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EU4Environment
Water and Data in Eastern Partner Countries

umweltbundesamt
ENVIRONMENT AGENCY AUSTRIA

Air quality indicators A-2.1 to A-2.12 – methodologies

Implementing partners

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Christian Nagl, 4.5.2023

CONTENT

- Proposed indicators
- Monitoring requirements
- Data validation
- Data aggregation
- Data quality criteria
- Limit values
- Population weighted indicators

PROPOSED AIR QUALITY INDICATORS

Number of days with exceeded daily limit value
A-2.1 PM_{10}
A-2.2 SO_2
A-2.3 O_3
A-2.4 NO_2
A-2.5 $PM_{2.5}$

Annual mean concentration in cities
A-2.9 $PM_{2.5}$
A-2.10 PM_{10}
A-2.11 SO_x (proposal: SO_2)
A-2.12 NO_x (proposal: NO_2)

A-2.7 Annual mean level of $PM_{2.5}$ in cities (population weighted) (SDG indicator 11.6.2)
A-2.8 Annual mean level of PM_{10} in cities (population weighted) (SDG indicator 11.6.2)

GENERAL REQUIREMENTS

- Suitable location of stations
- Knowledge about spatial representativeness of air quality stations
- Suitable monitoring instruments
- Fulfilment of data quality objectives (time coverage, data capture)
- Data reporting
- Quality management system

LOCATION OF STATIONS

- Assessment of **highest** pollution level population is exposed to
- Assessment of pollution level **population in general** is exposed to
- Assessment in the vicinity of **point sources** (downwind in nearest residential area)
- Assessment of AQ for the protection of **vegetation and natural ecosystems**
- Assessment of $PM_{2.5}$ constituents in the **rural background** (possible to share stations with neighbouring countries)

Close to heavily trafficked road, industrial sites
Representative for small number of people

Residential areas
Representative for large number of people

Industrial areas
Representative for small number of people

Rural areas
Representative for small number of people, but large area

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AIR QUALITY STATIONS

CLASSIFICATION OF STATIONS

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Urban traffic

© Amt der Oberösterreichischen Landesregierung

(sub-)urban background

© Umweltbundesamt

Rural background

CLASSIFICATION OF STATIONS

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Urban industrial

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Rural traffic

- Each station / type of station is representative for specific area
- Dependent on pollutant
- Exposure estimated mainly by urban background stations
- Traffic station usually area with highest, exposure relevant, concentrations

RECOMMENDATIONS FOR ASSESSING DISPERSION CONDITIONS

Local

- Street canyon
- Detached buildings or one-sided compact buildings
- Open terrain
- Elevated terrain

Regional

- Plane terrain
- Hilly terrain
- Mountainous terrain – slope
- Mountainous terrain – ridge, pass or summit
- High alpine terrain
- Valley in hilly terrain
- Valley in mountainous terrain
- Basin in hilly terrain
- Basin in mountainous terrain
- Basin partly surrounded by mountains
- Coast with plane terrain in interior
- Coast with mountainous terrain in interior

MONITORING INSTRUMENTS: REFERENCE METHODS

- European standards are required in Ambient Air Quality Directives (specific method for each pollutant)
- Other methods can be used if equivalence is shown (guidance available)
- Suppliers usually comply with European standards (except low-cost sensors)
- Passive samplers often fulfil data quality objectives

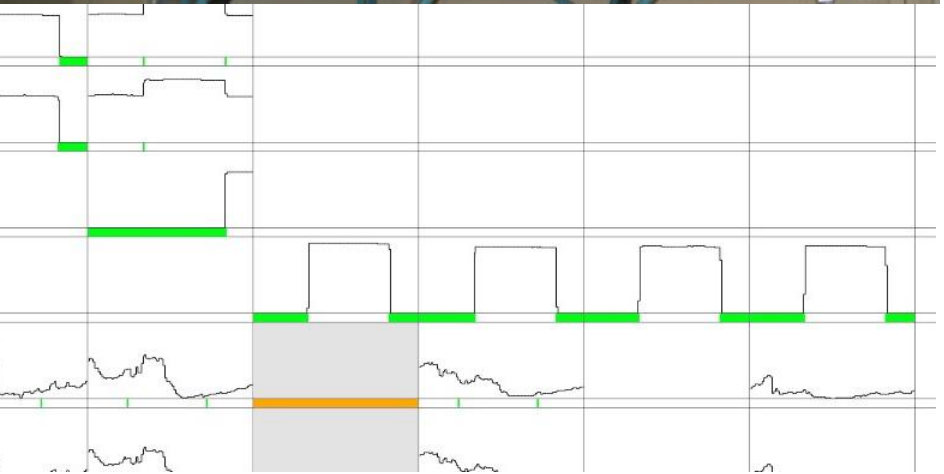
- SO_2 (EN 14212:2012): UV fluorescence
- NO_2, NO_x (EN 14211:2012): chemiluminescence
- PM_{10}, $PM_{2.5}$ (EN 12341:2014): gravimetry
- Pb, As, Cd, Ni (EN 14902:2005): chemical analysis
- Benzene (EN 14662): gas chromatography
- CO (EN 14626:2012): non-dispersive infrared spectroscopy
- B(a)p (EN 15549:2008): chromatography

NUMBER OF STATIONS

- Requirements according to EU Ambient Air Quality Directive 2008/50/EC
- Dependent on pollutant levels and population
- Approximately half the stations required if concentrations are between upper (60-70% of limit value) and lower assessment thresholds (40-50% of limit value)
- Below lower assessment threshold: modelling and / or objective-estimation techniques

Population (× 1000)	Gaseous pollutants		PM_{10} + $PM_{2.5}$	
	> upper	> lower < upper	> upper	> lower < upper
0-249	1	1	2	1
250-499	2	1	3	2
500-749	2	1	3	2
750-999	3	1	4	2
1000-1499	4	2	5	3
1500-1999	5	2	7	3
2000-2749	6	3	8	4
2750-3749	7	3	10	4
3750-4749	8	3	11	6
4750-5999	9	4	13	6
≥ 6000	10	4	15	7

Source: Directive 2008/50/EC



DATA QUALITY

DATA QUALITY OBJECTIVES

- Monitoring for air quality assessment needs to fulfil certain criteria
- Criteria in Annex I of AAQD (Dir. 2008/50/EC) and Annex IV of Dir. 2004/107/EC
- Uncertainty (fixed measurements) (see Guide to the Expression of Uncertainty in Measurement)
  - 15 %: SO_2, NO_x, CO;
  - 25 %: PM, Pb, C_6H_6
- Time coverage (proportion monitoring in operation):
  - Time coverage = 100 × $N_{planned}$ / N_{year} %
  - continuous fixed measurements: 100 %
  - indicative measurements: 14 %

Monitoring should take place the whole year

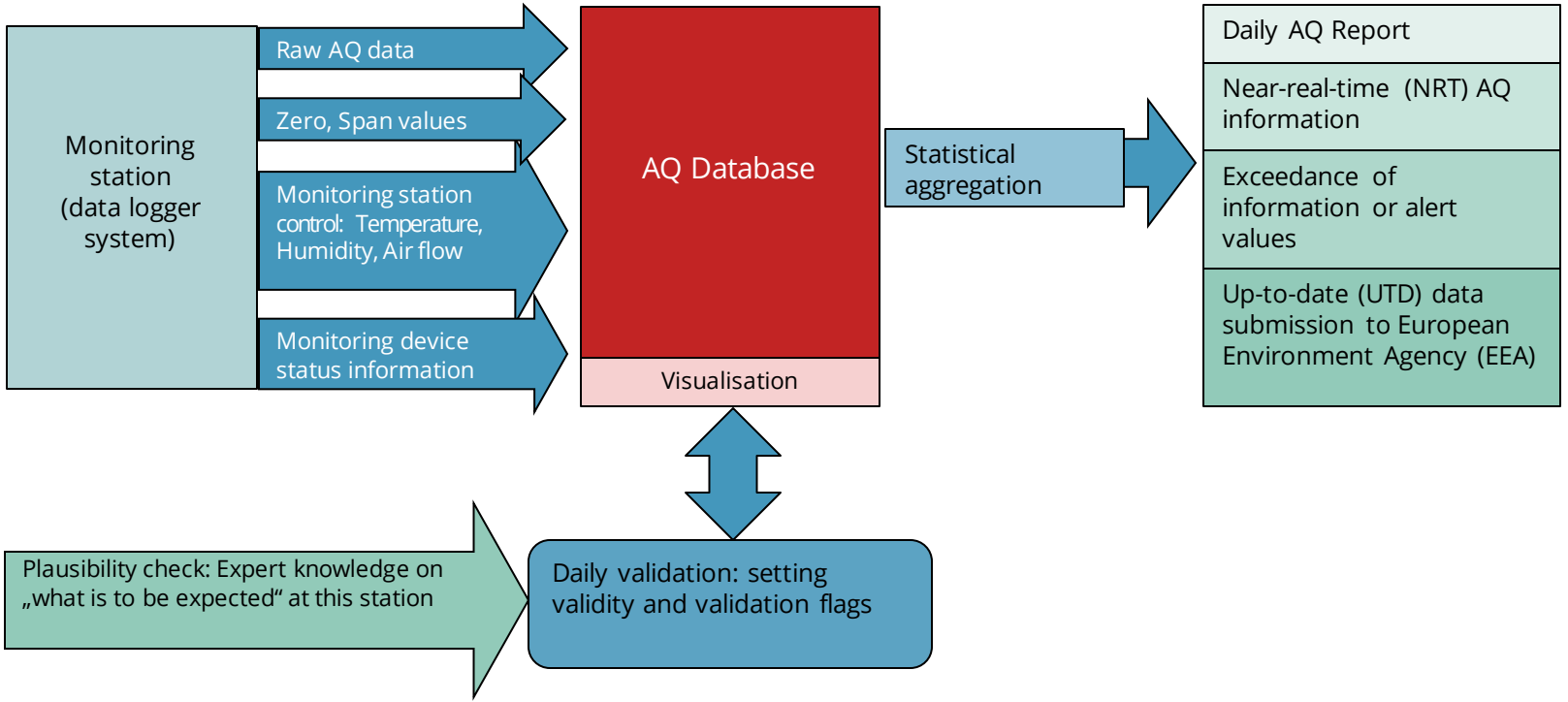
- Data capture (90 % for fixed measurement):
  - Data capture = 100 × N_{valid} / (N_{year} × MinTimeCov) %
  - regular calibration or normal maintenance not included (5 % of measurement time) ➔ "effective" data capture criterion for continuous measurement is 85 %

Instrument should provide data 85 % of the time

DATA VALIDATION

Step	Control procedure	Time interval	Data used for
0	raw data from station data logger		near-real-time information of the public
1	first plausibility check	daily	daily AQ report near-real-time information of the public
2	plausibility check based on information from station maintenance	monthly	monthly AQ report
3	Correction of zero-/span-deviation based on calibration	annually	annual AQ report data submission to international databases (e.g. EU/EEA, EMEP, GAW)

INFORMATION FLOW FOR DAILY DATA VALIDATION



DAILY DATA VALIDATION

Information

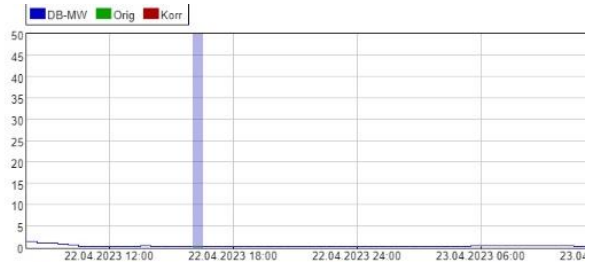
- AQ data (30 min mean levels)
- Validity flags of raw data
- Daily zero and span checks
- Status bits from monitoring devices
- Information on air conditioning system (temperature, humidity)
- Comparison with other stations
- Additional meteorological information
- Knowledge on usual pollutant levels

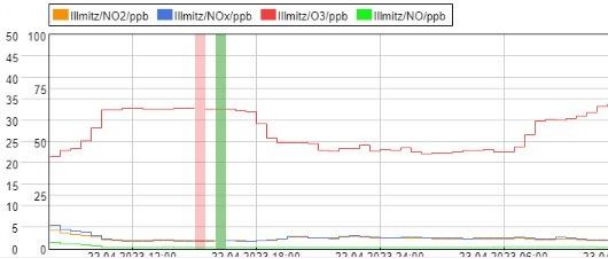
Criteria & actions

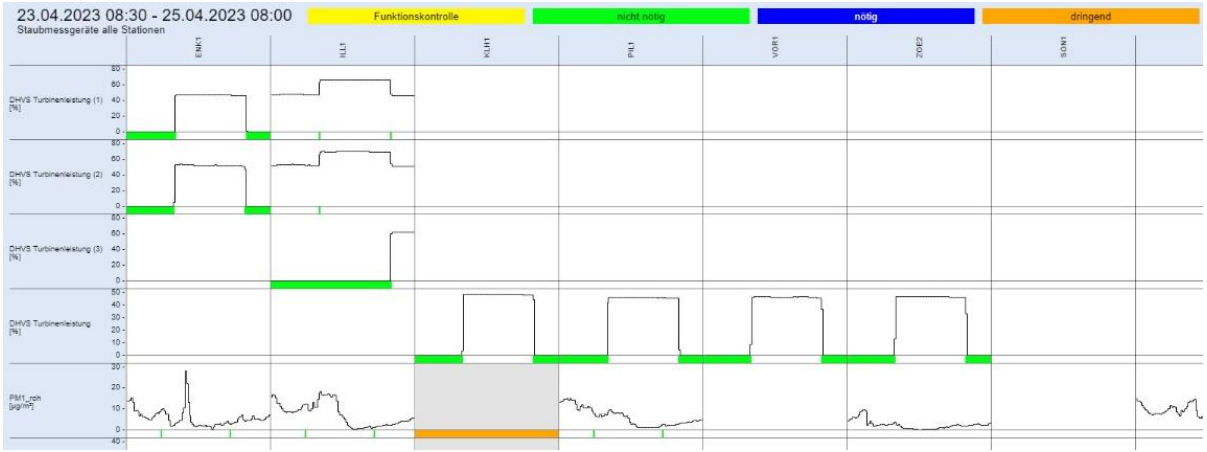
- No data
- Check of air conditioning
- Automatic zero/span checks
- Checks of plausibility of measurement data

EXAMPLES

- Data validation software helpful tool
- Can usually be configured to individual needs
- Automatic checks for outliers etc.







CRITERIA FOR DATA AGGREGATION

- Instruments provide hourly mean, daily mean values (PM gravimetry) ➔ data aggregation needed
- Laid down in annex VII and XI of the AQD (2008/50/EC)
- Application of specific rounding rules
- Certain data quality objectives apply (time coverage, data capture)
- Values below detection limit: Guidance to e-reporting Implementing Decision 2011/850/EU
- Aggregation according to definition of the threshold values (e.g. annual mean, number of daily mean values above a certain value, …)

ROUNDING RULES

- Data should be used with same number of digits as obtained
- Commercial rounding rules: < 0.5 rounded to 0, ≥ 0.5 rounded to 1
- Rounding should be very last step before comparing to threshold
- Rounding to same numeric accuracy as environmental objective (limit value, target value,…)

Examples

- Limit value (NO_2 in EU): 40 µg/m³
- Monitored annual mean: 40.528 µg/m³
- Rounded: 41 µg/m³ ➔ exceedance

- Target value benzo(a)pyren in EU*: 1.0 ng/m³
- Monitored annual mean: 1.047 ng/m³
- Rounded: 1.0 ➔ no exceedance
- However: if rounded twice:
- 1.047 ➔ 1.05 ➔ 1.1 ➔ (wrong) exceedance

* Currently, the target value is 1 ng/m³ (no decimal digit), however, the e-reporting guidance recommends to use at least one decimal digit

ROUNDING RULES WITHOUT AN ENVIRONMENTAL OBJECTIVE

Value x	Number of decimals	Example : before rounding	Example: after rounding
$x \geq 10$	Integer	17.83	18
$1 \leq x < 10$	1 decimal	2.345	2.3
$0.1 \leq x < 1$	2 decimal	0.865	0.87
$0.01 \leq x < 0.1$	3 decimal	0.0419	0.042
Etc…			

STANDARDISATION

- Gaseous pollutants: volume must be standardised at a temperature of 293 K and an atmospheric pressure of 101.3 kPa
- Particulate matter and substances to be analysed in particulate matter: sampling volumes refer to ambient conditions in terms of temperature and atmospheric pressure at the date of measurement.
- Provisions are to be used for the calculation of the conversion factor between mass fraction and mass concentration
- Conversion between ppb and µg/m³ is temperature-dependent and based on the ideal gas law
- NO_x (as NO_2) [µg/m³] = NO_2[µg/m³] + NO[µg/m³] × 1.912/1.247

- $X[\mu g/m^3] = X[ppb] \times \frac{M_X}{V_0} \times \frac{T_0}{T_1} \times \frac{p_1}{p_0}$
- M_x = molar mass in grams
- p_0 = 101.3 kPa
- T_0 = 273 K
- V_0 = 22.414 l/mol

Pollutant	$M_{pollutant}$ [g/mol]	Factor
NO_2	46.00449	1.912
NO	30.00546	1.247
O_3	47.99709	2.00
SO_2	64.05706	2.66
CO	28.00863	1.16
C_6H_6	78.10464	3.25

NUMBER OF DAYS WITH EXCEEDED DAILY LIMIT VALUE

Required data (according to EU Dir.)

- Daily mean concentrations (preferably by automatic, reference methods)
- Time coverage: calendar year
- Minimum data capture: 85 % including maintenance and calibration (≥ 309 daily means)
- However: some data better than no data ➔ data might be used even if data capture is lower
- 75 % data availability for valid daily mean (if e.g. based on hourly values)
- Limit value for daily mean for each pollutant

Metadata (proposal)

- Year
- Type of station
- Location of station
- Representativeness of reported station / aggregate of stations
- Limit value according to national legislation (➔ calculation of exceedance days)

Number of days with exceeded daily limit value
A-2.1 PM_{10}
A-2.2 SO_2
A-2.3 O_3
A-2.4 NO_2
A-2.5 $PM_{2.5}$

MISSING VALUES

European Union

- No procedure in current EU Directives to account for missing values ➔ invalid data if data quality objective not fulfilled
- Proposal for revision (Annex V.C): "*An assessment of compliance with the relevant limit and ozone target value shall be carried out regardless of whether the data quality objectives are achieved, provided the available data allows for a conclusive assessment*. […]"

United States

- Assumption: fraction of missing values that would have exceeded the standard level is identical to the fraction of measured values above this level
- $e_q = v_q \times \left(\frac{N_q}{n_q}\right), e = \sum_{q=1}^{4} e_q$
- *e*: exceedance
- *q*: quarter
- *v*: observed exceedances
- *N*: number of days in a quarter
- *n*: number of days in a quarter with measurement data

Source: US 40 CFR Part 50

SO_2

NO_2

AIR QUALITY STANDARDS

PM_{10}

$PM_{2.5}$

O_3

LIMIT VALUES FOR DAILY MEANS

EU limit / target values for daily means

- PM_{10}: 50 µg/m³ (not more than 35 exceedances)
- SO_2: 125 µg/m³ (not more than 3 exc.)
- O_3: 120 µg/m³ (target value: maximum daily eight-hour mean within a year not more than 25 exc. per year averaged over three years)
- NO_2, $PM_{2.5}$: no limit value

Source: Directive 2008/50/EC

EU proposal for revision of AAQDs

- PM_{10}: 45 µg/m³ (not more than 18 exc.)
- $PM_{2.5}$: 25 µg/m³ (not more than 18 exc.)
- SO_2: 50 µg/m³ (not more than 18 exc.)
- O_3: 120 µg/m³ (eight-hour mean, not more than 18 exc. per year averaged over three years)
- NO_2: 50 µg/m³ (not more than 18 exc.)

Source: Proposal for revision of AAQDS)

NB: Swiss Literature Database on Air Pollution and Health (LUDOK) provides reference list of air quality standards

WHO AIR QUALITY GUIDELINE LEVELS 2021 – DAILY MEANS

Pollutant	IT-1	IT-2	IT-3	IT-4	AQG level
PM_{10}	150	100	75	50	45
SO_2	125	50			40
O_3 (8h)	160	120			100
NO_2	120	50			25
$PM_{2.5}$	75	50	37,5	25	15

99th percentiles (i.e. 3 to 4 exceedances per year)

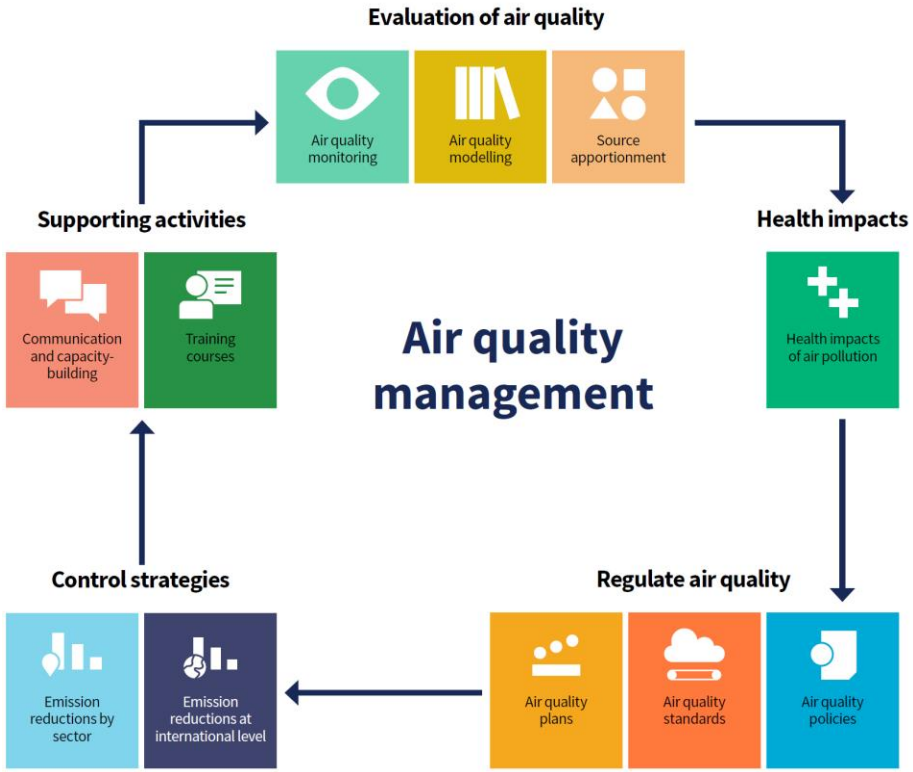
Source: WHO Air Quality Guidelines 2021

US NATIONAL AMBIENT AIR QUALITY STANDARDS – SHORT TERM

Pollutant	Level	Form
Ozone	140 µg/m³ (70 ppb)	Annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years
PM_{10}	150 µg/m³	Not to be exceeded more than once per year on average over 3 years
$PM_{2.5}$	35 µg/m³	98th percentile, averaged over 3 years

NB: only pollutants and levels shown that are close to daily mean levels

Source: US EPA



Source: WHO 2023

AQ STANDARD SETTING

- Outside EU: countries are free to choose to AQ standards
- WHO AQ guideline levels and interim target starting point for internal discussion
- WHO published resource package for implementation of AQ guidelines
- Considerations for target setting summarised in study for European Parliament

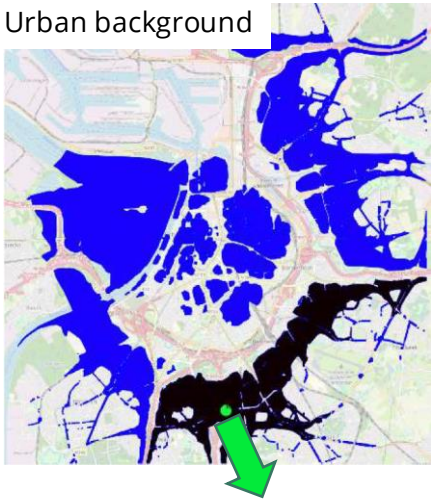
SPATIAL REPRESENTATIVENESS OF AQ STATIONS

- FAIRMODE (Forum for Air quality Modelling) developed guidance document
- Spatial representativeness necessary for:
  - Assessment of population exposure based on monitoring data
  - Assessment of exceedance situations based on monitoring data
  - Monitoring network design
  - Use of monitoring data for model validation and data fusion/data assimilation
- **Definition**: spatial representativeness area around a monitoring station is defined as an explicitly **delineated** geographical **area** for which the observed air quality metric at the monitoring station **does not vary more** than a pre-defined **tolerance level**

- Based on studies for DG ENV
- Proposed tolerance levels (annual means)
- ± 10 % for rural and urban background stations
- ± 20 % for traffic or industrial stations
- Modelling used to obtain area (
- Discussion for further refinements ongoing
  - Tolerance level
  - Lower cut-off values
  - Other aggregation times
  - Inter-annual variability
  - …

SPATIAL REPRESENTATIVENESS OF AQ STATIONS

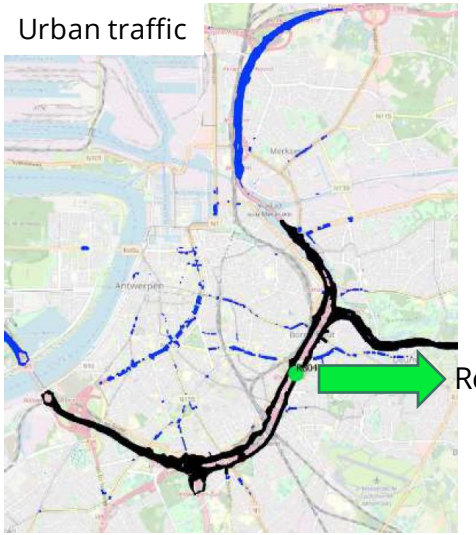
Urban background



Representative of residential areas in densely built-up areas

Example Antwerp

Urban traffic



Representative for heavily trafficked roads in inner city

- Still a lot of discussion on-going
- No definition in legislation

➔ expertise, expert judgement necessary

- Passive sampling campaigns, mobile stations helpful as modelling needs validation / emissions are uncertain or modelling is not available

Source: Ricardo 2020

ANNUAL MEAN VALUES IN CITIES

Required data (according to EU Directives)

- Annual mean concentrations (preferably by automatic, reference methods)
- Time coverage: calendar year
- Minimum data capture: 85 %

- SO_2, NO_2: passive sampling possible

Proposal

- NO_x ➔ NO_2
- SO_x ➔ SO_2

Metadata (proposal)

- Year
- Type of station
- Location of station
- Representativity of reported station / aggregate of stations

Annual mean concentration in cities
A-2.9 $PM_{2.5}$
A-2.10 PM_{10}
A-2.11 SO_2
A-2.12 NO_2

NO_X, NO_Y ⇔ NO_2

- NO_x: NO + NO_2
- Combustion processes: ≈ 90 % NO, 10 % NO_2
- Diesel vehicles with OxiKat: up to 70 % primary NO_2 emissions
- NO is converted to NO_2 in the atmosphere ➔ rural background mainly NO_2
- Automatic instruments provide both NO and NO_2
- Passive samplers available for NO_2, NO_x
- NO_y = NO + NO_2 + NO_z
- NO_z = PAN + HNO_3 + other

NO_x provided for

- Emissions
- Impact on ecosystems (amount of reactive N important)
- Air quality trends compared to emission trends

NO_2 provided for

- Impact on human health ➔ comparison with limit values, WHO air quality guidelines

Annual mean concentration in cities
A-2.9 $PM_{2.5}$
A-2.10 PM_{10}
A-2.11 SO_2
A-2.12 NO_2

$SO_X \Leftrightarrow SO_2$

- SO_2: predominant in lower atmosphere
- UNECE Guidelines for emission reporting:
  - "Sulfur", means all sulfur compounds **expressed as sulfur dioxide (SO_2)**
  - Includes sulfur trioxide (SO_3), sulfuric acid (H_2SO_4), and reduced sulfur compounds, such as hydrogen sulfide (H_2S), mercaptans and dimethyl sulfides, etc.)
  - Sometimes described as SO_x

- Ambient air quality monitoring, health impacts, limit values, WHO guideline levels: SO_2

Annual mean concentration in cities
A-2.9 $PM_{2.5}$
A-2.10 PM_{10}
A-2.11 SO_2
A-2.12 NO_2

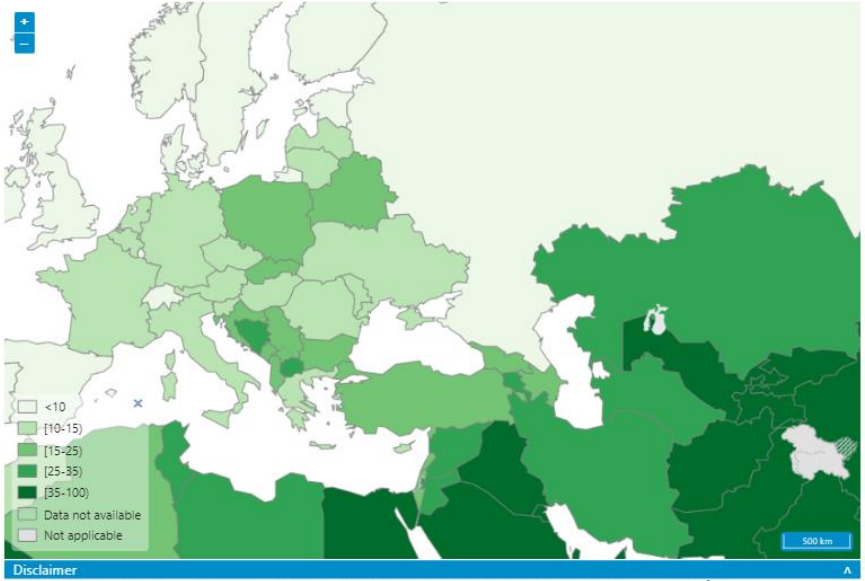
A-2.7 Annual mean level of $PM_{2.5}$ in cities (population weighted) (SDG indicator 11.6.2)

A-2.8 Annual mean level of PM_{10} in cities (population weighted) (SDG indicator 11.6.2)

POPULATION WEIGHTED PM LEVELS

SDG 11.6.2: EXPOSURE ESTIMATES AT URBAN LEVELS

- SDG indicator 11.6.2 provides "*Annual mean levels of fine particulate matter (e.g. $PM_{2.5}$ and PM_{10}) in cities (population weighted)*"
- WHO calculates every 2-3 years values on a 0.1° × 0.1° grid
- Values are available for 2010 to 2019
- Values are provided for all countries for different areas:
  - Rural
  - Towns
  - Urban
  - Cities
  - Total
- Calculation is based on modelling using data integration from satellite remote sensing, population estimates, topography and ground measurements (Shaddick et al. 2018)



POPULATION WEIGHTED EXPOSURE

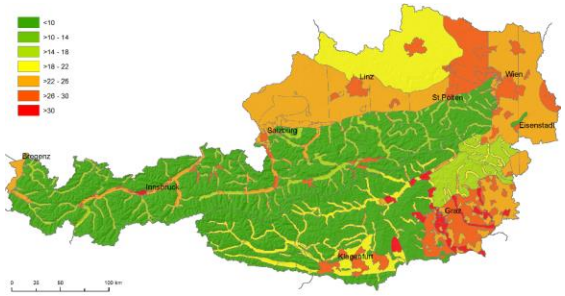
- Independent estimate useful
- Challenge: point data ➔ spatial data
- possible methods:
  - Monitoring data (+ representativeness of sampling point)
  - Land use data, topography, climate
  - Air quality modelling (however: high uncertainty for PM, O_3)
  - Satellite data

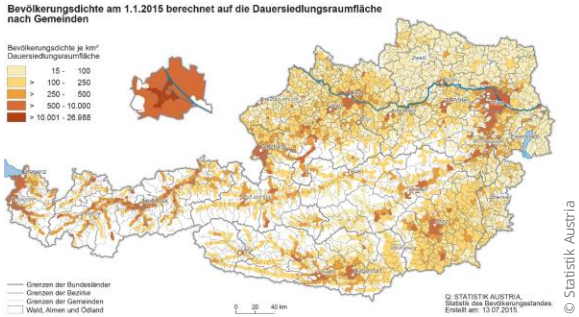
Austria

- monitoring data (+ additional information)
- urban and regional background stations
- check for inconsistencies in time series (change of location and/or equipment, construction activities, …)

A-2.7 Annual mean level of $PM_{2.5}$ in cities (population weighted) (SDG indicator 11.6.2)
A-2.8 Annual mean level of PM_{10} in cities (population weighted) (SDG indicator 11.6.2)

EXAMPLE PM EXPOSURE





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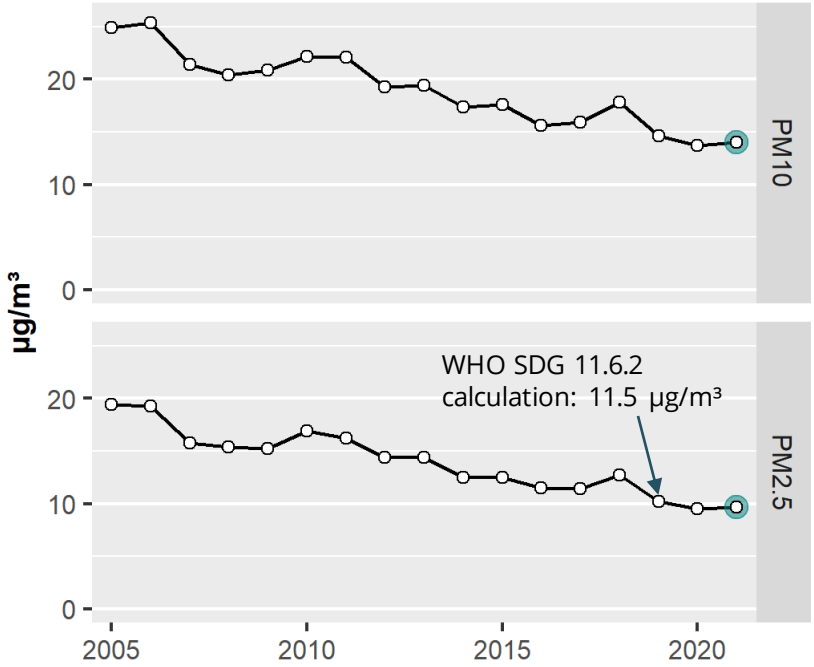
Climatic-topographic regions

Areas with specific PM concentration (based on AQ monitoring data of representative station)

Population density

TREND PM EXPOSURE IN AUSTRIA



Source: Umweltbundesamt

- Time series of population weighted data for PM_{10} and $PM_{2.5}$ exposure
- Fast update every year
- Use for SDG 11.6.2
- Good correspondence with calculations by WHO (2019: 10.2 vs. 11.5 µg/m³)
- Basis for SDG 3.9.1 (Mortality rate attributed to household and ambient air pollution)
  - AirQ+ WHO tool used for calculation of mortality rate

RECOMMENDATIONS

Institutional arrangements

- Monitoring, quality management is time consuming and expensive ➔ harmonised, centralised approaches crucial
- Regular exchange between institutions and other countries
- National reference laboratories can be shared between countries
- Rural background (EMEP) stations can be shared between countries

Monitoring, reporting

- Representativity of station important to know
- Data should be timely reporting in a user friendly way at national websites and international institutions
- Tools (including open source), good practice examples are available

SUMMARY & CONCLUSIONS

- Sufficient data coverage is required for reporting of indicators
- Representativity of stations has to be known and reported
- Ambiguity regarding limit value, aggregation of stations ➔ description in metadata
- WHO provides for regular updates of indicator SDG 11.6.2 = A-2.7, A-2.8

LITERATURE, DATA

- EU Air Quality Directives (2008/50/EC, 2004/107/EC, 2015/1480/EU, 2011/850/EU)
- US EPA Code of Federal Regulations NAAQS
- Proposal for revision of Ambient AQ Directives
- Guidance documents
  - Equivalence; QA/QC, traceability (AQUILA)
  - Natural sources
  - Representativeness
  - Modelling
  - Guide to the Expression of Uncertainty in Measurement
  - e-reporting
- Overview limit values worldwide
- WHO Air Quality Guidelines
- WHO resource package air quality management
- AirQ+ WHO
- WHO SDG 11.6.2
- FAIRMODE
- Studies on representativeness

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ENVIRONMENT AGENCY AUSTRIA

CONTACT & INFORMATION

Christian Nagl

Team Air Pollution & Buildings

+43-664-6210324

christian.nagl@umweltbundesamt.at

www.umweltbundesamt.at

twitter.com/umwelt_at

www.linkedin.com/company/umweltbundesamt

Regional training on statistics and indicators on air quality and emissions to air

Geneva, 4.5.2023

Implementing partners

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