Air Quality
Annual Report 2015

Report on Ambient Air Quality Monitoring at Frankfurt Airport

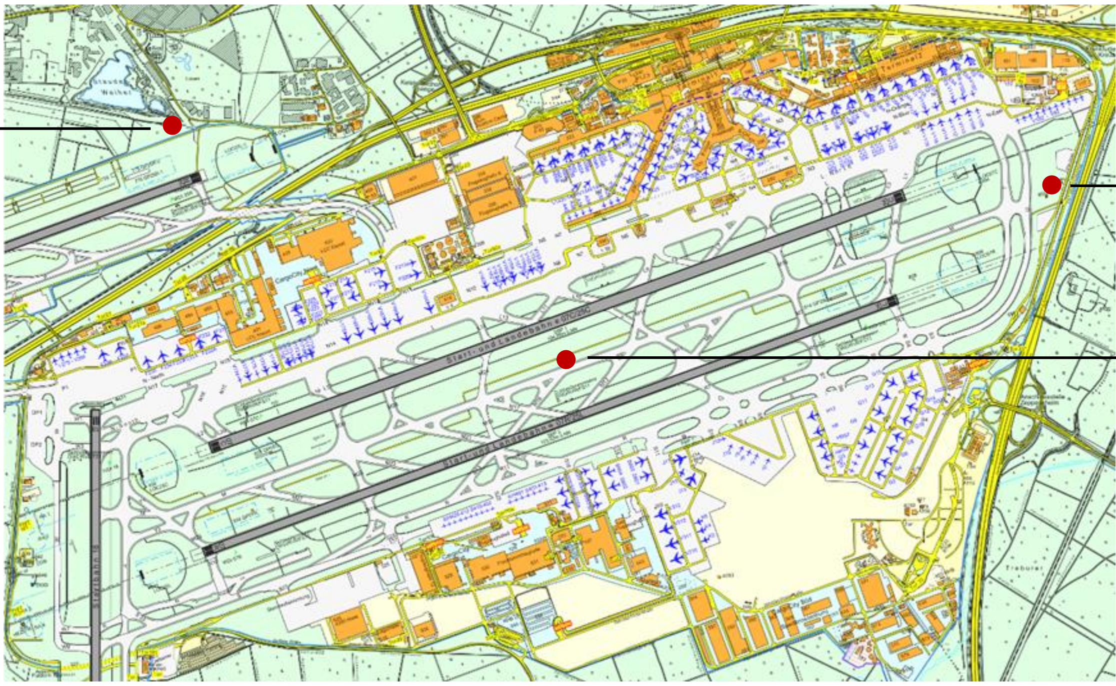
At the beginning of 2015 we extended our monitoring program by measuring particles in the 2.5 µm size category at the S2 site. Beyond the annual monitoring figures, the current report covers a detailed evaluation of this first one-year time series, in comparison to the already regular PM10 monitoring and to various monitoring sites as well. Additionally, the basic measurement techniques and the requirements for measuring accuracy are presented, being substantial boundary conditions for particle measurement.

As has been the case with the other components for years, the PM2.5 results are not unexpected. The concentration is at a rather constant ratio to PM10, ranging on a level of 14 $\mu g/m^3$, comparable with other urban sites, well below the 25 $\mu g/m^3$ limit value at annual average, which first came into force in 2015.

In order to display the additional results in an appropriate context, we removed ethylbenzene from the set of bar graphs since there is no reference value for this component from the public monitoring network, anyway. However, all results are listed in tabular form as before.

An additional change effects the bar graphs displaying the particle constituents[1]. Since in general the reference values from the public monitoring network are not available before our editorial deadline, only the data of the preceding year can be used for guidance. In order to achieve a consistent temporal relation in this case as well, in future the bar graphs displaying the Fraport particle constituents will also refer to the preceding year. In addition, the current values are marked in the diagram.

Ambient Air Quality Monitoring Stations in 2015



[1] Benzopyrene, arsenic, lead, cadmium, nickel

Annual Mean Values Compared to Air Quality Standards

		Measured Value	Air Quality Standard*
NO	S1	34	200 [1]
	S2	22	
	S5	14	
NO_2	S1	46	40 [2]
	S2	36	
	S5	29	
SO_2	S1	2	50 [3]
	S2	4	
CO	S1	0.3	- [4]
	S2	0.3	
O_3	S1	37	- [4]
	S2	43	
PM10	S1	18	40 [2]
	S2	18	
	S5	19	
PM2,5	S2	14	25 [2]
Benzene	S1	0.7	5 [2]
	S2	0.7	
Toluene	S1	1.5	30 [5]
	S2	1.4	
m/p-Xylene	S1	0.8	30 [5]
	S2	0.7	
Ethylbenzene	S1	0.3	20 [1]
	S2	0.3	
Benzopyrene	S1	0.2	1 [2]
	S2	0.2	
Arsenic	S1	0.3	6 [2]
Lead	S1	3.6	500 [2]
Cadmium	S1	0.1	5 [2]
Nickel	S1	1.6	20 [2]

Measuring unit: µg/m³, CO: mg/m³, benzopyrene, arsenic, lead, cadmium and nickel: ng/m³

PM10 = particles, passing a size selective airflow inlet with separation efficiency of 50% at aerodynamic diameter of 10 µm, PM2.5 definition corresponding

** Reference values used:*

[1] Reference value according to HLNUG (Hessisches Landesamt für Naturschutz, Umwelt und Geologie, Hessian State Agency for Nature Conservation, Environment and Geology)
[2] Limit value 39. BImSchV (German ordinance transposing Air Quality Directive 2008/50/EC into national law); arsenic, cadmium, nickel and benzopyrene: target value
[3] Limit value TA Luft 2002 (German Technical Instructions on Air Quality Control, for plants requiring licensing)
[4] No annual mean defined for assessment by respective regulations
[5] LAI recommendation (LAI = Länderausschuss für Immissionsschutz, Ambient Pollution Control Committee of German States)

Particles in the size of 2.5 µm (PM2.5), which can be assessed in terms of a limit value for the annual average since 2015, have been included into the Fraport monitoring program. No corresponding short-term value is defined.

The continuous monitoring equipment was available during more than 99% of the time. Likewise the analyses of particle composition were complete. BTEX data were only missing at S1 in September, thus the data capture was 92% at that site.

Exceedance Frequency of Short-Term Standards

		Short-Term Standard	Reference Interval	Recorded Exceedance Number per Year	Permissible* Exceedance Number per Year
NO_2	S1	200	1 Hour	10	18
	S2			0	
	S5			0	
SO_2	S1	350	1 Hour	0	24
	S2			0	
CO	S1	10 [1]	8 Hours	0	0
	S2			0	
O_3	S1	180 [2]	1 Hour	32	0
	S2			35	
	S1	240 [3]	1 Hour	1	0
	S2			6	
	S1	120 [1]	8 Hours	21 [4]	25 [4]
	S2			24 [4]	
PM10	S1	50	24 Hours	5	35
	S2			6	
	S5			7	

Measuring Unit: µg/m³, CO: mg/m³
** Short-term standards according to 39. BImSchV (for explanation on "permissible" refer to air quality report "Lufthygienischer Jahresbericht 2004", available in German only):*

[1] Maximum permissible eight-hour floating mean of the day derived from hourly means (ozone: target value)
[2] Threshold for the information of the public by responsible authorities in case of exceedance within their network
[3] Threshold for triggering the alert in case of exceedance within the public network
[4] Three-year average (2013, 2014, 2015)

Corresponding short-term values for the assessment of PM2.5, particle constituents, NO, benzene, toluene, m/p-xylene, and ethylbenzene are not available.

According to a mean temperature of 16°C, the year 2015 was only marginally less warm than the preceding one, but extremely dry. Along with sunshine duration above average, only less than 70% of the climatological average[2] precipitation fell over the year.

This was again reflected by elevated ozone maximum values on a large scale. Just like within the public monitoring network, the ozone information threshold was frequently exceeded, particularly in July and August, while on July 3 and July 5 even the ozone alert threshold was exceeded. In July, hourly mean values above the alert threshold did not only occur at the outskirts of the urban agglomeration or at elevated sites, where maximum values are usually found, but as well at the urban sites of Darmstadt, Frankfurt-Höchst, Frankfurt-Ost, Hanau, Raunheim and Wiesbaden.

As expected, the PM2.5 and PM10 concentrations were below the reference values for the annual mean. The PM10 daily mean threshold was exceeded on a few days only, well below the maximum permissible frequency of 35.

NO_2 concentrations remained at the prior-year level, continuing to exceed the annual reference value at S1. Concentrations exceeding the short-term threshold only occurred at S1. Again, these occasions were confined to situations with north-northeasterly wind direction (from outside the airport) or calm wind conditions during the evening rush hours or soon after.

Since the observed PM10 and NO_2 short-term exceedance frequencies were within the permissible range, the key figures of the reporting period would again broadly comply with human health protection standards, if they were applicable at airports. Once more, the only exception is the annual NO_2 mean at S1 being increased by vehicle emissions. It is similar to the concentration level at those urban sites that are also exposed to road traffic. Likewise, this year's high ozone maximum values do not constitute a distinctive feature of the airport site.

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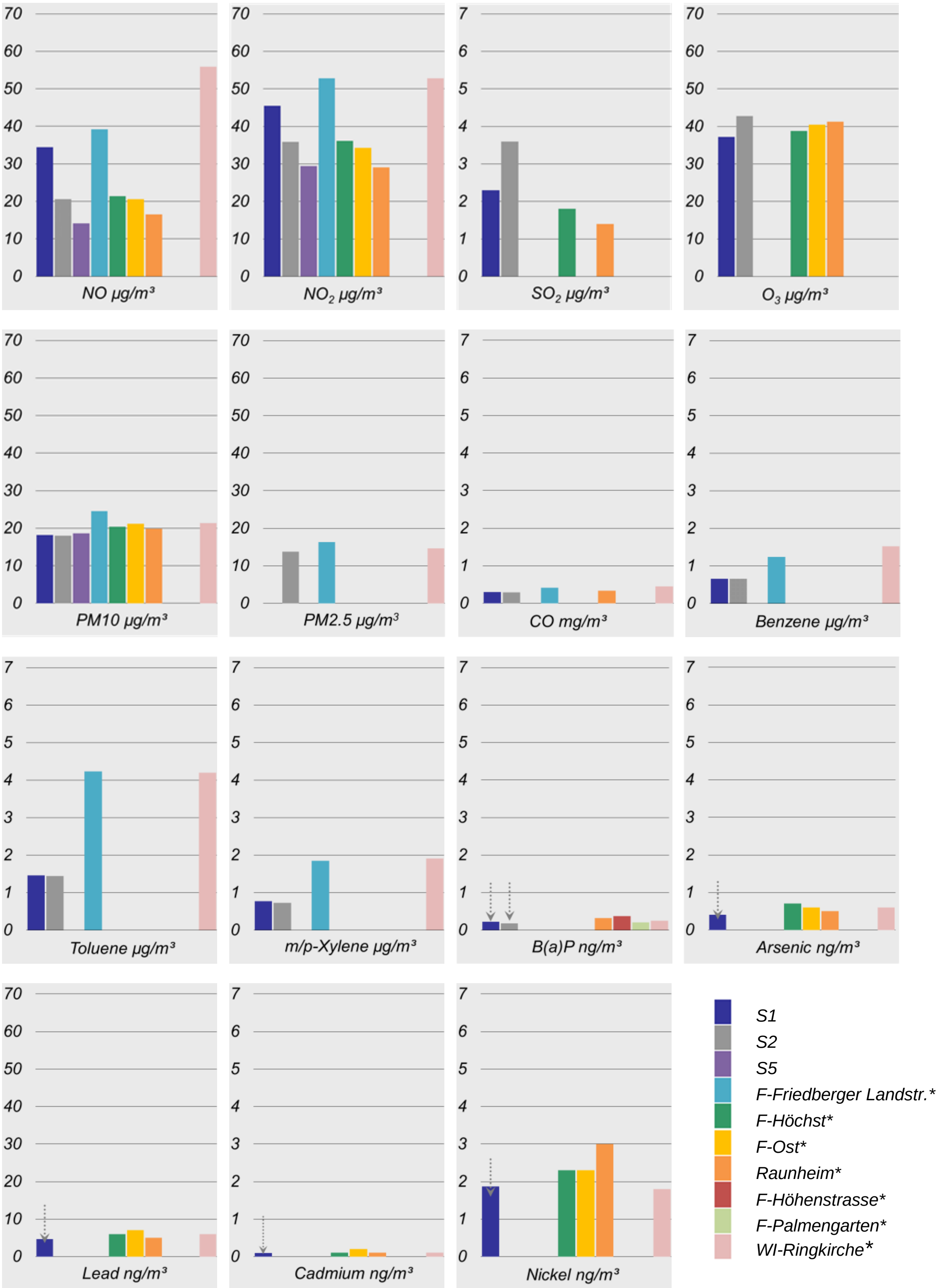
[2] 1981-2010 at the airport station of the German weather service

Annual Means at Airport Sites Compared to Values from Near Sites of Public Network (HLNUG*)



No bar = species not available at site, F = Frankfurt/Main, WI = Wiesbaden, particle constituents: bars = preceding year's data, arrows = current FRA data

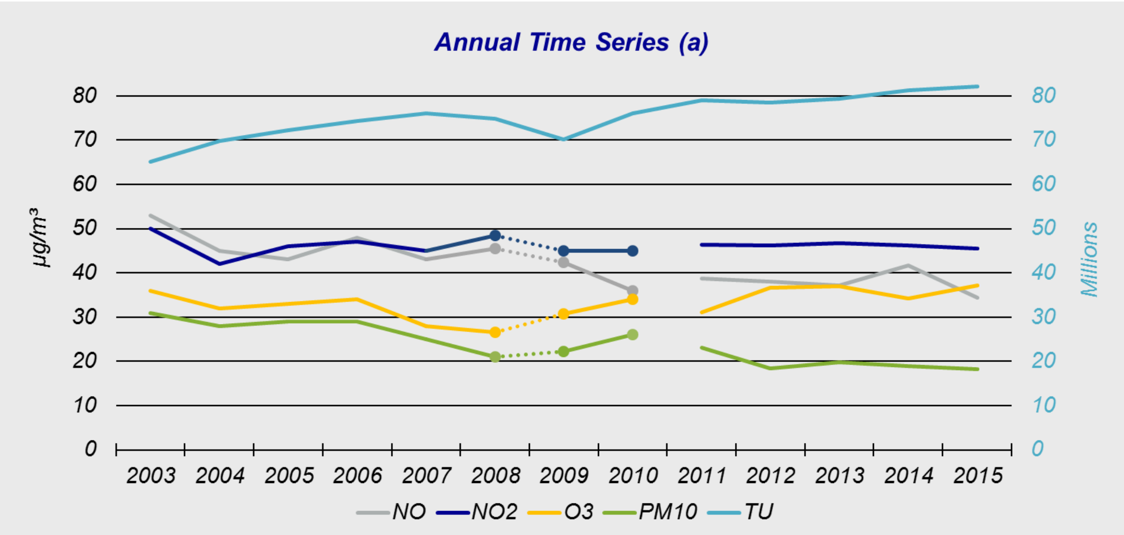
** Reference: Lufthygienischer Monatsbericht Dezember 2015 (floating annual means), HLNUG and Lufthygienischer Jahresbericht 2014 (Teil 2: Staub und Staubinhaltsstoffe), HLNUG.
Part 2 ("Teil 2") for particles and particle constituents for 2015 not available by editorial deadline of this report.*

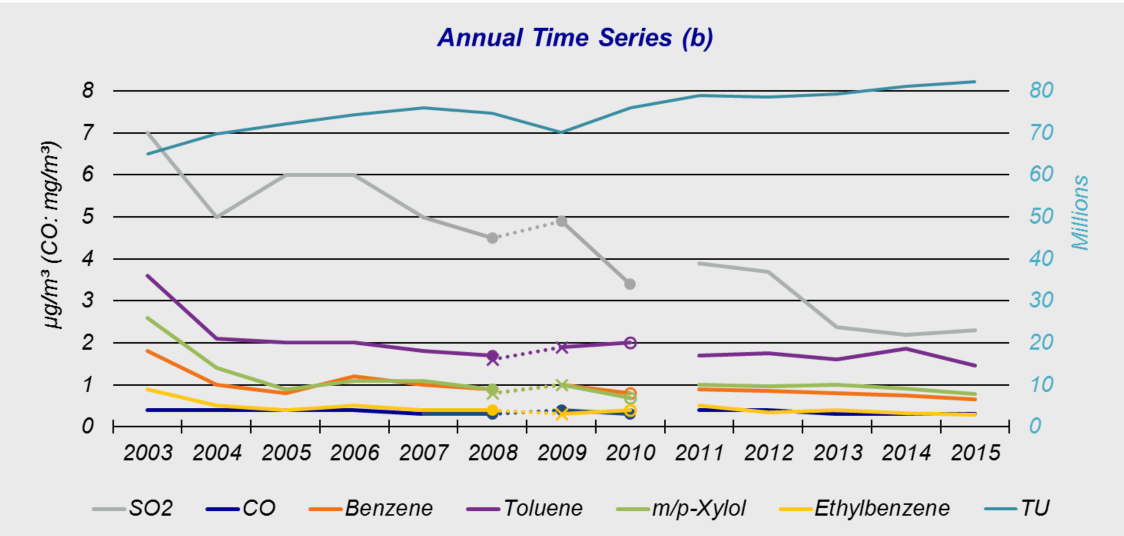
Comparison between Fraport Sites and Nearby HLNUG Sites

As in the preceding years 2015 concentrations at the airport sites were within the medium and lower range of those at the comparative HLNUG sites, except for SO_2. The same applies to the first one-year sample of the PM2.5 particle fraction that will be discussed further on the following pages. Because of the larger sulfur content of kerosene compared to other kinds of fuel an influence of aircraft emissions on SO_2 concentrations at the airport cannot be ruled out (see 2014 Air Quality Annual Report). However, the airport data are in the lower detectable range as well, thus small deviations or temporal fluctuations should not be over-emphasized. At all sites the concentrations of particle constituents, benzopyrene, arsenic, lead, cadmium and nickel, were very small in relation to the corresponding standards as they have been before. Since current comparative values from the HLNUG network were not available by the editorial deadline of this report, this is only valid to a limited extent. In order to compare simultaneous records though, the bar graphs for this substance group consistently cover the preceding year's results by now. Current Fraport values are marked with arrows.

Time Series of Annual Means (Station S1) and Traffic Units (TU)

Along with further increasing traffic units the concentration trend proves to be widely constant. The slight NO and PM10 decrease is opposed to a slightly increased mean ozone concentration. The pronounced SO_2 decline of the previous years does not seem to continue. Regarding the low values the reduction potential has probably been exploited to a large extent.





1 TU = 1 passenger including luggage or 100 kg of air freight or airmail respectively
Solid lines: measurement results at site, dotted lines: minor change of site 2008 / 2009, 2010 relocation approx. 1000m to the north-northeast
Large dots: correction for gaps of data at site, crosses: low data volume at site without correction,
Circles: data derived from two sites

Particle Concentration Measurement

In order to measure particulate matter, ambient air is conducted through a size-selective sampling unit that is designed to either deposit the PM10 or the PM2.5 particle fraction. The mass concentration is then determined according to scattering of the incoming light (nephelometer principle) as well as by particle induced extinction of weak radioactive radiation (β-absorption). The activity of the C14 radiation source implemented is low enough to fall below the legal tolerance and does not require permission.

Size Selection

The particle size category, which delimits the measured variables PM10 and PM2.5, is not a simple, descriptive measure of extent but a very particular technical parameter making a rough consideration of the physical behavior of particles in human organisms possible already at the time of measurement (see adjacent box). Size selection results from different behavior of particles different in size or density due to inertial force in the air flow of the sampling unit. Small particles are less deflected than large ones and thus advance farther – just like in the human organism.

Particles Definition

"PM10" is defined as particulate matter passing through an air inlet with a 50% efficiency cut-off at 10 µm aerodynamic diameter. A corresponding definition applies to PM2.5.

The aerodynamic diameter is equivalent to the diameter of a spherical particle of 1 g/cm^3 density (water) having identical aerodynamic properties to the particle to be measured.

This means, even within this category the size may indeed vary depending on the particle composition (density).

Accordingly, the barely descriptive delimitation of particle categories is defined by means of the measurement technique. Its sole purpose is the methodical surveillance of air quality with respect to human health. Definition, measurement technique, limit and target values form a unit, where the single elements offer only a limited amount of information beyond this scope. Within this scope, details are governed by directives in order to achieve comparable and reproducible results.

Requirements for Measuring Accuracy

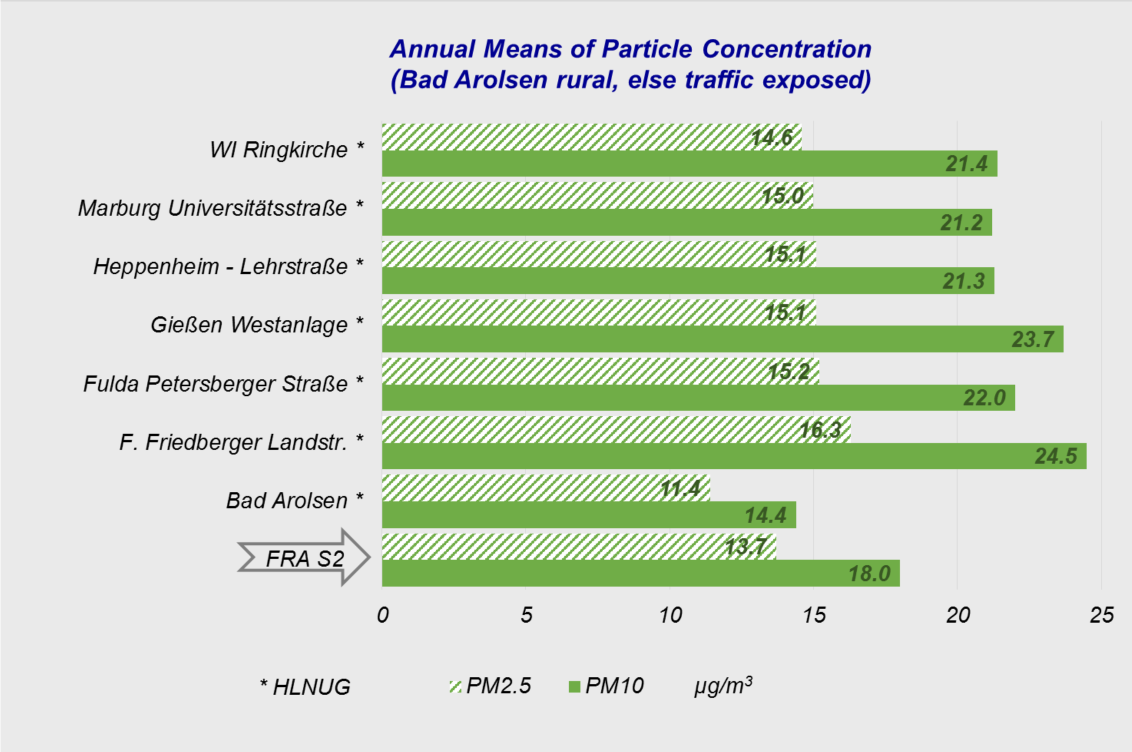
The accuracy requirements for particle measurement are guided by the reference values correspondingly. Therefore, the smallest unit for assessing particle concentrations, the daily mean, should be determined with an accuracy of ±25% as required. If nearly all the PM10 consist of the smaller PM2.5 particles there may be occasions within this tolerance margin, where the PM2.5 value recorded is the larger than the PM10 value, whereas it should rather be part of it.

This is mostly the case with low concentrations near the detection limit, where even small differences mean large relative deviations. Thus, a second quality criterion implies that the absolute difference between two measurements of the same kind (i.e. in case of PM2.5 ≈ PM10 as well) should not be more than 2.5 µg/m^3. Records of PM2.5:PM10 relations that are not reliable according to these two criteria are reanalyzed for discernible failure conditions and corrected or deleted respectively. The monitoring results quality-tested in this way are not always easily interpretable – particularly at higher resolution than designated – but they meet the purpose of standardized air quality surveillance.

Comparison of Particle Concentrations

Within the Hessian air quality monitoring network, the PM2.5 concentration[3] is broadly measured at sites exposed to traffic. Comparative data from urban background are not available. The Bad Arolsen site is the only one classified as rural providing PM2.5 measurement. Correspondingly the lowest annual mean of 11.4 µg/m^3 was recorded there, while the largely consistent result at the other sites was 15 to 16 µg/m^3. The annual mean of 13.7 µg/m^3 at the Fraport site S2 is in between. All results are significantly below the limit value of 25 µg/m^3.

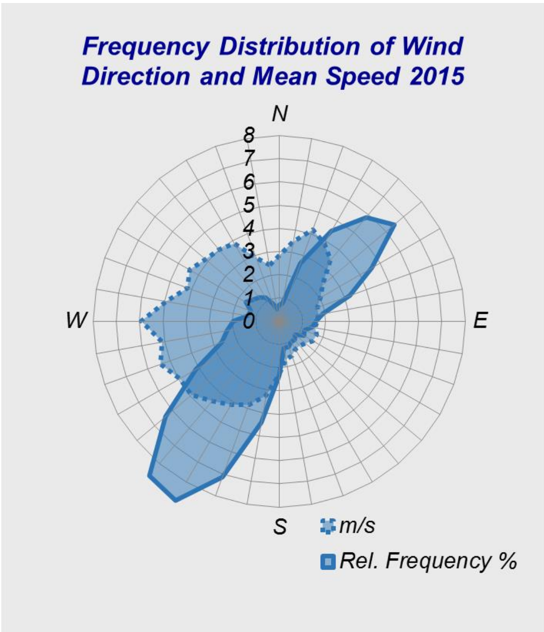
[3] The HLNUG annual means presented here are also floating means of the preceding year from the monthly report December 2015. Further evaluation is based on hourly values published via internet.

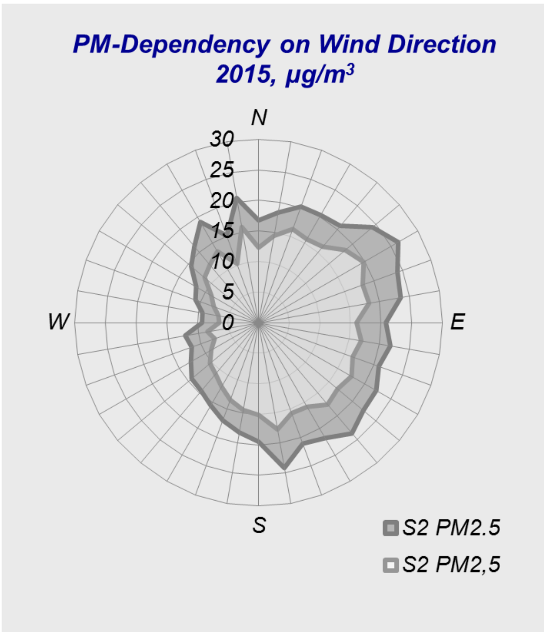


The average PM2.5 to PM10 ratio slightly depends on the location and is between 60% and 80% at all sites. At the airport, it amounts to 76%. Insofar, PM2.5 monitoring has not lead to basic new discoveries. With respect to air quality surveillance, PM10 continues to be a substantial measure, not least because a short-term limit exists, which however has not been exceeded in Hesse after 2011.

Influence of Wind Direction and Speed on Particle Concentration

Since particle concentration is distributed very homogenously over a large scale, conclusions about perpetrating emission sources cannot be drawn from the dependency on wind direction. In this respect, PM2.5 behaves just like PM10, while higher values occur with all sectors including easterly components. In general, these are sectors related to low wind speed and low atmospheric mixing conditions. Ground level emissions may then accumulate in the atmosphere.





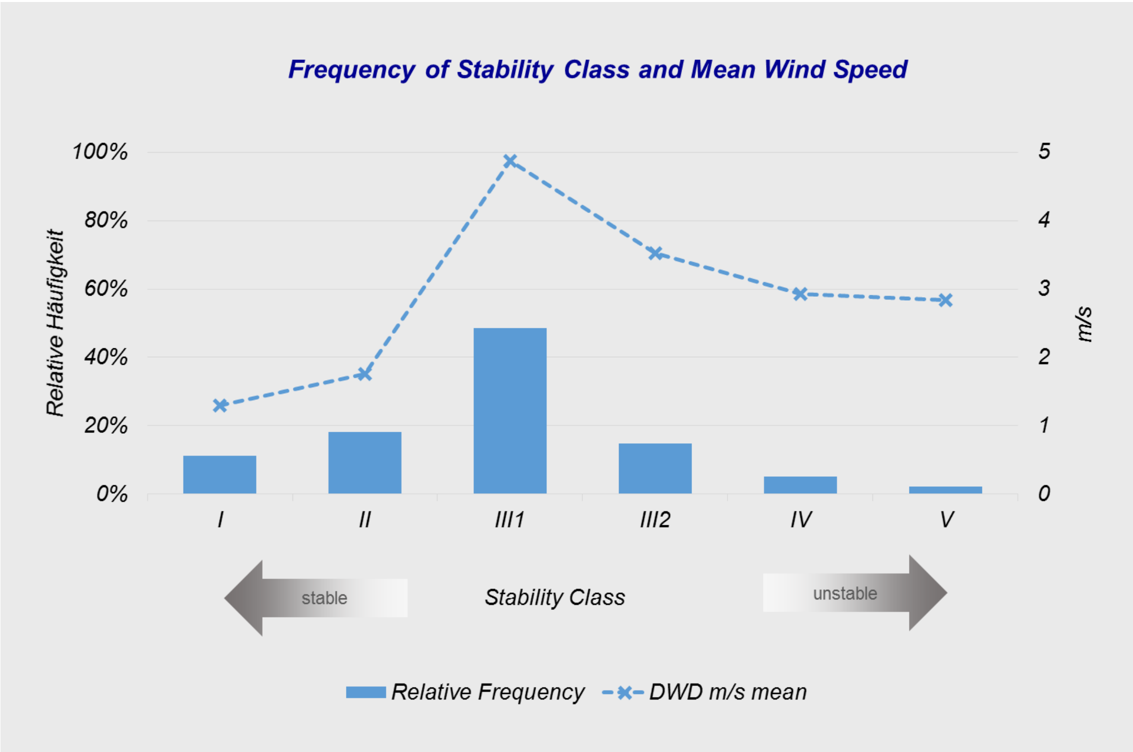
Evaluation of hourly data from WebWerdis (DWD)

With westerly wind directions in contrast, wind speed is mostly higher. This dilutes the pollution faster. The two wind rose diagrams above reveal a very characteristic airport pattern.

Influence of Atmospheric Stability

Thermal stratification of the atmosphere determines vertical mixing in particular. The larger the temperature decrease with height the stronger the vertical mixing. Constant temperature or even temperature increase with height is called stable stratification.

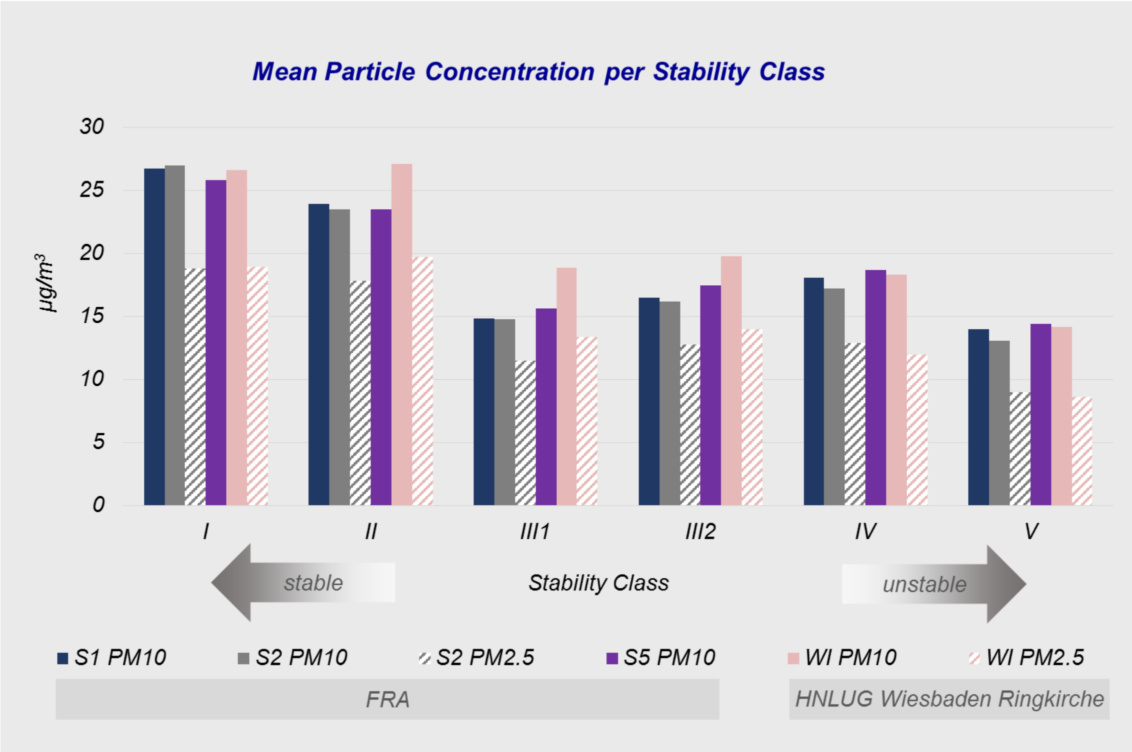
Stability may be described in terms of stability classes. Stability categories generally used in Germany are based on the Klug/Manier classification. They are denominated by Roman numerals partly indexed by Arabic numerals. The lower the numeral the more stable the atmosphere and the weaker the dilution of ground level pollution.



Evaluation of hourly data WebWerdis according to VDI 3782 (2009)

Accordingly, the lowest wind speeds occur with the two lowest, most stable classes. The highest wind speed results with the third and most frequent class, i.e. “neutral to stable”. Towards the unstable classes the (horizontal) wind speed declines again. However, vertical mixing is stronger then.

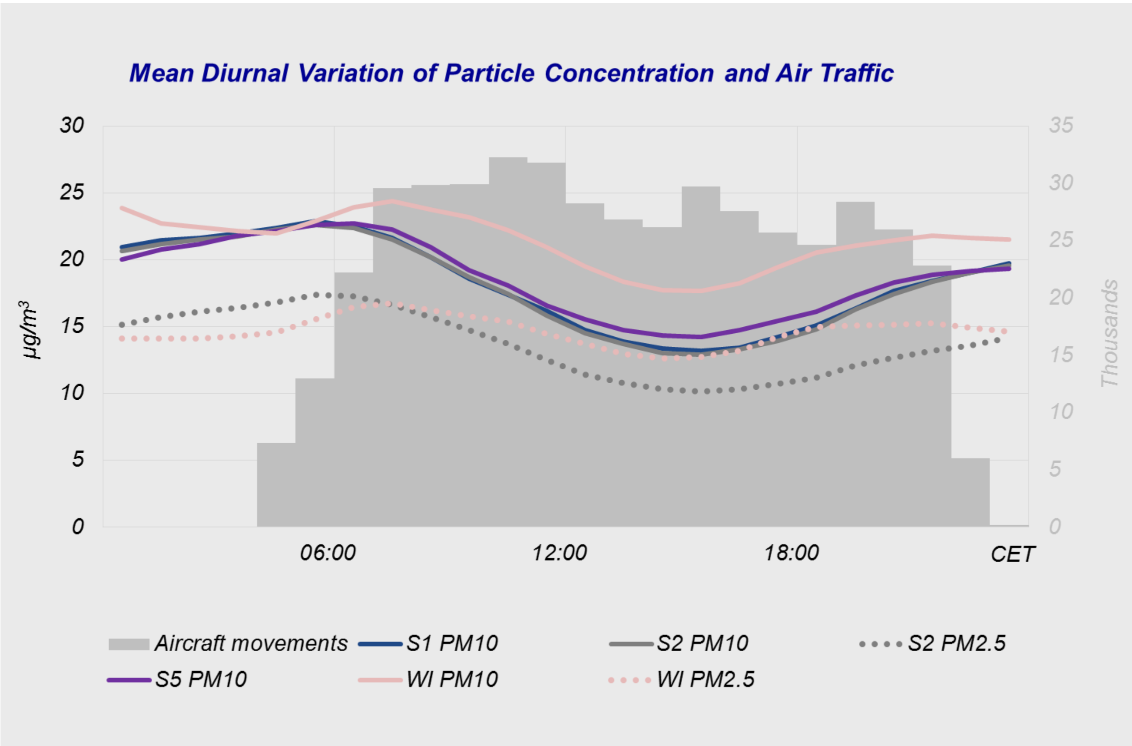
These relations are reflected in the distribution of particle concentration among stability classes as well. The highest values are found with the two stable classes, relatively low concentrations with the frequent neutral class accompanied by high wind speed and the lowest values with the most unstable class related to the most intense vertical mixing.



This result applies to PM2.5 and PM10 as well and also for all sites considered in a similar way.

Diurnal Course of Particle Concentration

Likewise the diurnal concentration course is strongly influenced by the atmospheric mixing development. Regardless of the site and particle size category, there is always a morning maximum and an afternoon minimum, as well as another increase towards the evening. In this course the effect of stable stratification at night and in the morning coincides with the rush hour emissions on one hand, while on the other hand the better mixing during daytime coincides with less emission periods between the rush hour peaks.



The PM10 curves from the Fraport sites are virtually identical. Particularly during daytime the values from Wiesbaden Ringkirche are higher, probably due to the urban road traffic.

As well as at the airport the PM2.5 curve at Wiesbaden reveals the same pattern as the PM10 curve on a lower level. As expected, no relation to air traffic can be recognized. Among other factors, the fact that the morning increase begins long before the outset of air traffic contradicts such a relationship.

Further Information:

Fraport AG
www.fraport.de

HLNUG Hessisches Landesamt für Naturschutz, Umwelt und Geologie
(Hessian State Agency for Nature Conservation, Environment and Geology)
http://www.hlnug.de

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
http://ec.europa.eu/environment/air/quality/legislation/existing_leg.htm

DWD data WebWerdis
https://werdis.dwd.de

Determination of Dispersion Categories
VDI 3782 (2009) Part 1
Environmental meteorology
Atmospheric dispersion models
Annex A

HLNUG Special Monitoring Campaign Frankfurt-Lerchesberg
http://www.hlnug.de/start/luft/sonstige-berichte.html
Erhebung der Luftqualität im Einzugsbereich der neuen NW-Landebahn des Flughafen Frankfurt Station Frankfurt-Lerchesberg

HLNUG Special Monitoring Campaign Flörsheim
http://www.hlnug.de/start/luft/sonstige-berichte.html
Erhebung der Luftqualität (Station Flörsheim) und des Staubniederschlags im Einzugsbereich der neuen NW-Landebahn des Flughafens Frankfurt

ACI Study on Air Quality during the Period of Cancelled Flights due to Volcanic Ash Plume
“Effects of Air Traffic on Air Quality in the Vicinity of European Airports“
www.fraport.de/aciluftqualitätsstudie2010

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