehicles.

The primary roads have to cope with much of the traffic load in urban areas. Although the primary road network of Berlin shown on the map, with its length of approx. 1,770 km, accounts for only about 32 % of the total network of about 5,410 km, the major share of all mileage travelled, and of traffic-related emissions, occur on this segment of the network (in both cases over 80 % of the total).

While Table 2 contains the individual totals, the map shows the spatial distribution among the over 10,000 count sections.

Almost all 1,009 sections with – in Berlin terms – "well above average" emissions of the pollutants NO_x and PM₁₀ have an "average daily traffic volume" (DTV) of more than 20,000.

Assignment to one of the four emissions classes does not allow direct conclusions to be drawn regarding the pollution/immissions situation in the respective section. For this purpose, separate calculations for concentrations of pollutants of major substances are carried out, which take into account such necessary marginal factors as meteorology, as a non-constant quantum, and the particular route environment (cf. Methodology section). The calculation model provides an estimate of the concentration of pollutants within the urban canyons, in areas in which people are likely to be present not only temporarily.

The sections of this evaluation level are predominantly such main roads as

- Parts of the city motorway A100
- Federal roads, such as Heerstraße or Potsdamer Straße
- Other important connecting routes, such as the routes Großer Stern – Kaiserdamm/Großer Stern – Martin-Luther-Straße, or the Leipziger Straße – Gruner Straße - Otto-Braun-Straße corridor.

Literature

- [1] **BMUNR (Federal Minister for the Environment, Conservation and Reactor Safety) (ed.) 1987:**
Auswirkungen der Luftverunreinigung auf die menschliche Gesundheit. [Effects of air pollution on human health]; Report for the Environmental Ministerial Conference, Bonn.
- [2] **IVU Umwelt GmbH 2016:**
Program system **IMMIS**^{***}
Internet:
https://www.ivu-umwelt.de/front_content.php?idcat=30&changelang=2&idart=23
(Accessed on 6 February 2019)
- [3] **Kalker, U 1993:**
Gesundheitliche Bewertung der verkehrsbedingten Schadstoffe Stickoxide, Benzol und Dieselruß-Partikel [Physical assessment of the traffic-related pollutants nitrogen oxides, benzene and diesel soot particulate], in: Forum Städte-Hygiene No. 44, Frankfurt.
- [4] **Kühling, W. 1986:**
Planungsrichtwerte für die Luftqualität [Planning reference values for air quality], in: Schriftenreihe Landes- und Stadtentwicklungsforschung des Landes Nordrhein-Westfalen. Materials, Vol. 4.045, ed.: Research Institute for Regional and Urban Development of the State of North Rhine-Westphalia, on behalf of the State Minister of the Environment, Spatial Planning and Agriculture, Dortmund.

- [5] **Liwicki, M., Garben, M. 1993:**
Emissionskataster Straßenverkehr Berlin [Berlin Emissions Register, Traffic] 1993, Expert report for the Senate Department for Urban Development and Environmental Protection, Berlin, unpublished.
- [6] **Nowak, D., Jörres, R., Magnussen, H. 1994:**
Luftverschmutzung – Asthma – Atewegsallergien. Zwischenergebnisse deutsch-deutscher epidemiologischer Studien [Air pollution, asthma, respiratory tract allergies. Intermediate results of East-West German epidemiological studies], in: Deutsches Ärzteblatt 91(1/2), Cologne.
- [7] **SenUVK (Senate Department for the Environment, Transport and Climate Protection) (ed.) 2016:**
Luftgüte-Meßnetz (BLUME, Berlin Clean Air Measurement Network), detailed monthly and yearly reports available for download, Berlin.
Internet:
<https://www.berlin.de/senuvk/umwelt/luftqualitaet/de/messnetz/monat.shtml> [only in German]
(Accessed on 6 February 2019)
- [8] **SenUVK (Senate Department for the Environment, Transport and Climate Protection) (ed.) 2016a:**
Luftreinhalte- und Aktionsplan [Clean Air and Action Plan] 2011-2017, Berlin.
Internet:
<https://www.berlin.de/senuvk/umwelt/luftqualitaet/de/luftreinhalteplan/> [only in German]
(Accessed on 6 February 2019)
- [9] **SenUVK (Senate Department for the Environment, Transport and Climate Protection) (ed.) 2016b:**
Stadtentwicklungsplan Verkehr [Urban development plan for transport], Berlin.
Internet:
https://www.berlin.de/senuvk/verkehr/politik_planung/step_verkehr/ [only in German]
(Accessed on 6 February 2019)
- [10] **SenUVK (Senate Department for the Environment, Transport and Climate Protection) (ed.) 2016c:**
Emissionskataster 2015, Abschlussbericht [Emissions register 2015, final report], Berlin.
Internet:
https://www.berlin.de/senuvk/umwelt/luftqualitaet/de/emissionen/ekataster_2015.shtml [only in German]
(Accessed on 6 February 2019)
- [11] **SenGesUmV (Senate Department for Health, the Environment and Consumer Protection Berlin) (ed.) n.d.:**
Emissionserhebungen und Immissionsberechnungen Kfz-Verkehr 2009 im Rahmen des Luftreinhalteplans 2009-2020 [Emissions surveys and immission calculations of motor vehicle traffic 2009 as part of the Clean Air Plan 2009-2020], Berlin, unpublished.

Laws and Ordinances

- [12] **Allgemeine Verwaltungsvorschrift über straßenverkehrsrechtliche Maßnahmen bei Überschreiten von Konzentrationswerten nach der 23. BImSchV (VwV-StV-ImSch) [General administrative regulation for traffic measures when concentration values are exceeded, as per 23rd BImSchV (VwV-StV ImSch)]**
Federal Journal no. 243, p. 13393, of December 31, 1996.
Internet:
<https://www.umwelt-online.de/recht/luft/bimschg/vo/vwv/23vv.htm> [only in German]
(Accessed on 6 February 2019)
- [13] **23. Verordnung zur Durchführung des Bundes-Immissionsschutzgesetzes (Verordnung über die Festlegung von Konzentrationswerten - 23. BImSchV) [23rd Ordinance for the Implementation of the Federal Immission Protection Law (Ordinance on the specification of concentration values – 23rd BImSchV)],**
BGBl I no. 66, p. 1962, of December 20, 1996.
Directive was replaced by the 39th BImSchV.

- [14] **Council Directive of 7 March 1985, on air quality standards for nitrogen dioxide (Directive 85/203/EEC)**
 EC Official Bulletin L 87/1.
 Internet:
<https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31985L0203>
 (Accessed on 6 February 2019)
- [15] **Directive 96/62/EC on ambient air quality assessment and management.**
 EC Official Bulletin of 21 Nov. 1996 no. L 296 p. 55.
 Internet:
<https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=LEGISSUM:l28031a>
 (Accessed on 6 February 2019)
- [16] **Directive 99/30/EC relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient Air.**
 EC Official Bulletin of June 29, 1999, no. L 163 p. 41.
 Internet:
<http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:1999L0030:20080611:EN:PDF>
 (Accessed on 6 February 2019)
- [17] **Directive 2000/69/EC relating to limit values for benzene and carbon monoxide in ambient air.**
 EC Official Bulletin of Dec. 13, 2000, no. L 313 p. 12.
 Internet:
<https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32000L0069>
 (Accessed on 6 February 2019)
- [18] **Directive 2002/3/EC relating to ozone in ambient air.**
 EC Official Bulletin of Mar. 9, 2002 no. L 67 p. 14.
 Internet:
<http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2002:067:0014:0030:EN:PDF>
 (Accessed on 6 February 2019)
- [19] **Directive 2004/107/EC relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air**
 EC Official Bulletin of Jan. 26, 2005 no. L 23 p. 3.
 Internet:
<http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2004L0107:20090420:EN:PDF>
 (Accessed on 6 February 2019)
- [20] **Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe**
 EC Official Bulletin of June 11, 2008 no. L 152/1.
 Internet:
<http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:152:0001:0044:EN:PDF>
 (Accessed on 6 February 2019)
- [21] **Siebttes Gesetz zur Änderung des BImSchG [Seventh Amendment to the BImSchG].**
 BGBl. Federal Journal. 2002, Part I, no. 66, p. 3622 Pt. I, of September 17, 2002.
 Internet:
https://dejure.org/BGBl/2002/BGBl._I_S._3622 [only in German]
 (Accessed on 20 December 2017)
- [22] **33. Verordnung zur Durchführung des Bundes-Immissionsschutzgesetzes vom 13. Juli 2004 [33rd Ordinance for Implementation, Federal Immission Protection Law of July 13, 2004].**
 BGBl. Federal Journal. I no. 36, 2004, pp. 1612 ff.
 Directive was replaced by the 39th BImSchV.

- [23] **39. Verordnung zur Durchführung des Bundes-Immissionsschutzgesetzes vom 2. August 2010 [39th Ordinance for Implementation, Federal Immission Protection Law of 2 August 2010].**
BGBI. Federal Journal. p. 1065Internet:
http://bundesrecht.juris.de/bundesrecht/bimschv_39/index.html [only in German]
(Accessed on 6 February 2019)