03.11 Traffic-Related Emissions and Immissions (Edition 2011)

Overview

Original situation

In the past, the reduction of emissions from industrial and domestic heating was the main focus of air quality planning. In these segments, sizeable reductions of airborne pollutant emissions could be achieved through extensive rehabilitation programmes and plant closures. Improvements were also achieved in the area of traffic, but nonetheless, **traffic is the largest single source** of both current and future air pollutants – not only in Berlin – and is the determining factor for the course of future action in air quality planning.

Due to historical development conditions, the spatial residential structure of Berlin and Brandenburg is "traffic-efficient". No other region in Germany has anywhere near such favourable conditions. Especially characteristic of Berlin are the clearly polycentric structures and the intensive utilization of limited space in the inner city, as well as in the centres on the periphery, with intensive large and small scale multiple uses resulting in a lower degree of suburbanization than in other large cities. Only 20% of the population of the metropolitan area lives in the surrounding suburbs. The share of commuters into Berlin, amounting to only around 10% of employed persons with mandatory social insurance payments, is very low, compared with other metropolitan areas. In must be noted, however, that unusually large sections of the urban peripheral area are within the administrative borders of Berlin, as a result of the establishment of the amalgamated municipality of "Greater Berlin" in 1920.

Since 1990, the city and its immediate suburbs in Brandenburg have experienced considerable changes in their spatial structure, in terms of the distribution of the population, businesses, and jobs. Moreover, significant locations for shopping and leisure activities have been established, especially in the eastern part of the city and in the surrounding areas. The dynamics of change is continuing, but at a reduced rate. To some extent, there has even been a trend toward "rediscovering" the benefits of inner-city living and shopping, a trend which may prove supportive to efforts to achieve a reduced-traffic, compact urban development.

Since reunification, the city of Berlin has been confronted with a considerable **increase in traffic**. The number of the motor vehicles registered in Berlin increased by 23% between 1989 and 2002, when a high point of 1,440,000 was achieved. This figure dropped continuously over the course of several years, and is now at 1,304,550 motor vehicles (as of Jan. 1, 2011), after a slight recent upturn.

Table 1: Number of motor vehicles and trailers in the State of Berlin (each reference date: Jan. 1)

Vehicle	2006	2007	2008	2009	2010	2011
Motorcycles and 3-wheeled motor vehicles	94,307	96,000	88,280	90,292	93,478	94,985
Automobiles	1,225,967	1,228,621	1,091,164	1,088,221	1,105,732	1,120,360
Buses	2,394	2,376	2,170	2,078	2,276	2,130
Trucks/Lorries	80,812	81,925	75,580	73,929	73,655	74,545
Tractor trucks	4,450	4,389	4,481	4,734	4,341	4,853
Other motor vehicles	8,449	8,376	7,784	7,625	7,711	7,677
Motor vehicles, total	**1,416,379**	**1,421,687**	**1,269,459**	**1,266,879**	**1,287,193**	**1,304,550**

Trailers, total	74,376	74,958	73,336	74,258	75,522	76,614

Table 1: Number of motor vehicles and trailers in the State of Berlin 2006 - 2011 (Statistical Office of Berlin-Brandenburg 2011; each reference date: Jan. 1.)

The traffic volume on the Berlin road network has, however, according to the Emissions Register, decreased only slightly, from 12,641,300,000 vehicle-km in 2005 to 12,055,700,000 vehicle-km in 2009 (see Table 3). In future too, moreover, traffic growth is to be expected, especially in road freight transport, which is very impact-intensive.

These far-reaching changes have not ended yet. The increase in non-local traffic is caused, among other things, by the continuing expansion of the combined Berlin-Brandenburg residential and commercial area; the intensification of international economic interdependence; and, especially in Berlin, increasing interdependence with Eastern Europe.

The contribution of motor vehicle traffic to air pollutant concentrations: Origins and trends

Berlin's motor vehicle traffic has for some years now been the cause **not only of considerable noise immissions** in significant problem areas (see Maps 07.05.1 and 2, Strategic Noise Maps, Road Traffic; 2008 Edition), but also of air pollution, especially since other categories that originally contributed to **air pollution** have been substantially reduced. Table 1 shows the combined emissions of all of Berlin's sources of major pollutants since 1989.

Since the fall of the Berlin Wall in 1989, many **industrial enterprises** have been rehabilitated or shut down, and the use of coal for fuel for home furnaces in Berlin's residential areas has been replaced with heating oil, natural gas, or district heating (cf. Map 08.02.1 Predominant Heating Types, Supply Shares of Individual Energy Carriers; 2010 Edition). In 1989, domestic heating and industry were significant sources of sulphur dioxide and particulate pollutants, but these have been reduced substantially. Between 2000 and 2009, total emissions of nitrogen oxides were reduced by almost 30 %, and of particulate matter by over 20 %.

Tab. 2: Emissions in Berlin by emission category, 1989 - 2020 (trend)									
	Figures in tonnes per year (t/a)								
	1989	**1994**	**2000**	**2002**	**2005**	**2008**	**2009**	**Trend 2015**	**Trend 2020**
Sulphur dioxide	**70,801**	**17,590**	**8868**	**7158**	**4666**	**3861**	**3838**	**3666**	**3153**
Facilities requiring authorization	60,470	10,870	5683	4433	2899	2319	2319	2310	2300
Home furnaces	8526	4890	2500	2400	1513	1305	1294	1150	663
Small business	75	70	60	60	50	45	45	43	41
Traffic (vehicles only)	1440	1400	400	55	16	15	13	10	6
Traffic (other)	140	140	75	75	68	62	54	51	45
Other sources	150	220	150	135	120	115	113	102	98
Nitrogen oxides	**69,971**	**42,417**	**25,981**	**21,913**	**20,292**	**20,744**	**18,619**	**16,620**	**13,006**
Facilities requiring authorization	41,757	16,172	8331	6499	6034	6594	6594	6400	6300
Home furnaces	2704	3120	2860	2860	2945	2900	2807	2739	1595
Small business	1200	700	190	185	160	150	127	124	120
Traffic (vehicles only)	21,410	19,025	12,400	10,455	9538	9500	7510	5822	3491
Traffic (other)	1400	1300	1000	900	652	650	641	635	630
Other sources	1500	2100	1200	1014	963	950	940	900	870
Carbon monoxide	**293,705**	**203,948**	**94,928**	**76,133**	**69,701**	**66,557**	**57,463**	**48,897**	**37,481**
Facilities requiring authorization	32,443	3888	2028	1581	1521	1637	1637	1630	1620

Home furnaces	68,712	41,560	8000	8000	5900	5800	5673	5100	3100
Small business	1500	800	200	193	168	150	150	140	135
Traffic (vehicles only)	182,050	144,200	76,500	51,259	47,767	45,000	36,053	28,607	19,426
Traffic (other)	4000	3500	3100	3100	2945	2970	2950	2920	2900
Other sources	5000	10,000	5100	12,000	11,400	11,000	11,000	10,500	10,300
Particulate matter (PM10)	**17,580**	**8804**	**4729**	**4199**	**3854**	**3623**	**3125**	**2993**	**2778**
Facilities requiring authorization	9563	3161	960	650	384	153	153	150	145
Home furnaces	2693	1148	131	132	96	96	95	90	84
Small business	250	220	160	153	149	258	258	250	240
Traffic (vehicles only, exhaust)	1736	1135	667	394	355	300	225	124	60
Abrasion and resuspension by motor vehicle traffic	1200	1150	997	1050	1099	1090	669	692	631
Traffic (other)	238	190	124	130	123	120	119	119	118
Other sources	1900	1800	1690	1690	1648	1606	1606	1568	1500
Particulate matter ($PM_{2.5}$)					**2363**	**2239**	**1829**	**1708**	**1563**
Facilities requiring authorization					211	89	89	87	84
Home furnaces					87	86	86	81	76
Small business					119	197	197	190	185
Traffic (vehicles only, exhaust)					337	285	225	124	60
Abrasion and resuspension by motor vehicle traffic					714	709	360	374	341
Traffic (other)					71	70	69	68	67
Other sources					824	803	803	784	750
Organic gases	**103,351**	**73,703**	**32,814**	**26,590**	**24,033**	**22,924**	**22,427**	**20,216**	**17,951**
Facilities requiring authorization	11,801	3473	2554	1966	1596	824	824	840	860
Home furnaces	5250	2340	550	550	550	500	478	450	400
Small business	15,500	15,000	6500	6484	5511	5600	5500	5300	5200
Traffic (vehicles only)	49,800	33,890	12,500	8000	7300	7100	6925	5326	3491
Traffic (other)	3000	2000	1710	1710	1590	1400	1200	1100	1000
Other sources and households	18,000	17,000	9000	7880	7486	7500	7500	7200	7000

Table 2: Emissions in Berlin by** emission category**, 1989 to 2020 (trend)

The particulate emissions from motor vehicle exhausts, which are an especially great health threat, also decreased by more than 80% between 1989 and 2002. This finding agrees substantially with the measurements of diesel soot detected in so-called "canyon streets" – the major component of motor vehicle exhaust emissions: the soot concentration measured at Measurement station 174 of the Berlin Air Quality Measurement Network BLUME (on Frankfurter Allee, in the Friedrichshain neighbourhood), dropped by 50% between 2000 and 2008 (see also the evaluations in Map 03.12.1, Station 174). However, since the particulate matter emissions from abrasion and resuspension of road transport decreased by only 43 % during these 20 years, road traffic is the second greatest sources of particulate matter in Berlin, after "other sources". The calculated decline from 2008 to 2009 was based on the use of new, significantly lower emissions factors; in actual fact, the emissions probably declined only commensurately with the decrease in traffic, or by about 10 %. Road traffic, including abrasion and resuspension, in 2009 accounted for 29 % of the particulate emissions of PM_{10} in Berlin, while “other sources” a counted for 51 % (for $PM_{2.5}$ particulate matter, the ratio was 32 % to 44 %).

By the beginning of the 1990s, road traffic had replaced industrial plants as the main source of nitrogen oxides in Berlin. As of 2009, street traffic produced 40 % of the nitrogen oxides in Berlin, whereas industrial plants accounted for 35.2 % of total emissions.

Especially high in relative terms is the pollution from motor vehicle traffic in the inner city, where over one million people live in an area of 100 sq km. If current trends for use of and competition for space continue, motor vehicle traffic will increase especially strongly here. If current conditions continue, freight transport will encounter a particularly major increase in bottlenecks in the streets.

In order to counteract these developments, which are to some extent incompatible with urban living and threatening to public health, two mutually complementary planning strategies have been developed for Berlin:

- the Urban Development Plan for Traffic; and
- the Berlin Clean Air and Action Plan , 2005 -2010.

With the revised **Urban Development Plan for Traffic**, the Berlin Senate in a resolution of March 29, 2011 presented an updated action plan which combines the possible and necessary steps for the further development of the Berlin traffic system for the coming years with a long term strategic orientation. The core of the action plan is a catalogue of measures that were previously analyzed in detail and coordinated for effectiveness, acceptability and fundability. With regard to the future development of traffic in Berlin and the surrounding area, the investigations for the Berlin Air Quality Plan are based on this long term action concept.

"Health and Safety", one of the key strategic components of the Urban Development Plan for Traffic, includes a number of important strategies to limit the increase of motor vehicle traffic and its associated effects, with the goal of a reduction of air and noise pollution in the primary road network. The implementation of the measures of the Urban Development Plan for Traffic is expected to be completed by 2015.

The target date for StEP Transport is 2025, which is rather the long term; however, with its "Mobility Programme 2016", it also takes short and medium term requirements into account.

The standardized **Air Quality Plan** mandated by the EU was adopted by the Berlin Senate in August 2005; a revision titled “**Air Quality Plan, 2009-2020**" is in preparation. Under Europe-wide standards, the Air Quality Plan data must include information on:

- pollution measurements
- the causes of high air pollution levels
- the frequency and degree of instances in which the limits are exceeded
- pollution immission and the proportions of the immission for each causative factor (e.g. industry, commercial activity, home heating, traffic)
- planned measures, and a schedule for implementation; and
- a prognosis of the goals to be achieved by such measures.

The present Air Quality Plan provides information about the legal framework and the prevailing situation, and describes the causes of air pollution. The measures take into account the developments to date of the condition of the air (through 2010), and future trends through 2020. The focal point is the presentation of a range of potential measures and their evaluation. Based on the effectiveness of these measures, a strategy will be developed for the Berlin Air Quality Plan. The Air Quality Plan documents that Berlin, like many other large German and European cities, faces a major challenge to meet the new EU limits.

The essential results can be summarized as follows: the locally generated segment of the pollution, the share which can only be reduced by Berlin measures, accounts for about half of the particulate pollution measured at a main traffic street; it is caused by the urban background and by the local sources. The urban background pollution share is caused mostly by road traffic (16 % of total PM_{10} pollution). The rest (11 %) consists of approximately equal shares of home heating, industry/ power plants, construction, and other emissions.

The results of the measurements of recent year and the model calculations carried out for 2009 lead, among other things, to the following conclusions:

- The multi-year trend of particulate and nitrogen dioxide pollution shows only a very slight decline. Both the high values for PM_{10} in 2005 and 2006 and the decline in 2007 and 2008, as well as the recovery in 2009 and 2010, show strongly weather-related components. Both the annual mean values, and, even more, the number of cases in which the maximum for the daily average was surpassed, is to a great extent dependent upon the meteorological dispersion conditions and the incidence of low-exchange high-pressure weather conditions with southerly to easterly winds.
  For nitrogen dioxide, this strong dependence does not apply. The steady development of emissions values is determined more by factors of the vehicle fleet itself. On the whole, the NO_2 levels have in recent years proven to be more resistant to air pollution control measures than has PM_{10} pollution. Even in the years with the best meteorological dispersion conditions, they still exceeded the limits for the annual average in force since Jan. 1, 2010, at all road sites.
- In 2010, the 24-hour values for particulates and the annual values for nitrogen oxide were exceeded at all measurement stations located close to traffic. The calculations for 2009 and for nitrogen oxide show instances of exceeding the limits in the entire primary road network, especially in the inner city, on a total length of approx. 55 km, while the (calculated) annual mean value for PM_{10} exceeded the limit value of 40µg/cu.m at only a few sites.

These investigations indicate that the two most problematic pollutants in Berlin are still NO_2 and PM_{10}. Because of their physical effect, strict limit values for these substances must be upheld in the European Union and in Germany.

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 (see 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 (PM_{10})** 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 "canyon streets" 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 (PM_{10}), 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 to the BImSchG (22nd BlmSchV).

Table 3 shows the corresponding values for the air pollutants which pose the greatest potential problem for Berlin: $PM_{2.5}$, PM_{10} and nitrogen dioxide.

Table 3: EU wide immission limit values and deadlines for $PM_{2.5}$, PM_{10} and nitrogen dioxide (NO_2)

Substance	Mean during period	Limit value	Compliance deadline
$PM_{2.5}$	Target 1 year	25 µg/cu m	since Jan. 1, 2010
	Limit value, stage 1, 1 year	25 µg/cu m	starting Jan. 1, 2015
	Limit value, stage 2, 1 year	20 µg/cu m	starting Jan. 1, 2020
PM_{10}	24 h	50 µg/cu m 35 exceedances/yr.	since Jan. 1, 2005
	1 year	40 µg/cu m	since Jan. 1, 2005
NO_2	1 h	200 µg/cu m 18 exceedances/yr.	since Jan. 1, 2010
	1 year	40 µg/cu m	since Jan. 1, 2010

Table 3: EU wide immission limit values and deadlines for $PM_{2.5}$, PM_{10} and nitrogen dioxide (NO_2), 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 distinct planning areas.

Problems in applying Directive 99/30/EC and the 39th BImSchV, using the example of PM_{10} pollution in the city

In the proximity of high pollution immission, such as on canyon streets, 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 for emissions at the locations of the highest concentrations, quantification of harmful pollutants must be as accurate 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 canyon street, the proportion of pollution stemming from other sources in the city or transported in from outside , 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 effect of pollution from the surrounding area as well as the effect of all emitters within the city, even on high-traffic canyon streets. The model uses the levels:

- "canyon streets"
- city wide background pollution, and
- regional background pollution.

The simplified diagram shown in Figure 1, which shows the spatial distribution of PM_{10} concentrations in Berlin and the surrounding area, was developed from these investigations of the source of particulate matter pollution in Berlin.

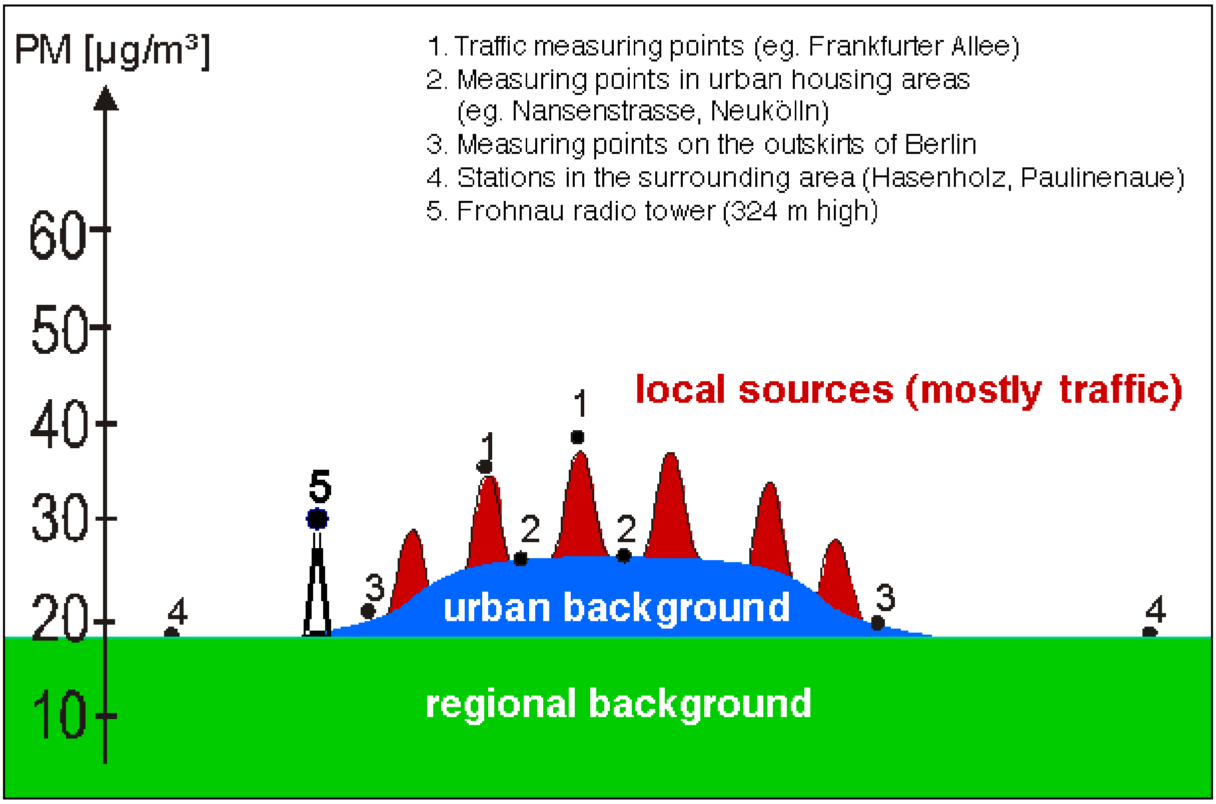

Fig. 1: Diagram showing the pattern of particulate (PM_{10}) pollution in Berlin and the surrounding area (SenStadt 2008b)

There is a broadly distributed background level (green area of chart) which, according to measurements taken at several rural stations in Brandenburg in 2002, amounts to almost 20 µg/cu.m. 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 PM_{10} pollution caused by local Berlin-based sources. It includes:

- that portion obtained by the combination of all of the emissions form all Berlin sources: power plants, industry, residential heating (blue area); together with the regional background, this reflects of 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 sum for Berlin, barely half the PM_{10} 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 2009, because according to experience to date, this category of polluters contributes significantly to particulate and nitrogen oxide pollution. Traffic counters have been installed at many locations on the primary roads of Berlin since 2001. This data serve to make the current traffic patterns in Berlin accessible, and to incorporate them into traffic management. This information is evaluated in the Office of Traffic Management (VKRZ), and is used to inform the populace (especially drivers) of traffic conditions and provide routing recommendations to avoid traffic jams via radio broadcasts, the internet, and centrally located sign boards.

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 Traffic Control Office (VLB). Many of these detectors distinguish between cars and lorries, and can be used for approximate annual traffic counts.

In addition for 2009, 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 Urban Development 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 2009 therefore, this traffic count was selected as the basis for the **Emissions Survey for Motor Vehicle Traffic, 2009-2020**, as had been the case for the previous Emissions Registers for Motor Vehicle Traffic in 1994, 1999 and 2005.

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 (VISA) by the Senate Department for Urban Development 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 Berlin Transit Company (BVG) was calculated on the basis of the bus schedule data for 2009.
- The calculation of the emissions with the emission factors from the UBA manual for emissions factors (Edition 3.1, 2004) with consideration for the type of road and its function, was 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".

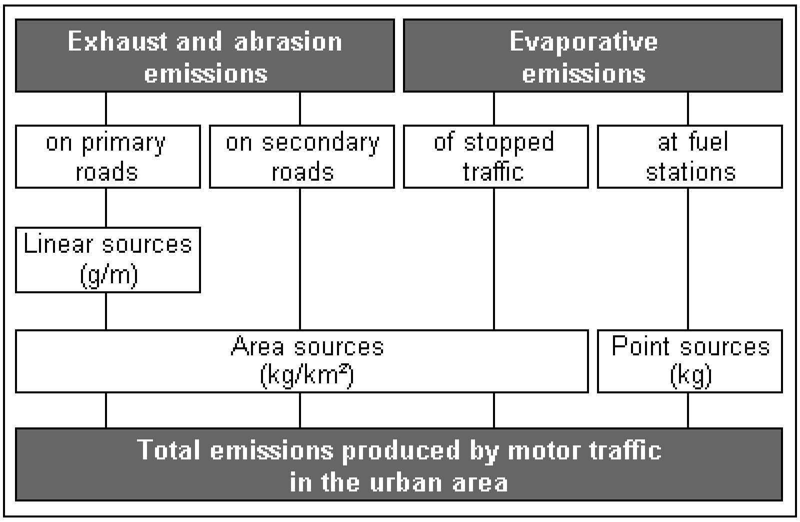

Fig. 2: Survey of emissions of motor vehicle traffic of the Air Quality Plan, 2009-2020.

The pollution and CO_2 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 the aforementioned DTV traffic counts 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)
- type of fuel (two-stroke mixture, gasoline, diesel)
- type of purification system, if any (regulated or unregulated catalytic converter, recycling of exhaust gases); 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 3.1) 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 five reduction levels (1980s ECE cycle, Euro 1, Euro 2, Euro 3, and Euro 4; Euro 5 only for heavy commercial vehicles), and for each type of road.

The stricter exhaust standard Euro 5 for cars is mandatory for new vehicles as of September 2009. However, the planned stricter standard Euro 6 for heavy commercial vehicles and Euro 6 for cars will very likely become effective only as of January 2013. These exhaust standards cannot be taken into account with the present version of the UBA manual, so that realistic forecasts for motor vehicle emissions are only possible through 2020.

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 do 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$^{em/air}$ are based on the modified EPA formula from corresponding investigations. This formula was developed from measurements taken on Schildhornstraße and on Frankfurter Allee, and is based on the finding that approx. 50% of the measured additional particulate in “canyon streets” in 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" add-on factors, cold weather start factors etc., as well as the results.

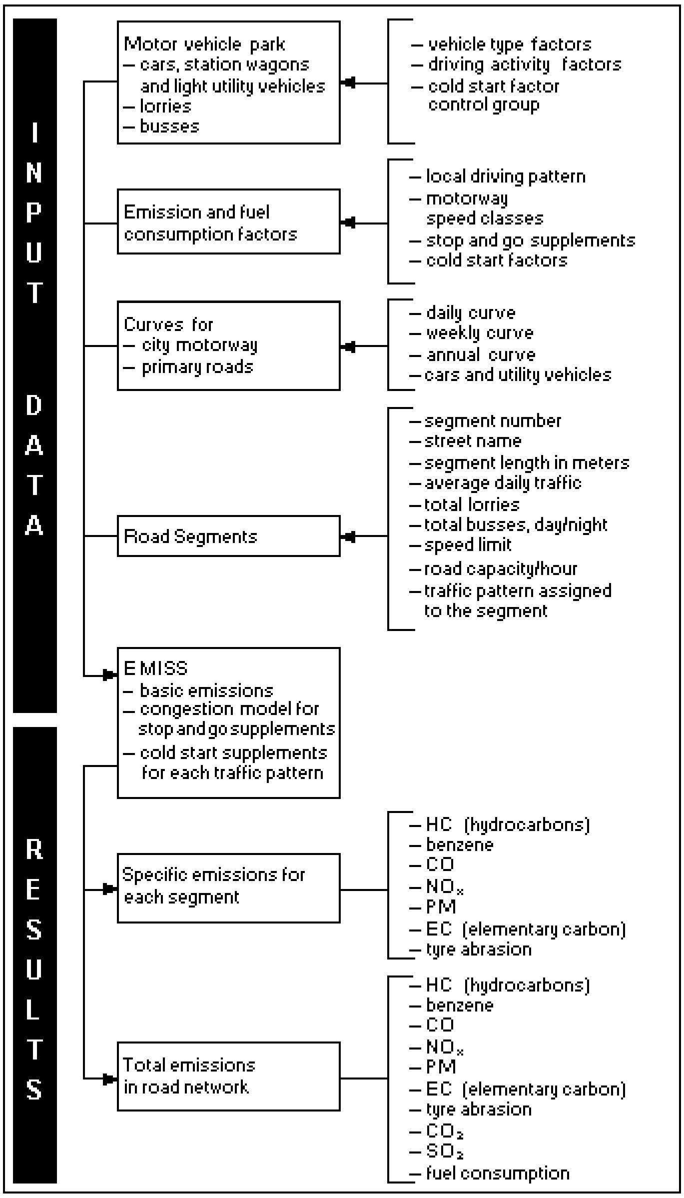

Fig. 3: Emission model for the calculation of quantities of emitted pollutants on primary roads (Liwicki, Garben 1993)

Emissions from motorized two wheeled vehicles cannot be shown due to a lack of traffic counts on the primary road network. Their contribution to the total is determined on the basis of the average traffic load in Germany, and available emissions data.

For areas with distinct orography, the road sections should be arranged in longitudinal categories. However, this is not necessary for Berlin.

Emission model for secondary roads networks (area sources)

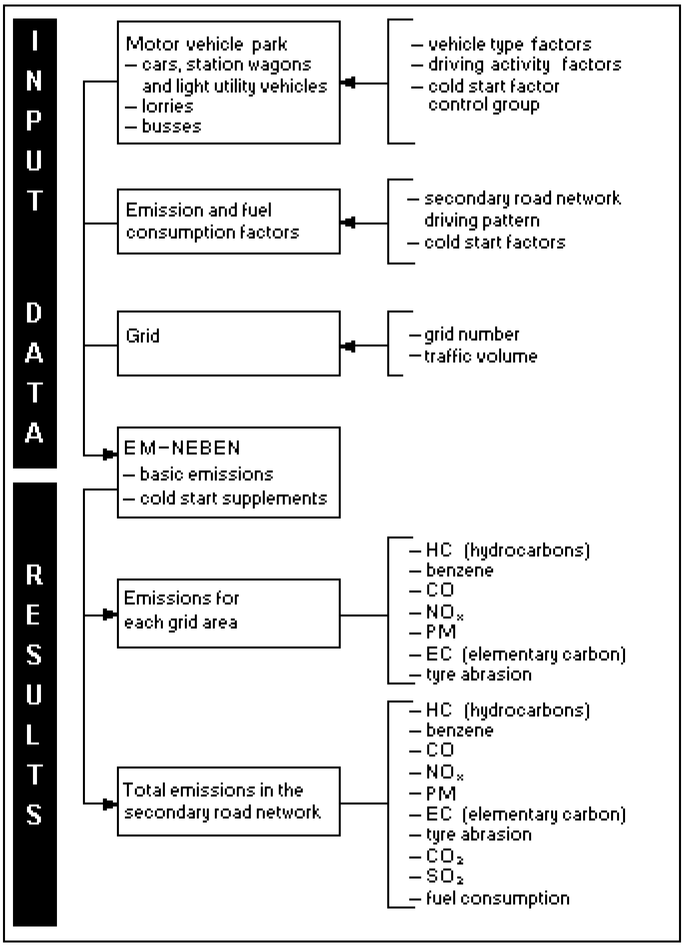

Fig. 4: EM-NEBEN – Emissions model for the secondary roads networks (area sources) (Liwicki, Garben 1993)

The traffic pollution on secondary roads for 2009 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$^{em/air}$ emissions module.

In secondary roads 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 roads network.

Exhaust and abrasion emissions in the city

Table 4 breaks down the driving activity caused by motor vehicle traffic in the city of Berlin (millions of vehicle kilometres per year); fuel use (t) and the exhaust and abrasion emissions of vehicular traffic (t/year), by type of vehicle, for the reference year 2009.

Table 4: Traffic volume (in millions of vehicle-km per year), fuel consumption (tonnes) and exhaust and abrasion emissions (t/year) in the municipal area of Berlin, by type of vehicle; Reference year: 2009

	Total	Cars and station wagons	Heavy lorries	Light commercial transport	City buses	Travel buses	Motorized two wheelers
Primary roads							
Driving activity	10,165.0	8,774.0	379.0	792.0	83.0	36.0	101.0
Fuel consumption	690,182.0	595,972.2	25,976.9	53,144.0	5,702.0	2,465.4	6,922.5
Hydrocarbons	5,645.0	4,877.1	210.7	435.0	46.1	20.0	56.2
Benzene	377.0	325.4	14.1	29.4	3.1	1.3	3.8
Carbon dioxide	2,176,640.5	1,881,705.7	81,912.0	165,424.7	17,922.9	7,775.1	21,899.0
Carbon monoxide	29,386.4	25,406.6	1,097.9	2,292.8	240.2	104.2	292.6
Nitrogen oxide	6,104.7	3,705.3	798.8	254.3	953.9	376.0	16.4
Particulate matter (PM_{10}) (total)	741.9	434.9	157.9	86.5	40.2	20.7	2.0
from exhaust	180.5	84.9	30.6	55.4	4.3	5.3	0.0
from tyre abrasion, stirred up by wind, etc.	561.8	350.0	127.4	31.1	35.9	15.4	2.0
Elemental carbon (exhaust and tyre friction)	100.0	87.1	3.7	7.8	0.8	0.3	0.3
Benzo(a)pyrene	0.0061	0.0053	0.0002	0.0005	0.0000	0.0000	0.0001
Sulphur dioxide	10.6	9.2	0.4	0.8	0.1	0.0	0.1
Secondary roads							
Driving activity	1,890.7	1,632.0	70.5	147.3	15.4	6.7	18.8
Fuel consumption	157,743.5	136,112.4	5,896.7	12,315.1	1,290.0	559.6	1,571.4
Hydrocarbons (also from tank respiration)	1,279.7	1,104.1	47.8	99.9	10.5	4.5	12.7
Benzene	85.4	73.7	3.2	6.7	0.7	0.3	0.9
Carbon dioxide	497,480.9	429,365.9	18,596.7	38,728.6	4,068.3	1,764.9	4,955.8
Carbon monoxide	6,666.7	5,752.3	249.2	520.5	54.5	23.7	66.4
Nitrogen oxide	1,406.1	1,213.3	52.6	109.8	11.5	5.0	14.0
Particulate matter (PM_{10}) (total)	151.9	100.8	29.5	11.6	5.9	3.0	1.1
from exhaust	44.6	32.8	6.5	3.4	1.3	0.6	0.0
from tyre abrasion, stirred up by wind, etc.	107.3	68.0	23.0	8.2	4.6	2.4	1.1
Elemental carbon (exhaust and tyre friction)	23.1	19.9	0.9	1.8	0.2	0.1	0.2
Benzo(a)pyrene	0.0014	0.0012	0.0001	0.0001	0.0000	0.0000	0.0000
Sulphur dioxide	2.4	2.1	0.1	0.2	0.0	0.0	0.0
Entire City							
Driving activity	12,055.7	10,406.0	449.5	939.3	98.4	42.7	119.8
Fuel consumption	847,925.5	732,084.6	31,873.6	65,459.1	6,992.0	3,025.0	8,493.9
Hydrocarbons	6,924.7	5,981.2	258.5	534.9	56.6	24.5	68.9
Benzene	462.4	399.1	17.3	36.0	3.8	1.6	4.6
Carbon dioxide	2,674,121.4	2,311,071.6	100,508.7	204,153.3	21,991.2	9,540.0	26,854.8
Carbon monoxide	36,053.1	31,158.9	1,347.1	2,813.3	294.7	127.8	359.0
Nitrogen oxide	7,510.8	4,918.6	851.3	364.1	965.4	381.0	30.4
Particulate matter (PM_{10}) (total)	893.8	535.7	187.4	98.1	46.1	23.7	3.1
from exhaust	225.1	117.7	37.1	58.8	5.6	5.9	0.0
from tyre abrasion, stirred up by wind, etc.	669.1	418.0	150.4	39.3	40.5	17.8	3.1
Elemental carbon (exhaust and tyre friction)	123.1	107.0	4.6	9.6	1.0	0.4	0.5
Benzo(a)pyrene	0.0075	0.0065	0.0003	0.0006	0.0000	0.0000	0.0001

Sulphur dioxide	13.0	11.3	0.5	1.0	0.1	0.0	0.1

Tab. 4: Traffic volume (in millions of vehicle-km/year), fuel consumption (t) and exhaust and abrasion emissions (t/year) in the municipal area of Berlin, by type of vehicle; Reference year: 2009

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 increases, 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 air quality measurement network BLUME. In order to comply with EU Directives and the amendments to the BlmSchG and the 39th BlmSchV of 2010, resulting from those directives, revisions of the Berlin air quality 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 (PM_{10})** and **nitrogen dioxide**, 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 "03.12 - Long-Term Development of Air Quality".

Measurement of immissions in the municipal area

In 2010, air pollutant measurement was 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 are collected as weekly samples. In addition, passive samplers were placed at these sites to measures nitrogen oxides. These devices collect samples during a sampling period of 14 days, which are then analyzed in the laboratory; for the locations of these measurement stations, see Figure 5. The exact addresses are listed in the monthly reports on air-pollution control of the Senate Department for Urban Development (only in German).

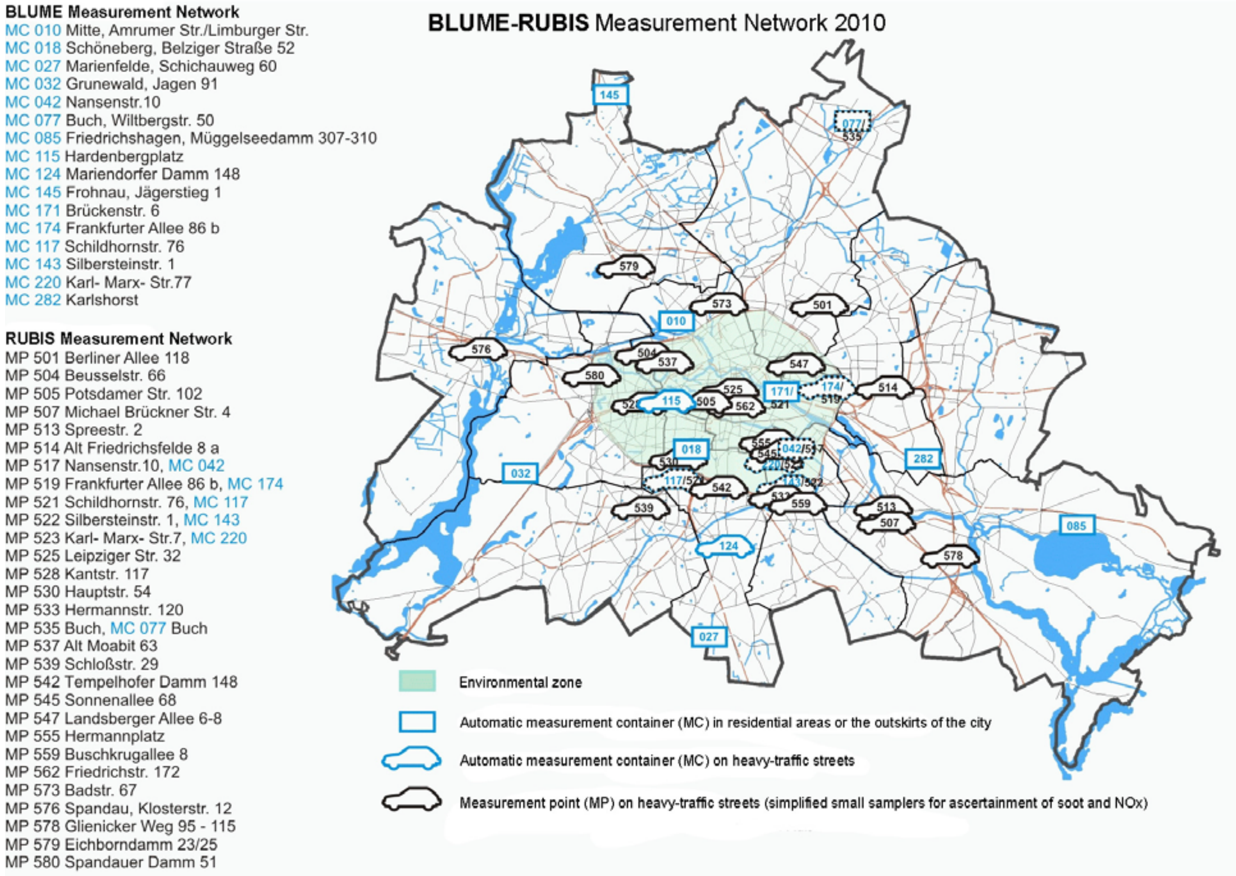

Fig. 5: Locations of the automatic container measurement stations of the Berlin Air Quality Measurement Network (BLUME), and the RUBIS measurement points, 2010.

Fig. 5: Locations of the automatic container measurement stations of the Berlin Air Quality Measurement Network (BLUME), and the RUBIS measurement points, 2010.

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 meters 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. A higher position may also be appropriate if the measurement station is to be representative for 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 (“canyon streets”), 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

6 shows typical pollution distribution in a canyon street. Such distribution develops if the wind direction (above roof level) leads from the measurement point towards the road, resulting in the formation of a turbulence in the canyon street. This blows the motor vehicle emissions to the side of the road where the measurement station is located.

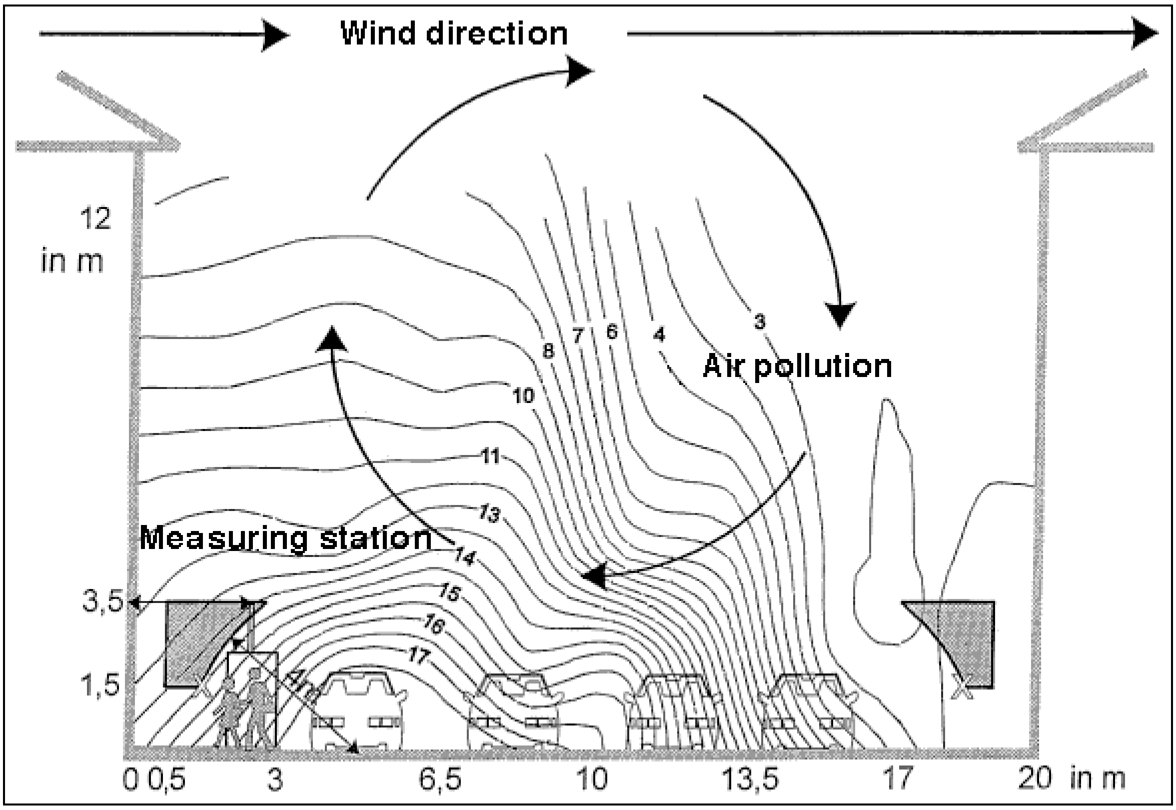

Fig. 6: Pollution distribution on an "canyon street", with the measurement range as per 39th BImSchV, and the receptors used for calculation with the IMMIS$^{em/air}$ "canyon street" model

Long-term trend of NO_2 concentration in the municipal area

The results of the measurements carried out in 2010 throughout Berlin indicate the following long-term trend (cf. Figure 7):

- A clear drop in nitrogen dioxide concentrations was achieved around 1995 by equipping the Berlin power stations with denitrification facilities and the introduction of the regulated catalytic converters for gasoline-powered vehicles.
- NO_2 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/cu.m.
- The expected reduction in nitrogen oxide emissions due to the improvement in exhaust gas technology in vehicles has not included any reduction in nitrogen dioxide pollution.

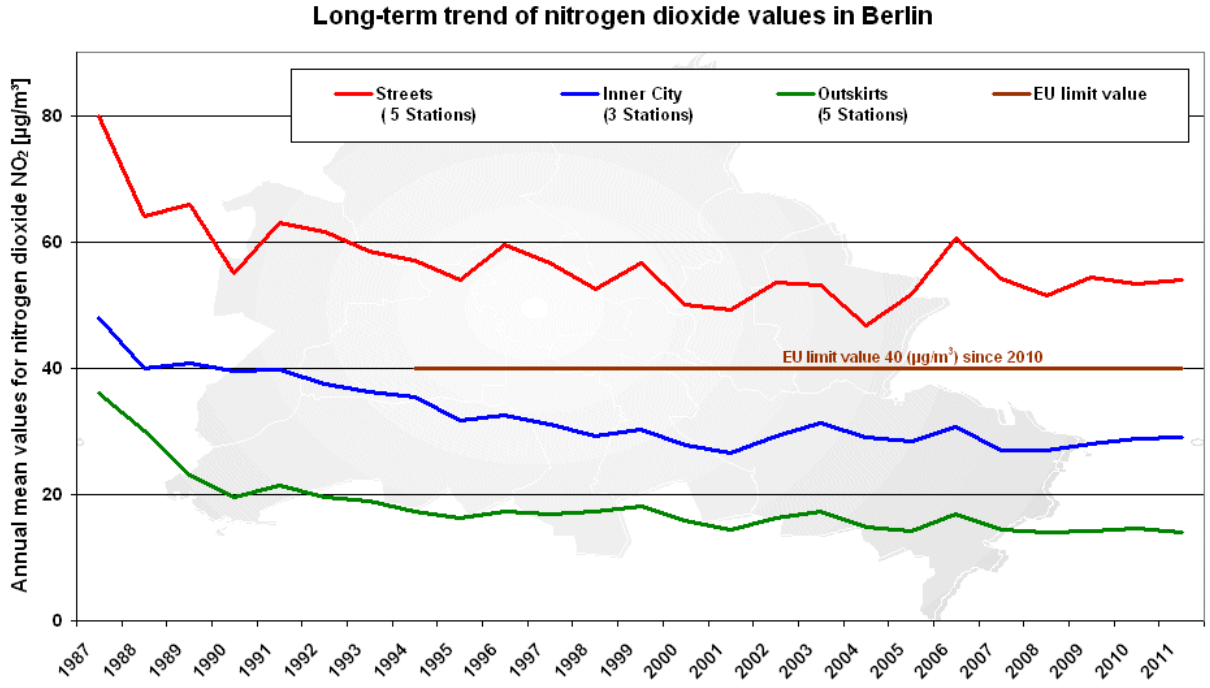

Fig. 7: Long-term trend of nitrogen dioxide values in Berlin
(more information provided under Long-Term Development of Air Quality)

Long-term trend of PM_{10} concentration in the municipal area

Figure 8 shows the development of PM_{10} and total particulate concentrations in Berlin and the surrounding areas over the past more than 20 years (in 1997, the measurement system was changed from overall dust to particulates [PM_{10}]).

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

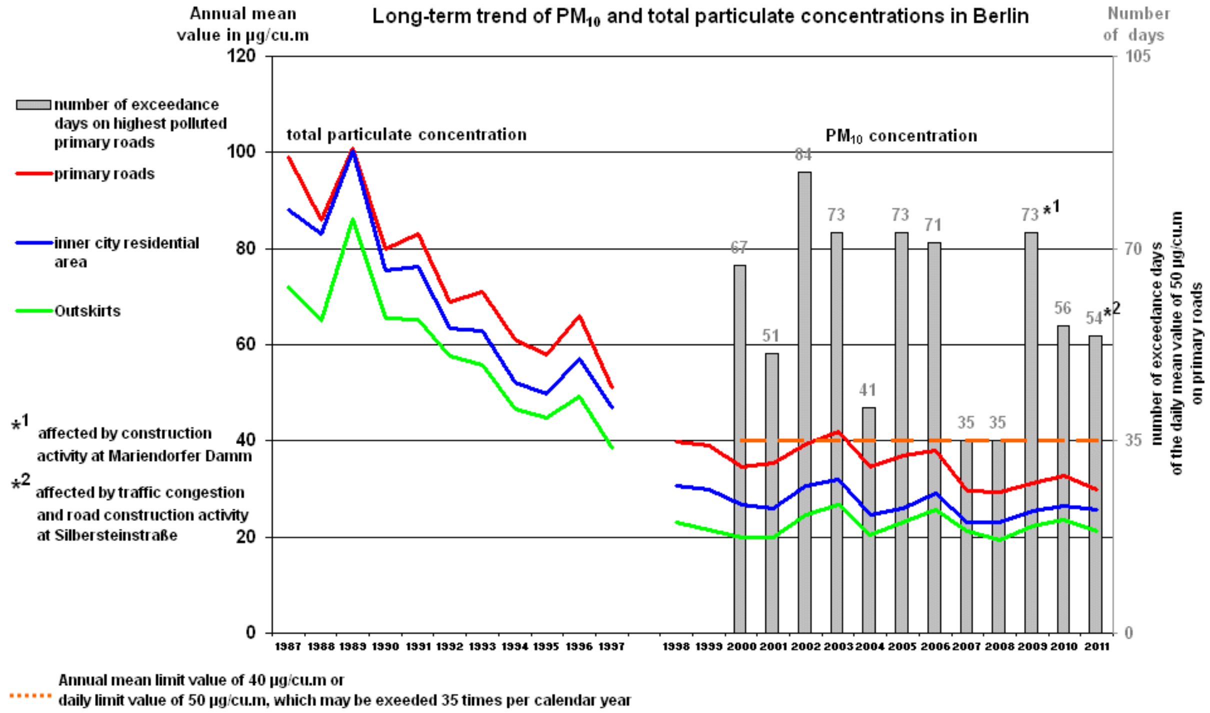

Fig. 8: Long-term trend of PM_{10} and total particulate concentrations in Berlin, and number of exceedance days (more information is provided under Long-Term Development of Air Quality)

A comparison of the curves reveals the following noteworthy points:

- The PM_{10} concentrations on the outskirts of Berlin and in the rural areas of Brandenburg around the city had by 2003 already reached approx. half the PM_{10} pollution level on major Berlin inner-city streets. By 2010, due to a continual annual mean drop in concentrations in the traffic sector, the ratio between the outskirts and the major inner-city streets 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 on major streets declined continuously from 1998 to 2004, by almost 40 %, one cause being the improvements in exhaust gas technology in the vehicles, including those of the bus fleet of the Berlin Transport Company (BVG).
- The annual mean for fine particle pollution near traffic has since 2004 been below the EU limit of 40 µg/cu.m. However, before 2006 and after 2009, the more stringent 24-hour limit was exceeded on some occasions. The 24-hour limit of 50 µg/cu.m. 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 in 2007 and 2008 is also attributable to favourable meteorological conditions, and to the establishment of the Environmental Zone. In 2010, the number of exceedance days above 50 µg/cu.m. would have been higher by about 10 days without the Environmental Zone.
- The annual variation of PM_{10} levels is similar at all stations. In particular, the clear resurgence of PM_{10} levels in 2002, 2003, 2005, 2006 and since 2008 is a phenomenon that has appeared at the same time throughout the city, as well as at stations located on the outskirts of the city. The cause is hence not primarily to be found in Berlin's PM_{10} 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

Map 03.11.1 Auto Traffic Emissions

The basis for the presentation of auto traffic emissions was provided by the traffic counts on the primary road network in Berlin carried out in 2009. As described in the chapter "Survey of emissions," the traffic-related pollutants for the 2009 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 indicators with a special air-hygienic significance for determination of air quality levels, the pollutants nitrogen oxides (NO_x) and particulate matter (PM_{10}), 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 PM_{10}, respectively.

The assignment of the decile ranges to groups, with evaluations, are shown in Figure 9.

Evaluation of the emission quantities, auto 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	8th and 9th decile (71 - 90 % of emissions values)
Group 4	far above average	10th decile (top 10 % of emissions values)
		100 % = 8.338 road sections

Figure 9: Grouping of emissions quantities in the primary road sections, based on the indicators NO_x and PM_{10}

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 Map 03.11.1 Auto Traffic Emissions

The data displayed in the FIS Broker provides detailed information about the road section selected. In addition to the key number of the section, they show the following parameters:

- Length of section
- Name of road section
- Number of heavy trucks (> 3.5 t) per day
- Number of light trucks (<3.5 t) per day
- Number of motorcycles per day
- Number of buses per day
- Average daily traffic volume (DTV)
- Nitrogen dioxide emissions in [g/(m/day)]
- Nitrogen oxides emissions in [g/(m/day)]
- Particulate emissions in [g/(m/day)]
- PM_{10} 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)]
- Non-methane hydrocarbon emissions, in [g/(m/day)]
- Source of data traffic count, 2009
- Evaluation of the emission levels based on NO_x and PM_{10}.

Map 03.11.2 Traffic-caused air pollution

Use of the model

The results of street measurements show that the concentration levels set forth in Directive 99/30/EC and the 39th BImSchV were exceeded at a large number of primary roads – continually, in the case of NO_2. Since measurement-based investigations are, for cost reasons, not possible on all streets in the city, the pollution immission from all the primary roads networks in Berlin were ascertained using emission and dispersion calculations. Under this process, those streets are ascertained where the legal limit values are almost certain to be exceeded, or where they will be met.

To achieve this, these measurements are supplemented with model calculations in all traffic filled streets in which limits are potentially exceeded. However, even in a traffic filled canyon street, the background pollution produced by other sources in the city, and introduced by the long distance transportation of pollution, is an important factor. Therefore, to plan the improvement of air quality in Berlin, a system of models was developed that can calculate both the large scale influence of distant sources and the contribution of all emitters in the city, even in traffic filled canyon streets. For such an estimation of all primary roads ("**screening**"), the aptly designed modular programme system IMMIS■■■ is suitable.

IMMIS-Luft■■■ (air) is a screening programme system for the evaluation of pollution caused by road traffic. It was developed specifically for application in the context of traffic related assessments. Provided the necessary input data is known, a rapid calculation of pollution immissions is possible with the aid of this programme, both for particular streets and for comprehensive street systems.

In this process, the pollution immission is calculated on both sides of the street for one point on each side, at an elevation of 1.5 m, and at a distance of 0.5 m from the edge of the building (cf. Figure 6). The mean of the calculated immission at these two points is considered the characteristic estimate of the immission pollution in this section.

Traffic-caused air pollution immission in “canyon” streets was modelled with the programme segment $IMMIS^{cpb}$. It enables the calculation of hourly values of pollutant immissions produced by local traffic at any receptor in a “canyon” street with varying building heights and with spaces between buildings which allow the passage of wind, on the basis of easily accessible meteorological quantities. An additional required input quantum is the emission level for each section of the street. The emissions were calculated from the current traffic data using the programme segment $IMMIS^{em}$. The pollution produced by the city is derived from the sum of the additional pollution measured using the “canyon street” model, the local street traffic, and the urban background pollution calculated using the $IMMIS^{net}$ programme.

Evaluation based on an index

The map drafted using this process shows the spatial distribution of traffic caused air pollution for NO_2 and PM_{10}. A comprehensive assessment was conducted for both substances. The index developed weighs the calculated concentrations of both pollutants according to their limit values throughout the network of road sections of the primary roads network for 2009, which has been expanded to some 10,000 for this purpose, and adds the quotients. For example, if the two components both reach 50% of the limit, an index of 1.00 will result. All sections that show a reading in excess of 1.8 (90% or more of the limit value) will require special attention in future (cf. Effects on Human Health).

Data display for Map 03.11.2 Traffic-caused air pollution

The data display in the FIS Broker includes the following detailed information on selected road sections:

- Section Number
- Name of the road section
- Length of road section [m]
- Average daily traffic volume (DTV) 2009
- Number of heavy trucks (> 3.5 t) per day in 2009
- Number of light trucks (<3.5 t) per day in 2009
- Number of public transport buses per day in 2009
- Number of motorcycles per day 2009
- Location in the Environmental Zone (1 = yes)

- Affected residents on the road section
- Emission data for 2009 based on the following substances:
  - Nitrogen oxides emissions in [g/(m/day)]
  - PM_{10} emissions in [g/(m/day)]
  - $PM_{2.5}$ emissions in [g/(m/day)]
- The calculated emissions for 2009 based on the following substances:
  - NO_2 (annual average in mg/cu.m) 2009
  - PM_{10} (annual average in mg/cu.m) 2009
  - $PM_{2.5}$ pollution (annual average in mg/cu.m) 2009
- The trend calculations of emissions for 2015 and 2020, respectively based on the following substances:
  - NO_2 (annual average in mg/cu.m) 2015
  - PM_{10} (annual average in mg/cu.m) 2015
  - $PM_{2.5}$ pollution (annual average in mg/cu.m) 2015
  - NO_2 (annual average in mg/cu.m) 2020
  - PM_{10} (annual average in mg/cu.m) 2020
  - $PM_{2.5}$ pollution (annual average in mg/cu.m) 2020
- The calculation of the air pollution index based on the pollutants NO_x and PM_{10}:
  - Air pollution index for NO_2
  - Air pollution index for PM_{10}
  - Overall air pollution index for NO_2 and PM_{10}.

Map Description

Map 03.11.1 Auto Traffic Emissions, 2009

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. 1,380 km, accounts for only about 25 % 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 4 contains the individual totals, the map shows the spatial distribution among the approx. 8,330 count sections.

All 945 sections with – in Berlin terms – "well above average" emissions of the pollutants NO_x and PM_{10} have an "average daily traffic volume" (DTV) of more than 20,000, each with a lorry share of well above 10 %. Especially the heavier ones, those > 3.5 t, due to their powerful engines, account for a disproportionately large share of motor vehicle-related emissions (e.g. up to 75 % of soot particles).

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, which take into account such necessary marginal factors as meteorology, as a non-constant quantum, and the particular route environment (see Methodology section). The calculation model provides an estimate of the concentration of pollutants within the street 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.

Map 03.11.2 Index of air pollution for PM_{10} and NO_2 in 2009

Measurements of the concentrations are only representative for a limited area around the measurement station, and particularly for the particulate PM_{10}, strongly dependent on meteorological conditions.

These dependences are elucidated by the following depictions in Figures 10 to 13.

The trend of PM_{10} daily mean values in 2002, 2005, 2007 and 2010, at the measurement stations of the BLUME measurement network

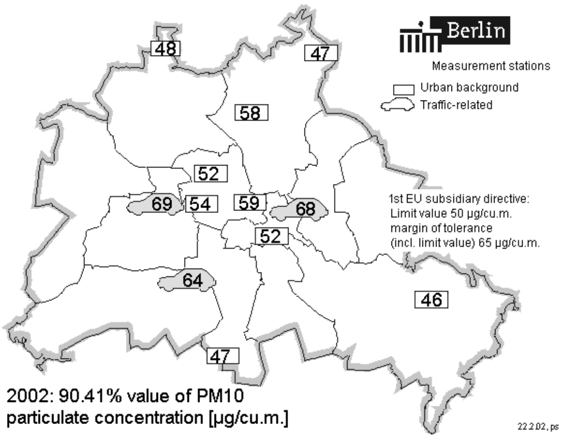

Fig. 10: 90.41 % value of particulate concentration PM_{10} [µg/cu.m.] in 2002 at the measurement stations of the BLUME measurement network

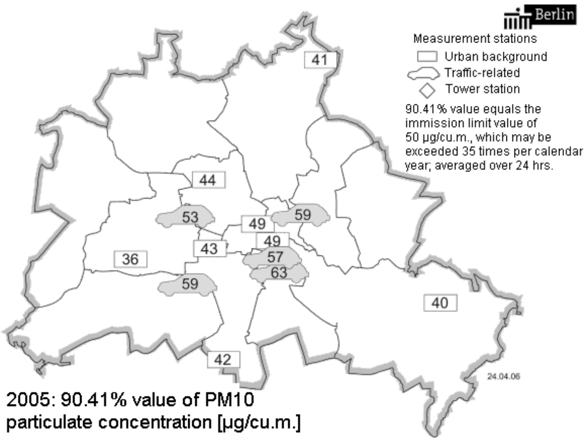

Fig. 11: 90.41 % value of particulate concentration PM_{10} [µg/cu.m.] in 2005 at the measurement stations of the BLUME measurement network

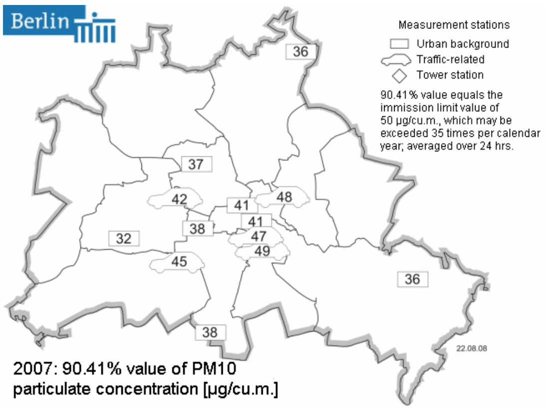

Fig. 12: 90.41 % value of particulate concentration PM_{10} [µg/cu.m.] in 2007 at the measurement stations of the BLUME measurement network

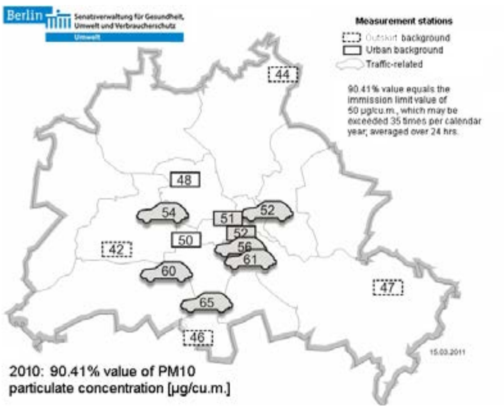

Fig. 13: 90.41 % value of particulate concentration PM_{10} [µg/cu.m.] in 2010 at the measurement stations of the BLUME measurement network

The daily mean value of particulate concentration PM_{10} of 50 µg/cu.m, corresponding to the value 90.41%,may not be exceeded on more than 35 days a year.

Evaluations of the causes of particulate pollution show that approx. half of the particulate concentration in near-traffic measurement points in central Berlin stem from sources outside the Berlin area. Depending on the process of meteorological conditions, this external influence can lead to a more or less strong exceedance, particularly of the second PM_{10} limit value. No more than 35 exceedances of a daily mean value of 50 µg/cu.m of particulate PM_{10} are permitted.

While the short term limit value in some cases considerably exceeded in 2002 and 2005, according to measurements (e.g. 2005: 82 exceedances at the Frankfurter Allee measurement station), in 2007, favourable meteorological conditions, with a large number of west wind weather situations causing a high degree of air exchange, caused not only the mean annual value to be met at all measurement stations for the first time, but the results also were below the second limit value. In 2010, another year with adverse meteorological conditions, the PM_{10} limit value was met in terms of the annual average of 40 µg/cu.m. at all stations. However, the same year 90.41 % value was exceeded at all street measurement stations, and also at the urban background monitoring station in Neukölln; at the BLUME Station 124 on Mariendorfer Damm, this in fact occurred more than 20 times.

However, this proven external influence on the particulate concentration does not provide any excuse to fail to make an effort locally to ensure the permanent reduction in PM_{10} pollution.

In order to permit a long-term reduction of particulate matter, even with adverse weather conditions on major roads, the Berlin Air Quality and Action Plan for 2005-2010 was drafted; one of its measures was the introduction of the Environmental Zone as of Jan. 1, 2008, which has led to a long-term reduction in air pollution. In 2010, the number of exceedance days would, without the Environmental Zone, have in any case exceeded 50 µg/cu.m. on 10 more days.

For a complete and up-to-date picture of the existing pollution and the distribution of pollutants in the municipal area beyond the information obtained from the BLUME measurement stations, elaborate model calculations were carried out in 2009 in the context of the new survey of motor vehicle traffic under the revised Air Quality Plan for 2009-2020, as described above in detail in the chapter on Methodology, with reference to the canyon streets. These were based on weather conditions and traffic and emissions data from 2009.

The municipal background PM_{10} pollution for the exemplary year 2009 is shown in Figure 14; it shows a noticeable increase in values as one moves from the outskirts towards the city centre, i.e., the area within the urban rail (S-Bahn) Circle Line (the "Big Dog's Head" – so-called for the line’s shape on the map).

The concentration calculated for the inner city of between 25 and 27 µg/cu.m. is representative for the pollution in residential areas with low traffic and a considerable distance from industrial plants.

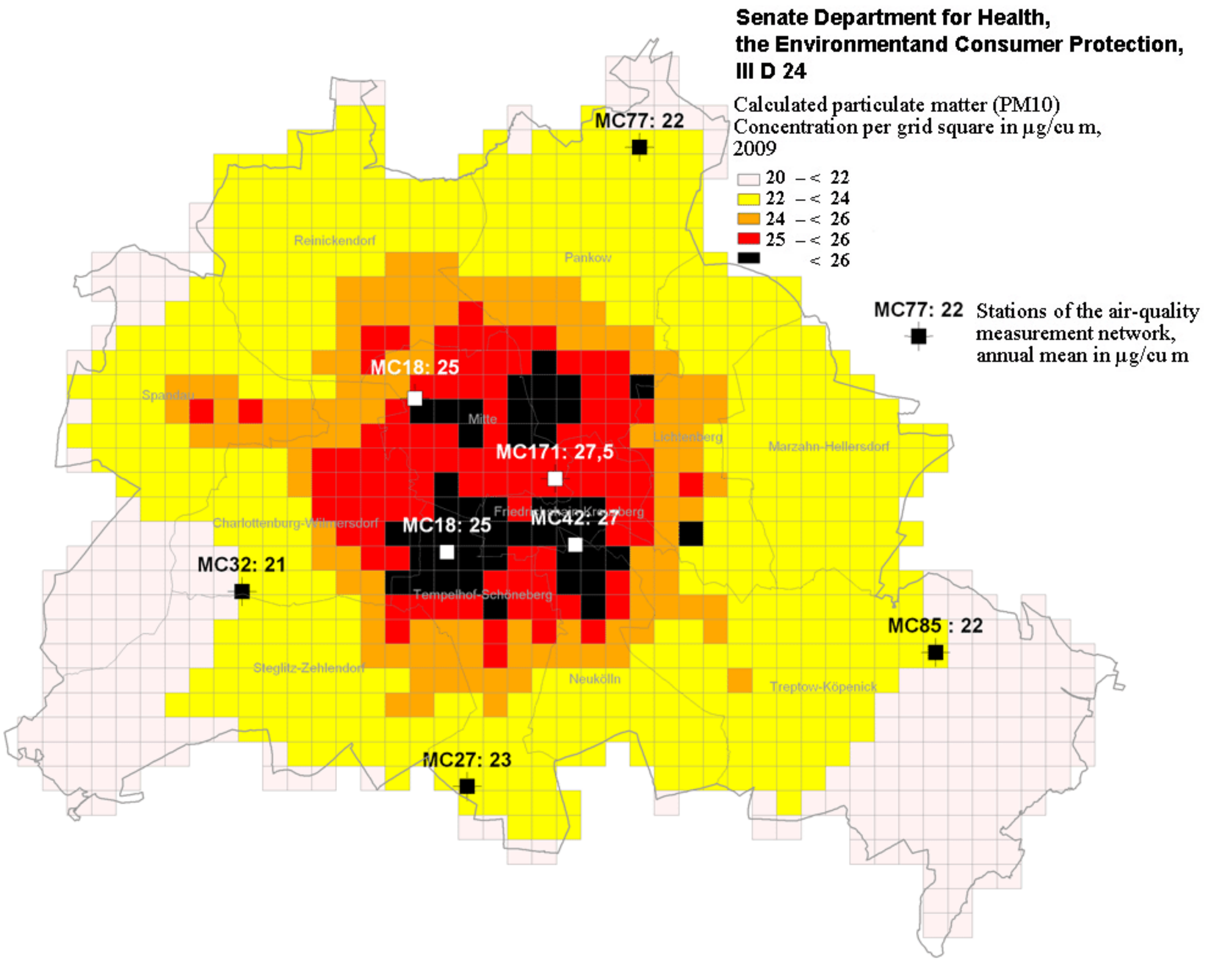

Fig. 14: PM_{10} pollution (annual mean) in the Berlin municipal background, calculated with $IMMIS^{net}$ and measured at BLUME measurement stations for the base year 2009 (SenGesUmV undated)

The calculation of the PM_{10} and NO_2 immissions shown on the map was carried out on the primary road network using the $IMMIS^{luft}$ model, complemented by a detailed data display for each road section assessed. This results from the overlaying of the respective concentration in the municipal background and the calculated additional pollution from local traffic in the respective section of each major road.

All road sections shown in purple show exceedance **of the PM_{10} limit values for 24 hours and/or the annual mean average value of NO_2** in terms of the year 2009 (cf. Table 2).
As of 2015, an EU-wide limit value of an annual mean of 2.5 µm ($PM_{2.5}$) is provided for very fine particulate matter smaller than 25 µg/cu.m. Those sections in which limit value exceedances were calculated were therefore classified as "**very high pollution levels**", and will furthermore require special attention in future with regard to minimizing near-surface air pollution. These sections are distributed throughout the city; however, they are concentrated in a ring around the inner city, on the major radial roads leading to the south and the east, and on the important connecting roads within Berlin, such as the Bismarckstraße/ Kaiserdamm corridor in Charlottenburg, Tempelhofer Damm, Frankfurter Allee, or Torstraße in Mitte. The total length of these road sections adds up to approx. 47 km of roadway, or 3.4 % of the primary road network; more than 39,000 people live along these streets (cf. Table 5). Thus, both the total length and the number of affected people has been markedly reduced by comparison with the 2005 evaluation (cf. 2008 Edition, Table 4).

Most persons affected live in the area of the so-called "Big Dog's Head" (see above), and along the radial roads. The urban motorway, which stands out for very high emissions values on the map in fact affects only a few residents, since the distance to residential areas is relatively great, and the air is well mixed, due to the open situation of the motorway.

Moreover, the map indicates that on some 10% of the total length of all sections, the index value of 1.51 to 1.80 is exceeded. This 150 km long part of the primary road network may constitute a problem in future, at least in some areas, since at least one parameter generally shows a exceedance of the respective limit value here.

Table 5: Section lengths of the air pollution index and affected residents in the primary road network of Berlin, 2009

Index of air pollution by PM_{10} and NO_2	Assessment, primary road network			
	km Road length	%	% Running total	Residents affected
</=1.20 slightly polluted	750.3	54.5%	54.5%	74,249
1.21 - 1705 moderately polluted	429.5	31.2%	85.7%	154,117
1.51 - 1.80 highly polluted	150.1	10.9%	96.6%	100,251
> 1.80 very highly polluted	47.0	3.4%	100.0%	39,070
Total	**1376,8**	**100.0%**		**367,687**

Tab. 5: Section lengths of the air pollution index and affected residents in the primary road network of Berlin, 2009

The approach used to calculate the number of residents affected by limit value exceedances was also taken from the noise mapping procedure (see Maps 07.05 Strategic Noise Maps, 2008 Edition). The number of residents in the flats facing the street front was counted. The number of citizens affected by limit value exceedances thus ascertained represents a rather conservative estimate, because the pollutants spread everywhere, so that increased concentrations can also occur outside highly polluted canyon streets.

Calculated trends for 2015 and 2020, for the substances PM_{10} and nitrogen dioxide (NO_2)

With regard to permanent compliance with air quality limit values, the calculation of trend scenarios is of great importance. It permits the future development of large-scale and local air pollution to be assessed, and also enables an evaluation of whether additional measures beyond those already initiated are necessary to achieve a reduction in air pollution. The immission values for 2009, which are also the basis for the calculation of the air pollution indices, constitute the point of departure. The resulting trend scenario takes into account the reduction on emissions at the trend points in time 2015 and 2020, for Europe and Germany, and also at the local level in Berlin. Thus, progress due to the implementation of European regulations for pollutant emissions by plants, power stations and motor vehicles is incorporated, as are agricultural emissions of particulate matter.

The exhaust emissions from motor vehicle traffic is likely to decrease, due to the gradual removal of older vehicles with high pollutant emissions; even by 2015, this will amount to almost 40 % for nitrogen oxides and more than 50 % for particulates. However, the particulate matter produced by the abrasion of the road, tyres and brakes, as well as by the resuspension of street dust, will increase insignificantly, due to increased driving activity.

In sum, the result for Berlin will be a drop in NO_x emissions by 23 % over 2005 levels by 2015, and by almost 54 % by 2020; and in PM_{10} emissions by about 9 % and 23 %, respectively.

However, in order to comply with the 24 hour limit for particulate matter everywhere, a significantly greater decrease in concentrations is required, but no such improvement is to be expected without additional mitigation measures, either for the local nor for the imported share of particulate matter air pollution. Hence, exceedance of the 24-hour value for PM10 is still to be expected for 2015 (see Table 6). By 2020 however, no further exceedance of PM_{10} and NO_2 values are in not expected, at least with respect to the limits for the annual mean.

The results in terms of air pollution for 2020 thus promise a much better situation than that which existed in 2009. Compliance with the currently or presumably applicable annual limit values seems possible. However, even in 2020, more than 35 exceedances of the daily limit of 50 mg/cu.m are predicted at many major roads Nonetheless, compared with 2009, the length of the sections of main roads with exceedances and the number of affected local residents is expected to drop by approx. 32 % by 2015, and by approx. 79 % by 2020. Additional measures to reduce particulate air pollution are also necessary

Table 6: Section lengths and residents affected by limit value exceedance in the primary road network, Calculation for 2009 and trend calculations for 2015 and 2020

Substances examined: PM_{10} and NO_2	**Calculation of limit exceedance in 2009**		**Trend calculation of limit exceedance for 2015**		**Trend calculation of limit exceedance for 2020**	
	km Road length	**Residents affected**	**km Road length**	**Residents affected**	**km Road length**	**Residents affected**
NO_2 [exceedance of anual limit value]	57.85	47,715	12.80	11,400	0	0
PM_{10} [exceedance of daily limit value]	0.47	429	15.90	14,000	2.70	2700

Table 6: Section lengths and residents affected by limit value exceedance in the primary road network, Calculation for 2009 and trend calculations for 2015 and 2020

In sum it can be stated that:

- on the measures side in Berlin, the emission of pollutants of industrial plants has been reduced considerably under the limit values stipulated since 2007
- the measures already realized or initiated will mean that by 2015, the particulate pollution levels in municipal residential areas will drop by 7-10 %, and the nitrogen dioxide levels by approx. 23 %, compared with 2009
- this reduction will suffice to enable the limit values for particulates and NO_2 defined as annual means to be complied with, even in years with unfavourable weather conditions, and for a reduction of the total length of road sections with exceedances of the 24 hr. limit value for particulates by approx. 90 % to be achieved, by 2015.

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