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COMPAIR D5.1 Guide to Air Quality Monitoringy

Disclaimer

This training was developed for the H2020 CompAIR project.

The training is meant for educational purposes related to air quality experiments with citizens.

The CompAIR pilot's can use these slides to educate the people who will participate in their pilot. A subset of slides may be selected as not all content might be of use for every pilot. Pilots are also encouraged to adapt the slides to their specific needs (e.g. a map with air quality in Europe is presented in the slides, but a regional map will provide much more specific information for the pilots).

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COMPAIR D5.1 Guide to Air Quality Monitoring

Chapter 1: Air quality training

Content

Introduction

- What is air?
- How is air quality changing over time?
    - High pollution episodes with high concentrations (smog, ...) but in general improving quality
- More evidence on health effects -> limit values are reduced
- NO_2, PM, BC relevant pollutants + measured in CompAIR

Per pollutant

- What is it?
- Sources
- Health impact
- Situation in EU

Environmental impact

- Meteo
- Transportation
- Street canyons

Introduction

More information on: Together for Clean Air

What is air?

Air:

- 78% nitrogen (N_2) + 21% oxygen (O_2)+ 0,9% argon (Ar)
- 0,1% other
  - 0,04% CO_2 (=400 ppm)
  - **Particulate Matter (PM), nitrogen dioxide (NO_2)**
  - O_3, CO, SO_2,VOC, heavy metals, PAH's, dioxins,
  - Black carbon (BC), ultra fine particles (UFP), NH_3…

The quality of our air is depending on <1% of its content (micrograms & nanograms/m³)

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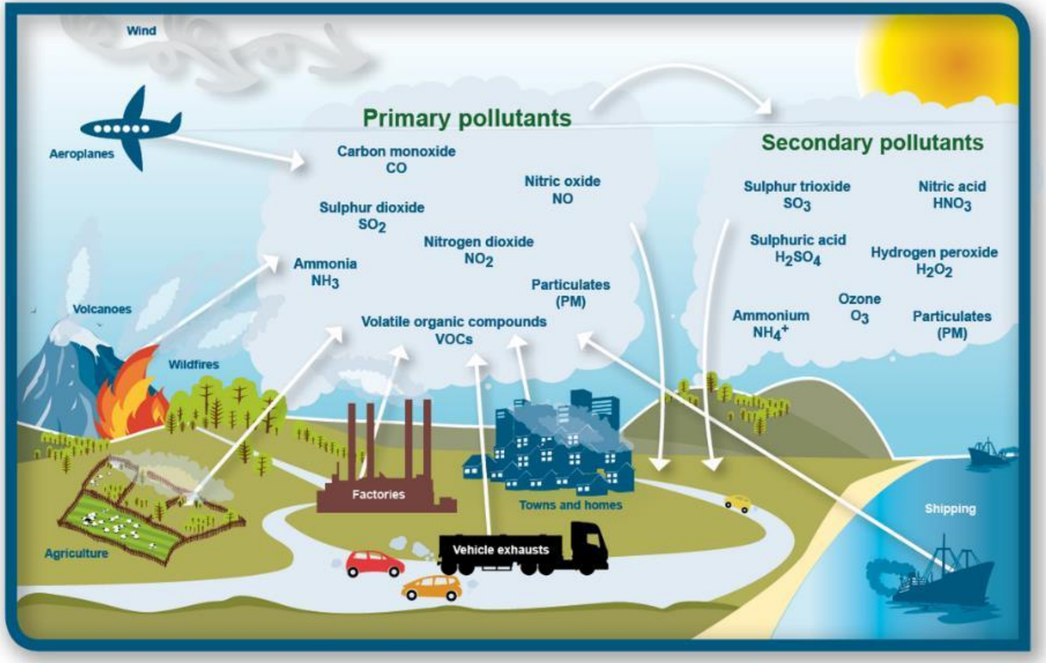
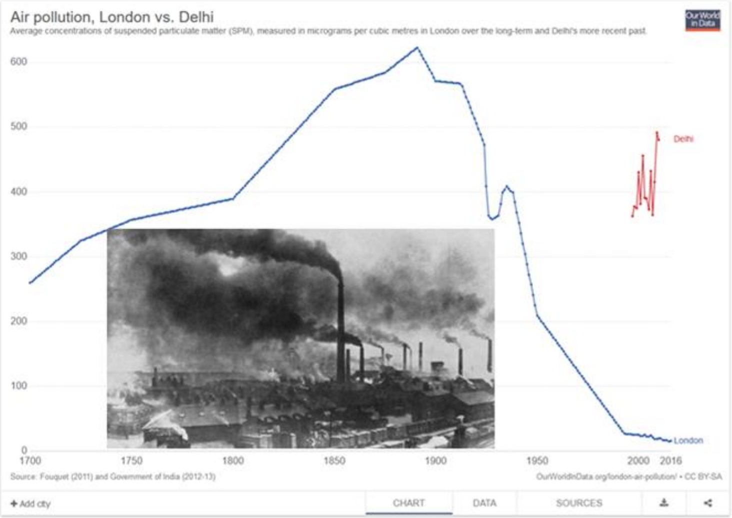
Many pollutants, many sources



Negative episodes



Total dust London 1700-2016
Peak second half 19th century

Smog episodes

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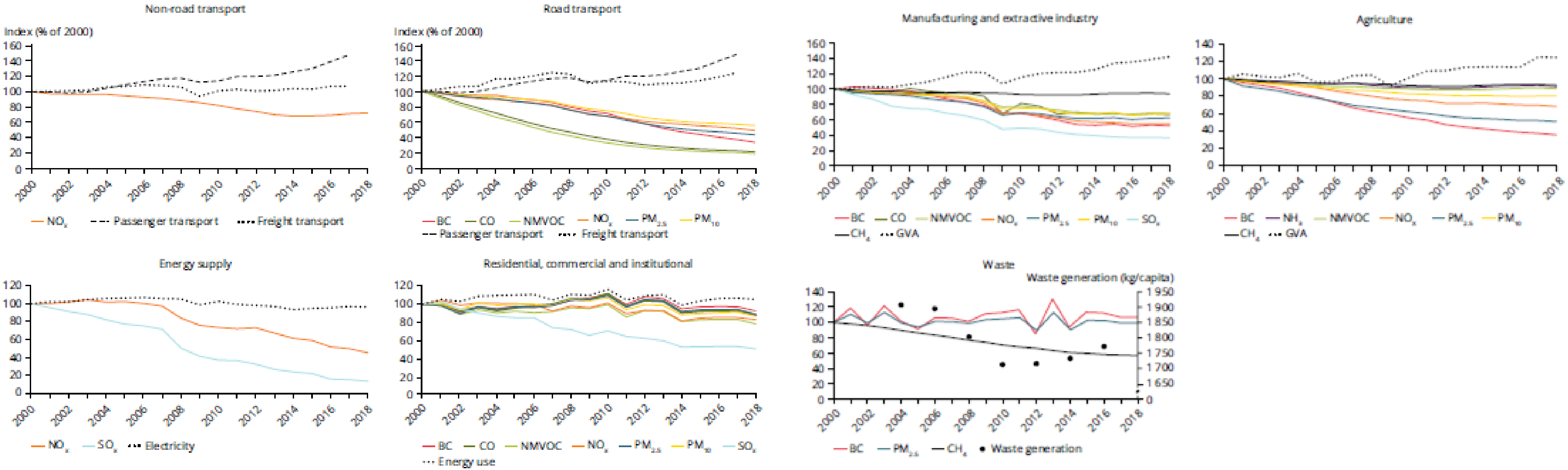
BUT in general air quality is improving

Figure 3.2 **Development in EU-28 emissions from the main source sectors of NO_X, PM_{10}, $PM_{2.5}$, SO_X, NMVOC, NH_3, BC, CO and CH_4 between 2000 and 2018 (% 2000 levels). For comparison, key EU-28 sectoral activity statistics are shown (% 2000 levels, except waste (kg per capita))**



Notes: Only pollutants for which the sector contributes more than 5 % to the total pollutant emissions are shown in the figures.

Sectoral statistics are plotted as an index (% of 2000 levels), except for the waste sector, where total waste generated was available only from 2004. These data are therefore plotted on a secondary (right-hand) axis.

Sources: EEA (2020e; 2020f), Directorate-General for Mobility and Transport (2020a, 2020b), Eurostat (2020c, 2020d, 2020e, 2020f, 2020g, 2020h).

Source: European Environment Agency, Air quality in Europe - 2020 report

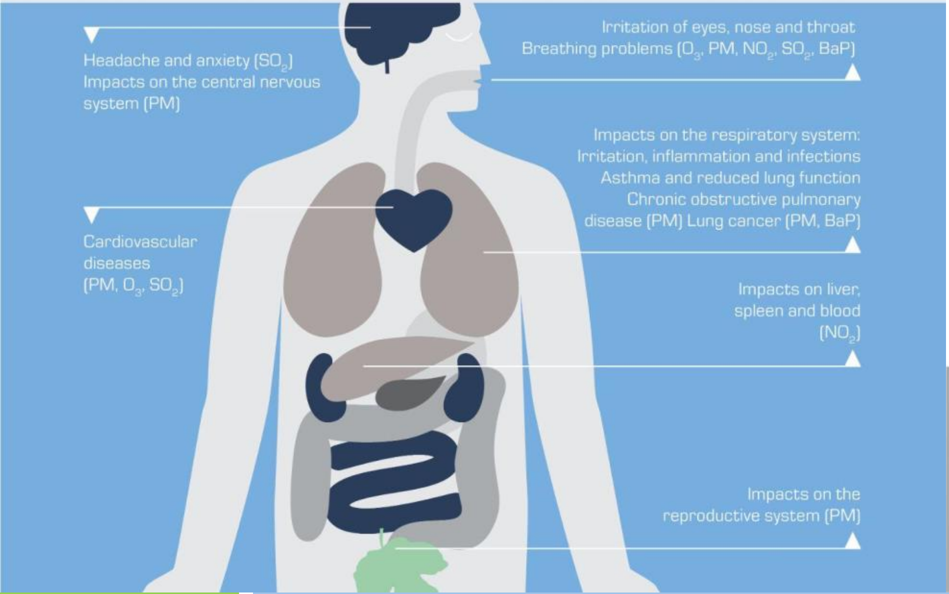
Health effects more clear

Health effects more clear

European Environment Agency

Health impacts of air pollution

Air pollutants can have a serious impact on human health. Children and the elderly are especially vulnerable.



Particulate matter (PM) are particles that are suspended in the air. Sea salt, black carbon, dust and condensed particles from certain chemicals can be classed as a PM pollutant.

Nitrogen dioxide (NO_2) is formed mainly by combustion processes such as those occurring in car engines and power plants.

Ground-level ozone (O_3) is formed by chemical reactions (triggered by sunlight) involving pollutants emitted into the air, including those by transport, natural gas extraction, landfills and household chemicals.

Sulphur dioxide (SO_2) is emitted when sulphur containing fuels are burned for heating, power generation and transport. Volcanoes also emit SO_2 into the atmosphere.

Benzo(a)pyrene (BaP) originates from incomplete combustion of fuels. Main sources include wood and waste burning, coke and steel production and motor vehicles' engines.

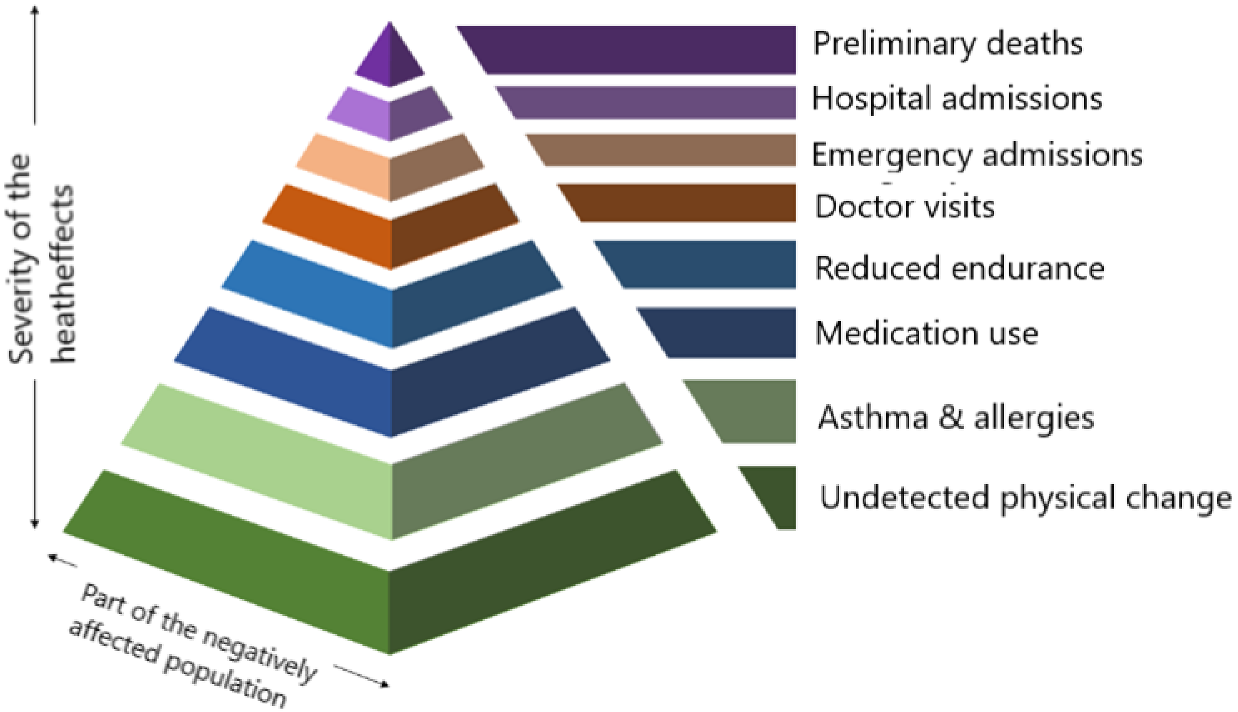
97%
of Europeans are exposed to O_3 concentrations above the World Health Organization recommendations.

EUR 220-300
is how much air pollution from the 10 000 largest polluting facilities in Europe cost each EU citizen in 2009.

63%
of Europeans say they reduced their car use in the last two years in order to improve air quality.

Sources: EEA, WHO, Eurobarometer

Health effects more clear



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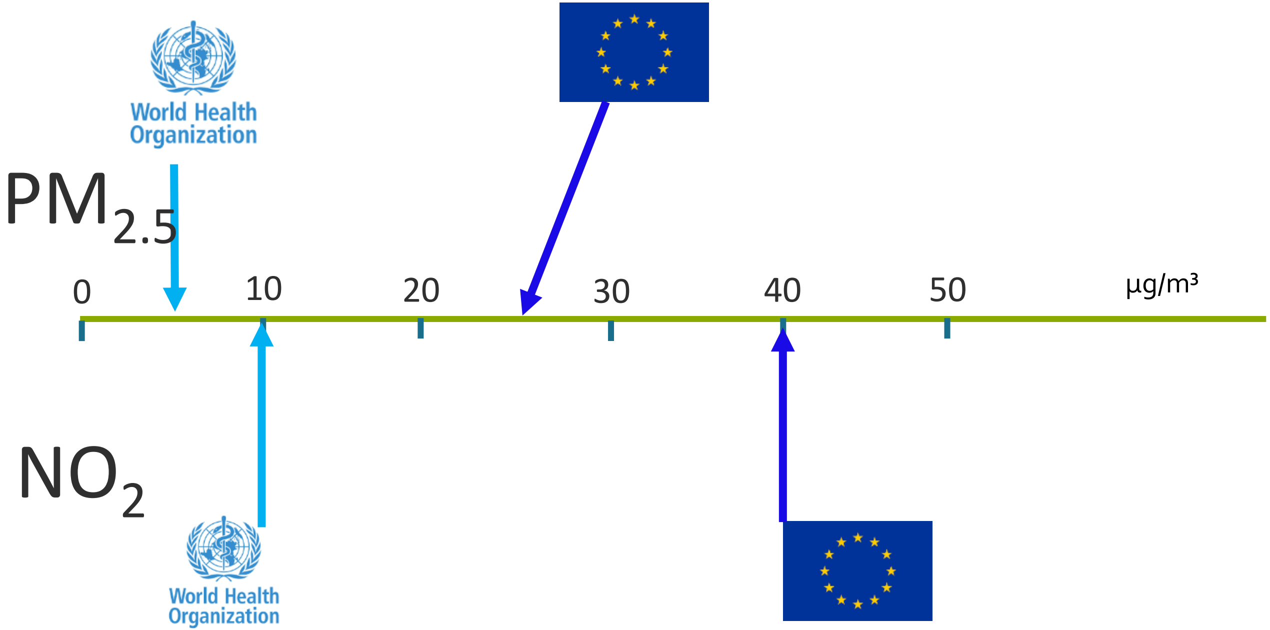
Limit values (EU) and WHO guidelines- yearly



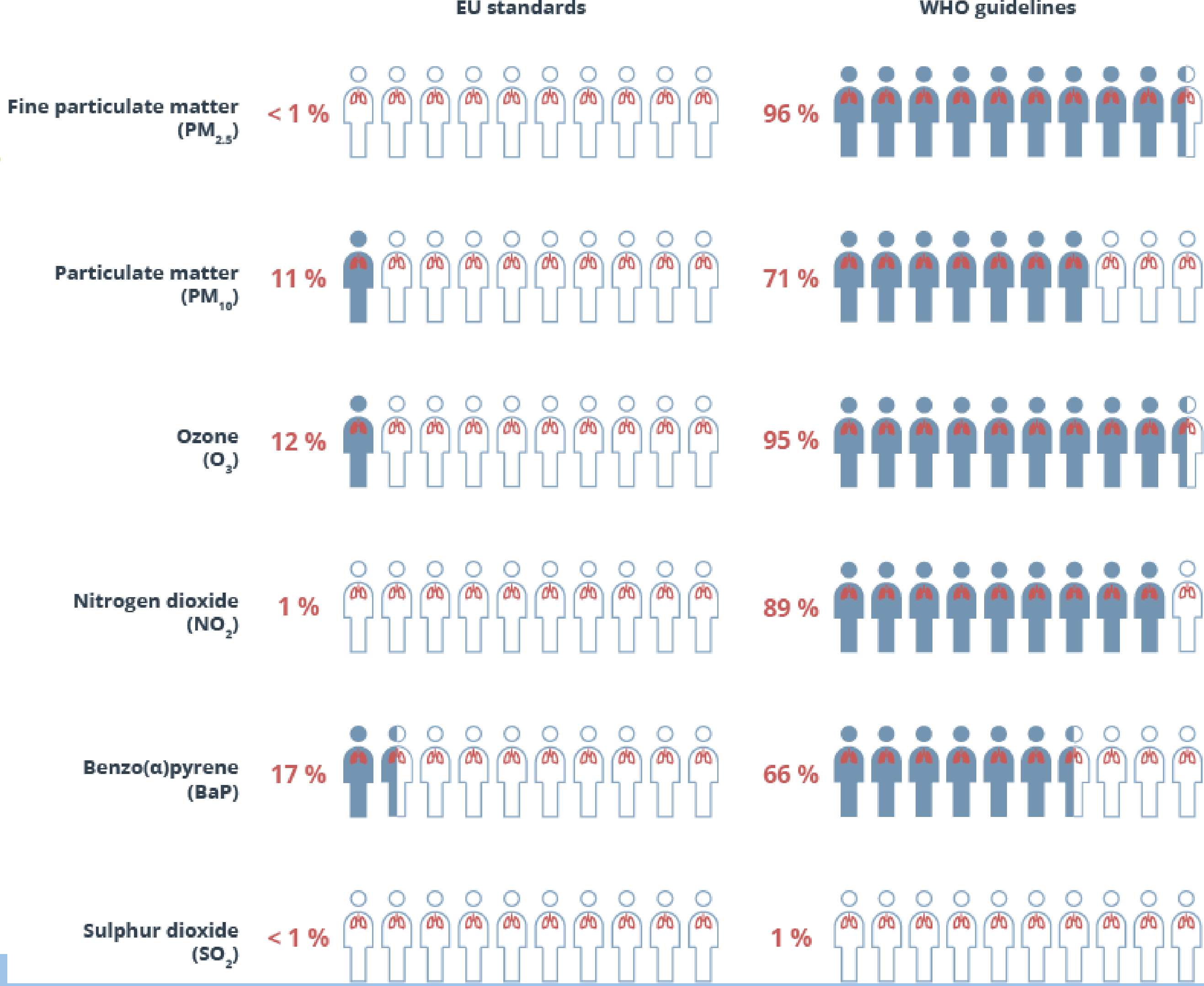
Limit values (EU) and WHO guidelines

	EU	World Health Organization
Fine dust (PM_{10})	yearly average < 40 µg/m³	yearly average < 15 µg/m³
	daily average max 35 x > 50 µg/m³	day max 3 x > 45 µg/m³
Fine dust ($PM_{2,5}$)	yearly average < 25 µg/m³	yearly average < 5 µg/m³ day max 3 x > 15 µg/m³
Nitrogen dioxide (NO_2)	yearly < 40 µg/m³	yearly < 10 µg/m³

Limit values (EU) and WHO guidelines

Limit values

Share of the EU urban population exposed to air pollutant concentrations above EU standards and WHO guidelines in 2020



Source: AIR003

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Important pollutants

Pollutant	Premature deaths attributed (41 European countries)	Years of life lost (41 European countries)
$PM_{2.5}$	417 000	55 000
NO_2	4 806 000	624 000
BC	NA	NA

- Black Carbon is carcinogenic

Source: European Environment Agency, Air quality in Europe - 2020 report

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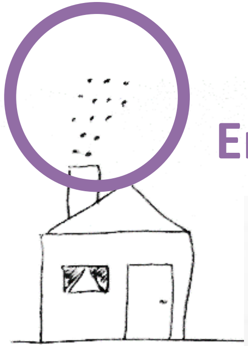
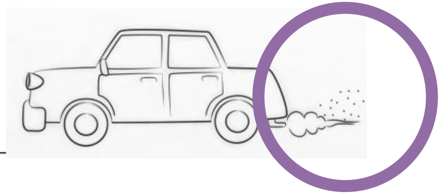
Air pollution

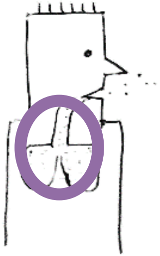
Concentration (in air)

What is measured



Emission





Exposure

Where you are + what you breath in

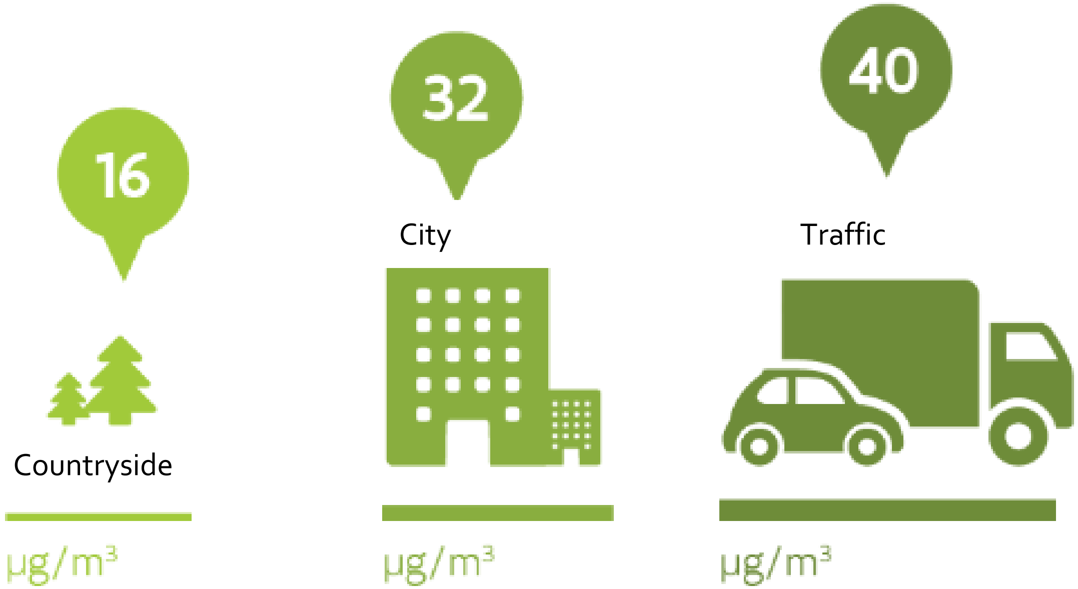
Nitrogen dioxide (NO_2)

More information on: Together for Clean Air

What is NO2?

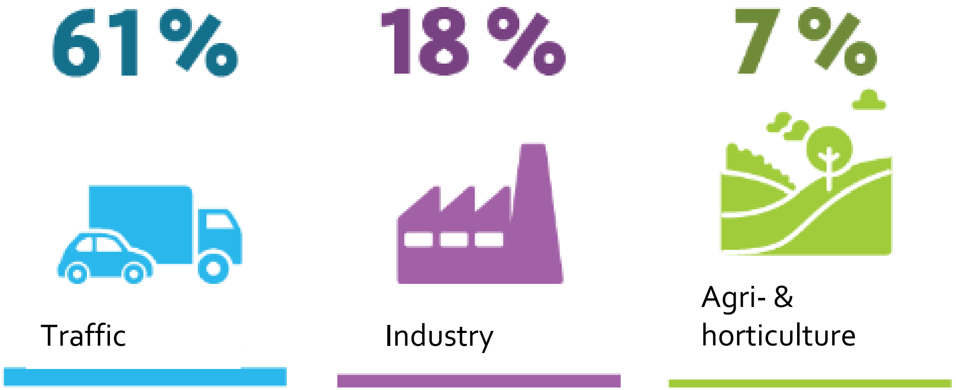
Nitrogen dioxide =

- a harmful gas
- released during high temperature combustion

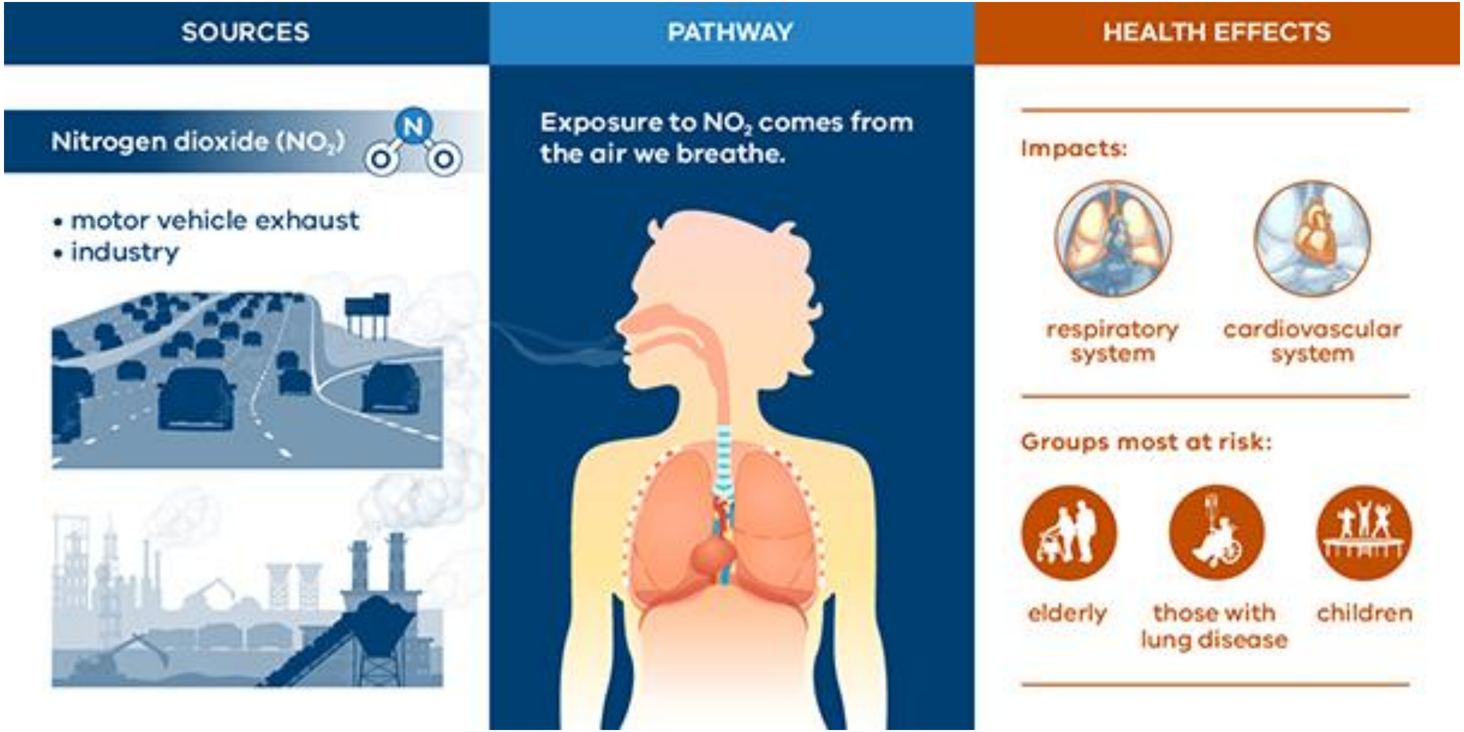


Sources

- **Traffic** is the main source (diesel engines)
- The relative importance of traffic continues to increase



Health effects



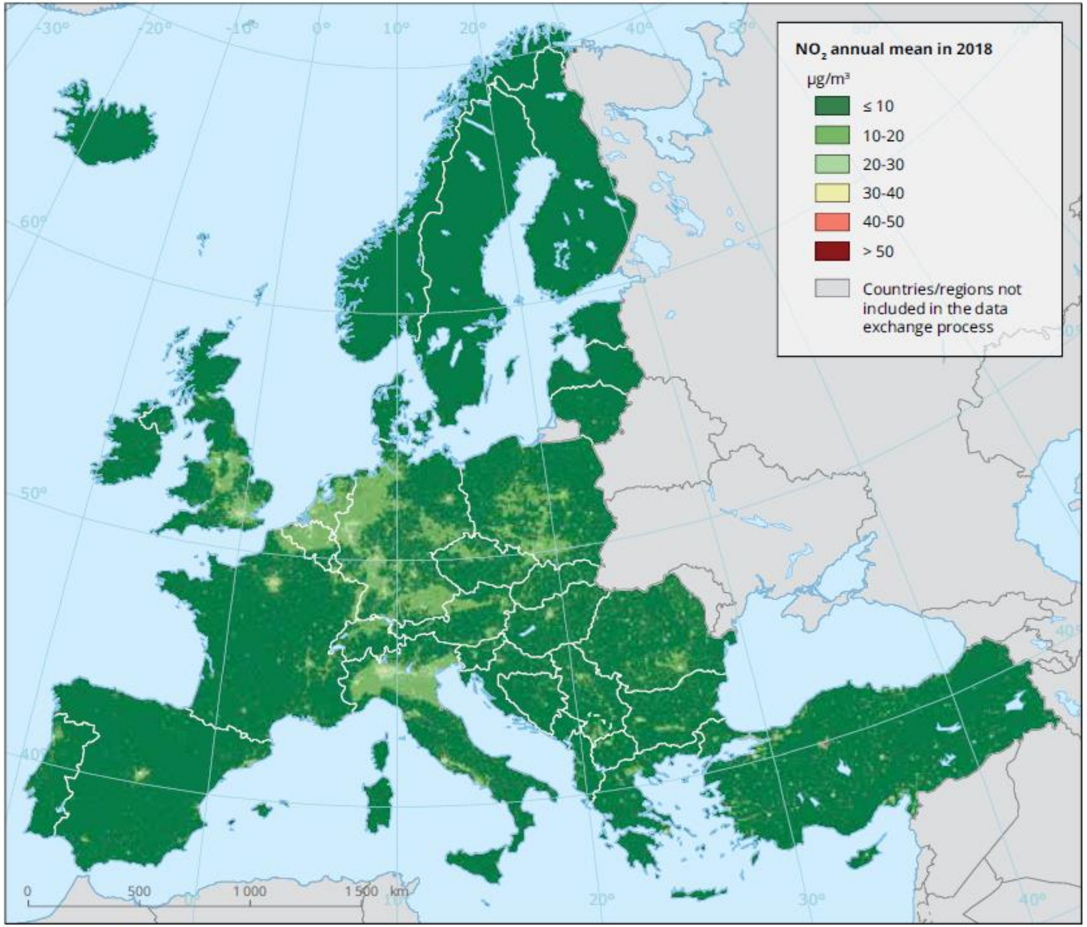
Source: EPA Victoria State Government of Victoria

Current situation

NO$_2$

Map 9.1 Concentration interpolated maps of (a) PM_{10} (annual mean, µg/m³), (b) $PM_{2.5}$ (annual mean, µg/m³), (c) O_3 (SOMO35, µg/m³·days) and (d) NO_2 (annual mean, µg/m³) for 2018 (cont.)

d)



Reference data: ©ESRI

Source: European Environment Agency, Air quality in Europe - 2020 report

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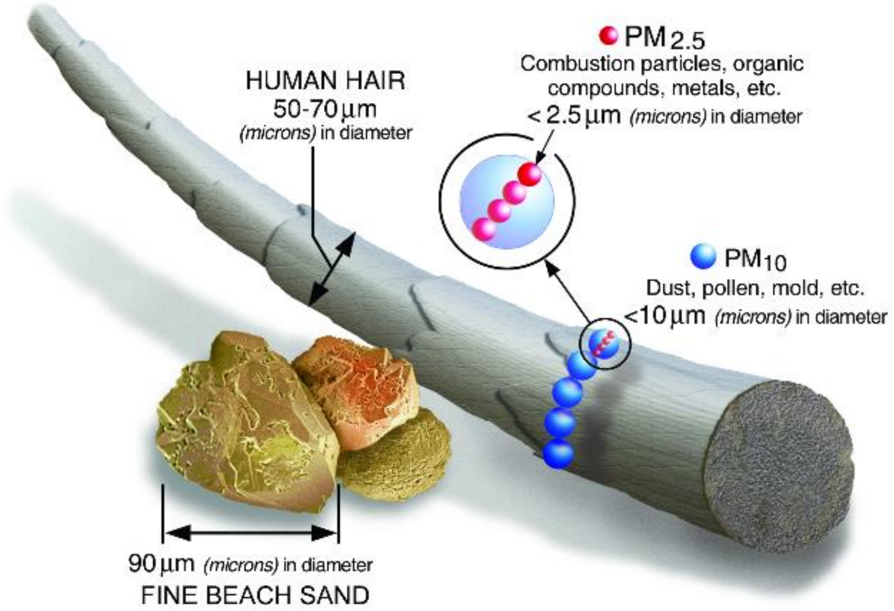
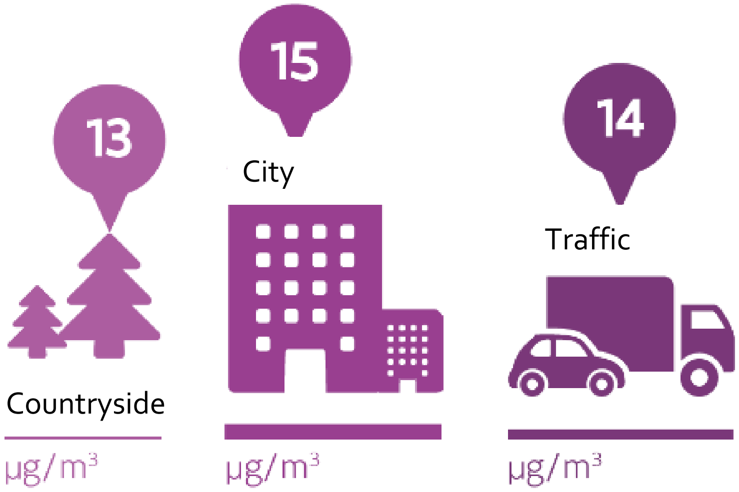
Particulate matter (PM)

More information on: Together for Clean Air

What is PM?



HUMAN HAIR
50-70µm
(microns) in diameter
PM2.5
Combustion particles, organic compounds, metals, etc.
< 2.5µm (microns) in diameter
PM10
Dust, pollen, mold, etc.
<10µm (microns) in diameter
90µm (microns) in diameter
FINE BEACH SAND



13
Countryside
µg/m³
15
City
µg/m³
14
Traffic
µg/m³

What is PM?

Particulate Matter is a MIX:

- Primary particles (emitted straight into the air)
  - Wood smoke, diesel soot, road dust,...

- Secondary particles (formed after reactions in the air)
  - Ammonium salts

- Natural particles
  - Sea salt, Sahara dust,...

Sources

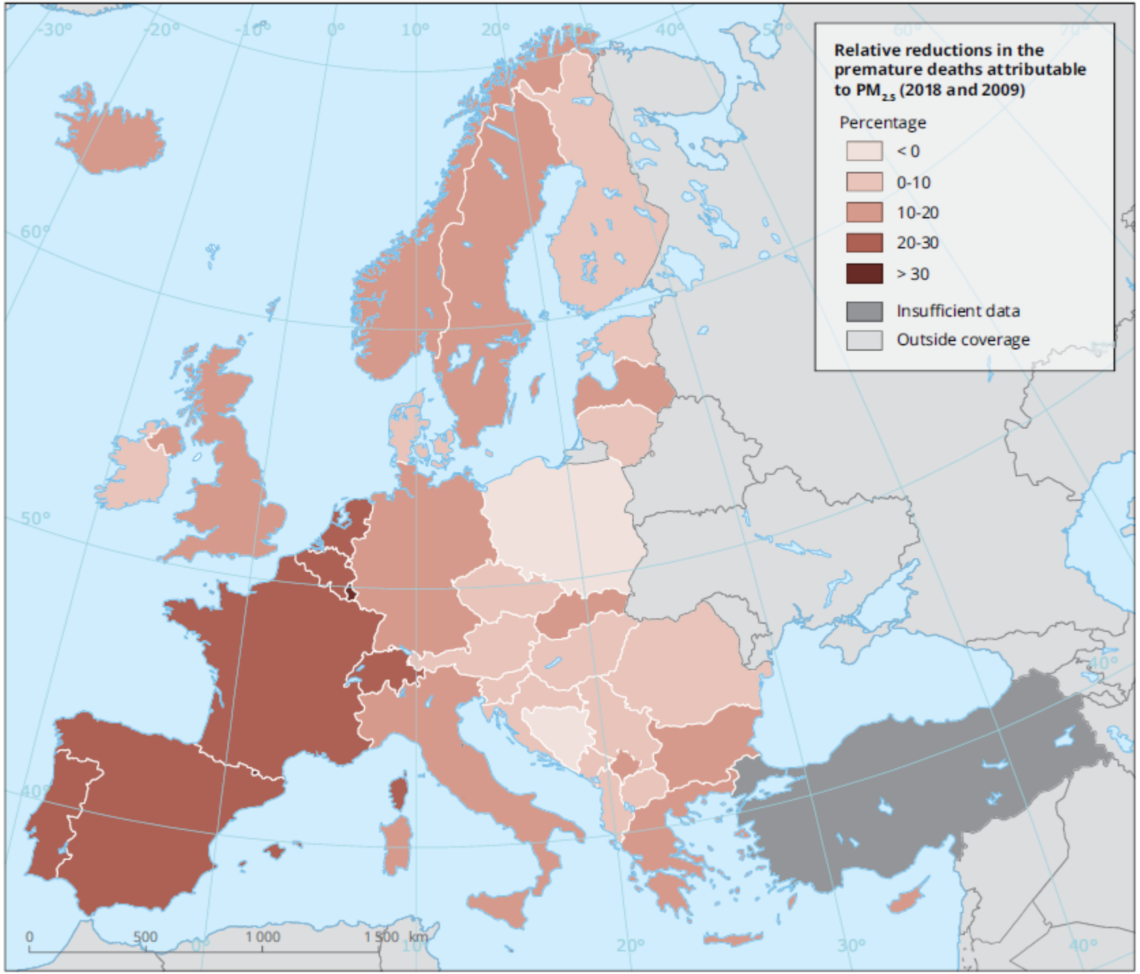
- **Households** make the largest contribution through **heating**

- **Wood burning** is mainly responsible for the emission of particulate matter by households

57 %	21 %	15 %
Households	Traffic	Industry

Health effects

Map 10.1 Relative reductions in the premature deaths attributable to $PM_{2.5}$ (2018 and 2009)



Reference data: ©ESRI

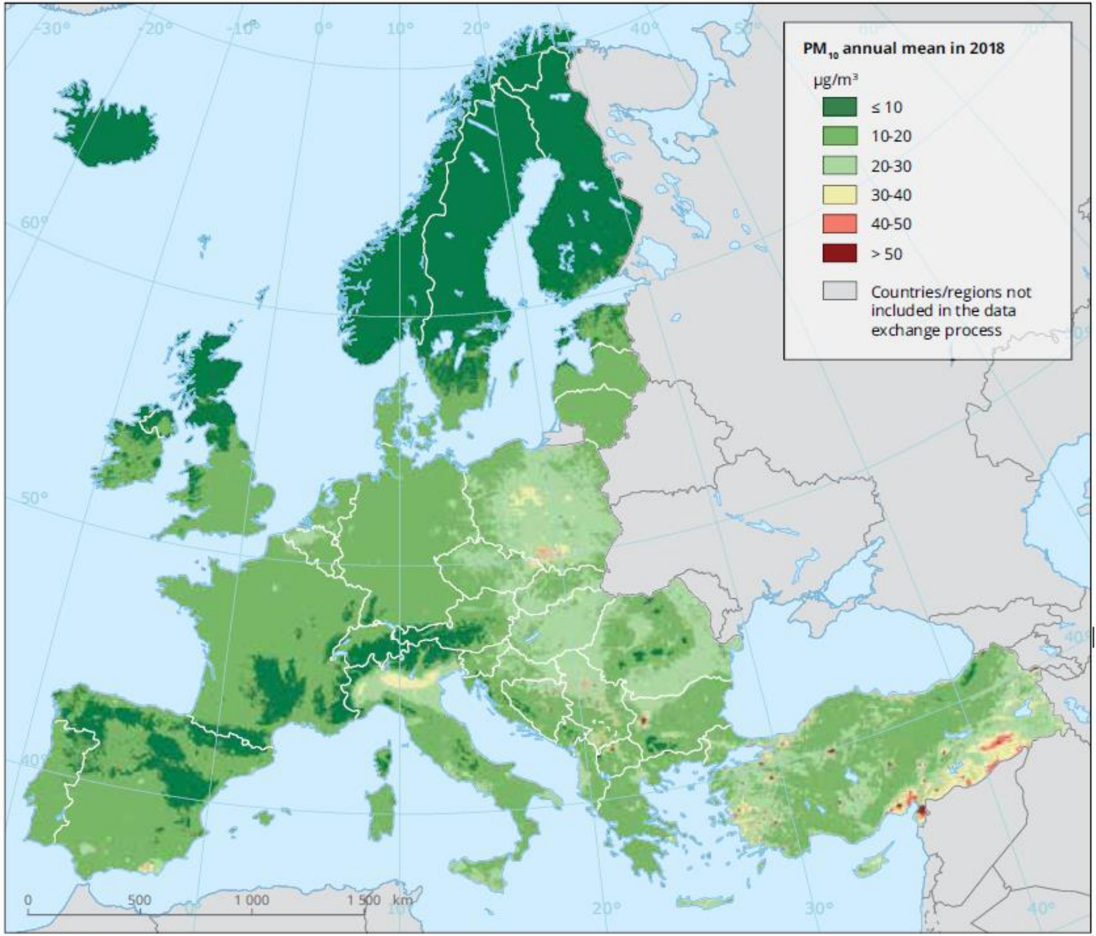
Source: European Environment Agency, Air quality in Europe - 2020 report

Current situation

PM_{10}

Map 9.1 **Concentration interpolated maps of (a) PM_{10} (annual mean, µg/m³), (b) $PM_{2.5}$ (annual mean, µg/m³), (c) O_3 (SOMO35, µg/m³·days) and (d) NO_2 (annual mean, µg/m³) for 2018**

a)



Reference data: ©ESRI

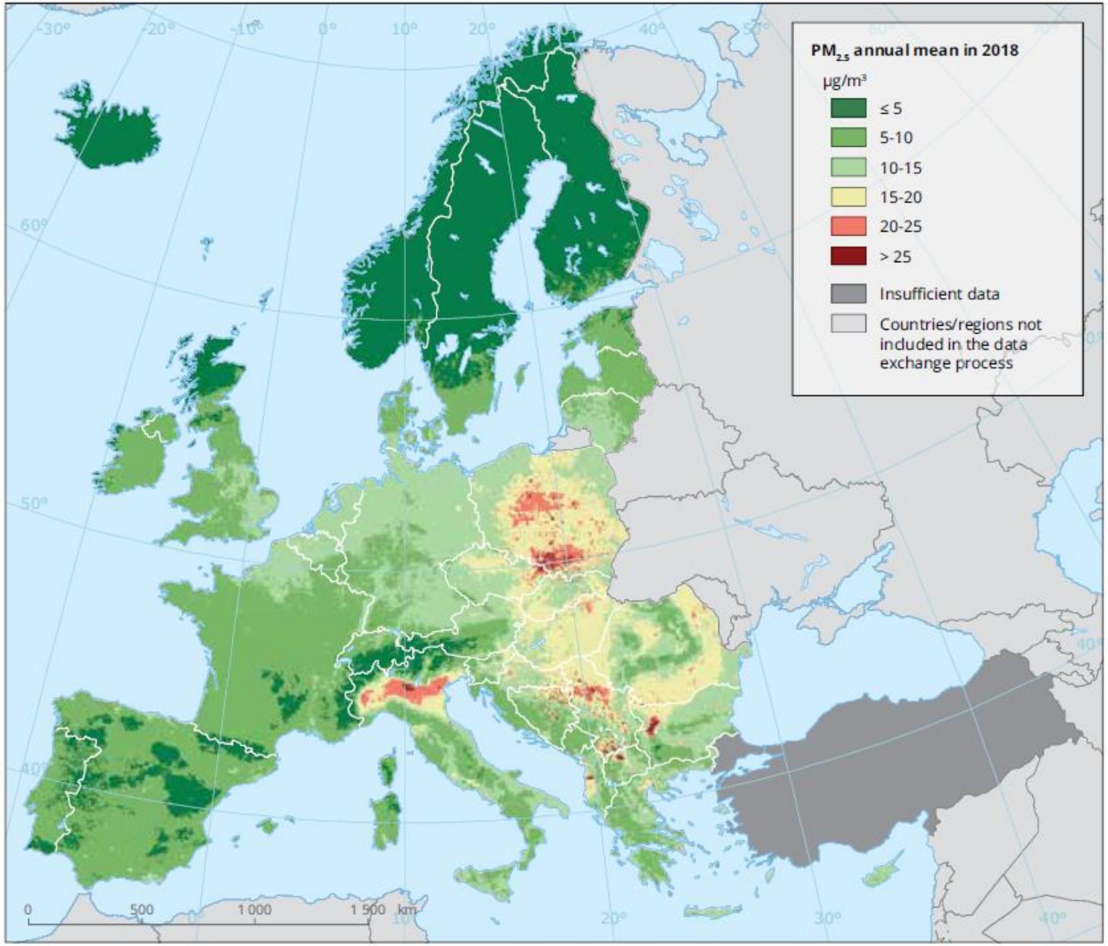
Source: European Environment Agency, Air quality in Europe - 2020 report

Current situation

$PM_{2.5}$

Map 9.1 **Concentration interpolated maps of (a) PM_{10} (annual mean, µg/m³), (b) $PM_{2.5}$ (annual mean, µg/m³), (c) O_3 (SOMO35, µg/m³·days) and (d) NO_2 (annual mean, µg/m³) for 2018 (cont.)**

b)



Source: European Environment Agency, Air quality in Europe - 2020 report

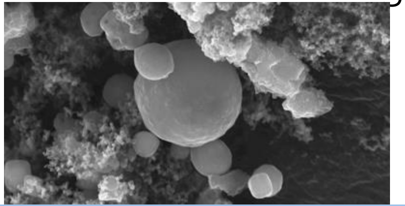
Black carbon

More information on: Together for Clean Air

What is Black Carbon?

Black Carbon or BC or Soot

- Mixture of very small particles with high light absorption, i.e. “black”
- Formed through incomplete combustion
- Black carbon levels are a measure of the “carbon” content in particulate matter
- Typical size of these particles is 100 - 600nm ⇒ **part of $PM_{2.5}$**
- Particles coagulate quite rapidly to form larger, less dark/black particles = “regular” $PM_{2.5}$
- Concentration levels vary strongly across a few 100 m <-> $PM_{2.5}$
- BC also contributes to climate change: particles absorb heat because of blackness and locally increase the air temperature
    - particles are even associated with melting of ice caps after deposition on snow etc.

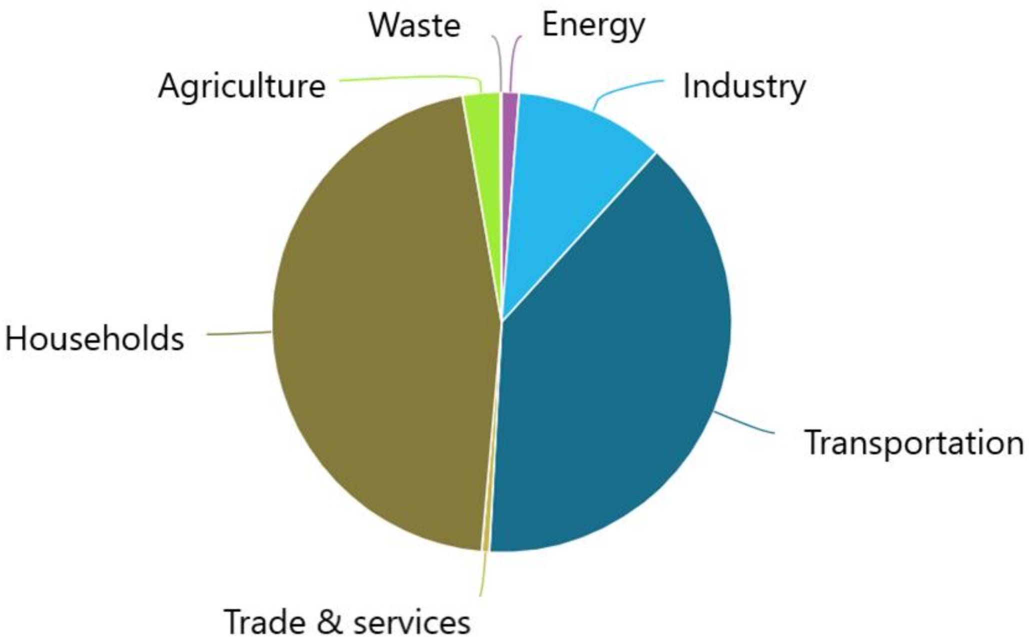


Sources

Mainly consists of particles created by incomplete combustion of fossil and other fuels. E.g. diesel, wood or coal.

Traffic and households are by far the 2 main sources of soot emissions.

- **Traffic** mainly concerns the combustion of diesel and to a lesser extent petrol.
- Households mainly emit soot by **burning wood** in stoves and fireplaces..



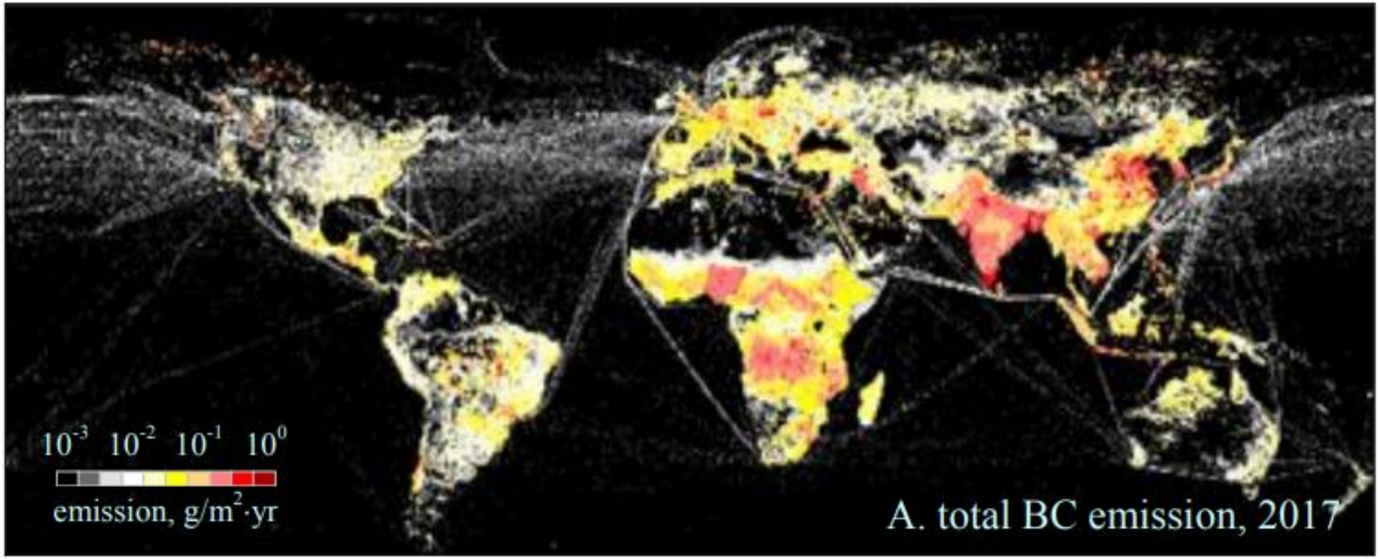
Health effects

- #1 rule on health effects: the smaller the particles, the further they can move inside our bodies
  - black carbon particles have been found in the placenta, urine ...
- BC has a very large surface area, i.e. a lot of interface that can react with components in our body
  - Additionally it can act as a universal carrier for other chemicals of varying toxicity, e.g. heavy metals, polyaromatics and semi-volatile organics
- Black carbon is considered "**possibly carcinogenic** to humans" by the IARC

Typical health effects:

- chronic exposure to higher concentrations has been associated with elevated rates of **lung cancer**
- chronic exposure to higher concentrations has been associated with **increased mortality**
- chronic exposure to higher concentrations has been associated with **increased hospital admissions** for asthma and cardiovascular diseases
- acute (short term) exposure is associated with **irritation of the upper respiratory tract**
- was found in the **placenta** and in **different organs of unborn babies**

Current situation



Spatial distribution of global BC emission densities from all sources (including wildfires) in 2017 derived in this study*

Impact environmental factors

Weather

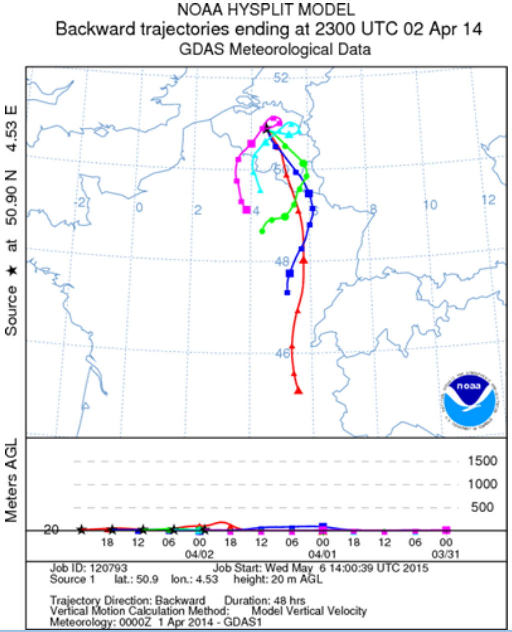
The weather is an important factor in the formation and spread of air pollution

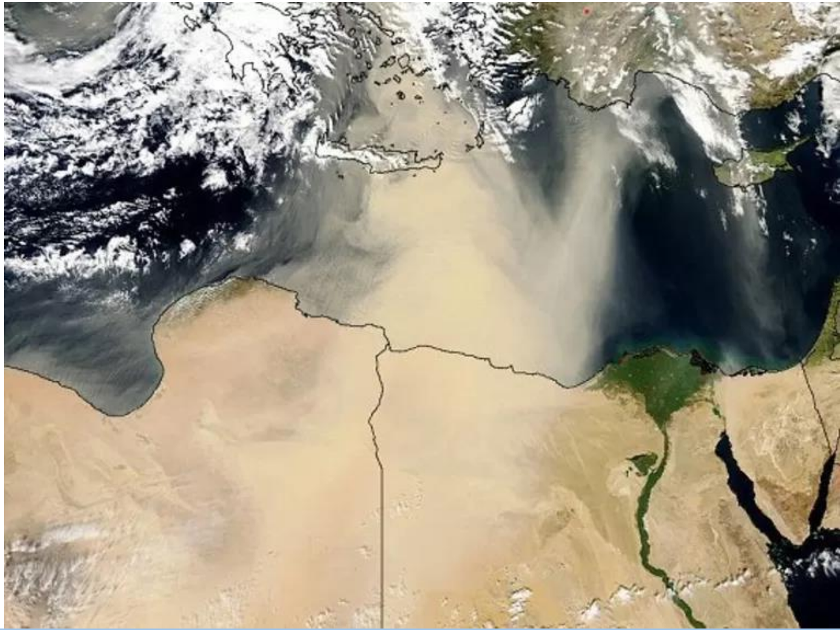
- humidity influences the formation of PM out of NOx
- rain removes PM from the air
- wind will dilute and spread pollution
- wind direction determines the direction in which pollutants are spread
- during heat waves more ozone is formed than during cold days because temperature and sunlight influence the chemical process
- atmospheric conditions influence secondary PM formation
- atmospheric inversion layers formed during winter captures polluted air in the lowest air layers

Transportation

Air pollution can travel long distances through the different air layers

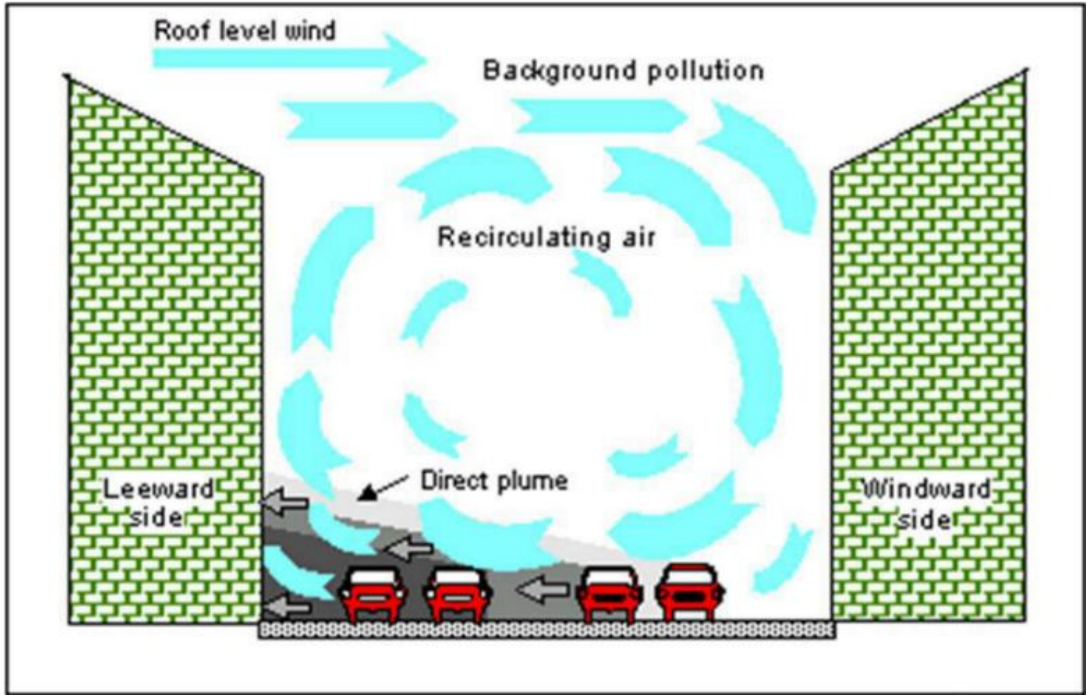
E.g. in this way sahara dust can cause a peak in PM in western Europe





Street canyons

Air moves differently within a narrow canyon formed by buildings in urban areas



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Interesting websites

Interesting websites

- https://samenvoorzuiverelucht.eu/en/together-clean-air
- https://www.eea.europa.eu//publications/status-of-air-quality-in-Europe-2022
- https://www.eea.europa.eu/data-and-maps/dashboards/air-quality-statistics
- https://www.eea.europa.eu/publications/air-quality-in-europe-2021/health-impacts-of-air-pollution

COMPAIR D5.1 Guide to Air Quality Monitoring

Chapter 2: Low-Cost Sensor (LCS) Training

Chapter 2: Low-Cost Sensor (LCS) Training

- Types of PM Measurement Equipment
- Types of NO_2 Measurement Equipment
- Types of Black Carbon (BC) Measurement Equipment
- Measurement Approaches of Low-Cost Sensors (LCS)
- LCS Applications
- LCS response time and overall performance

Types of PM Measurement Equipment

- LCS (optical sensors)

- Reference Station

EU gravimetric reference ($PM_{2.5}$ only)

EU equivalent method (Palas Fidas 200)

Measurement Approach of PM LCS

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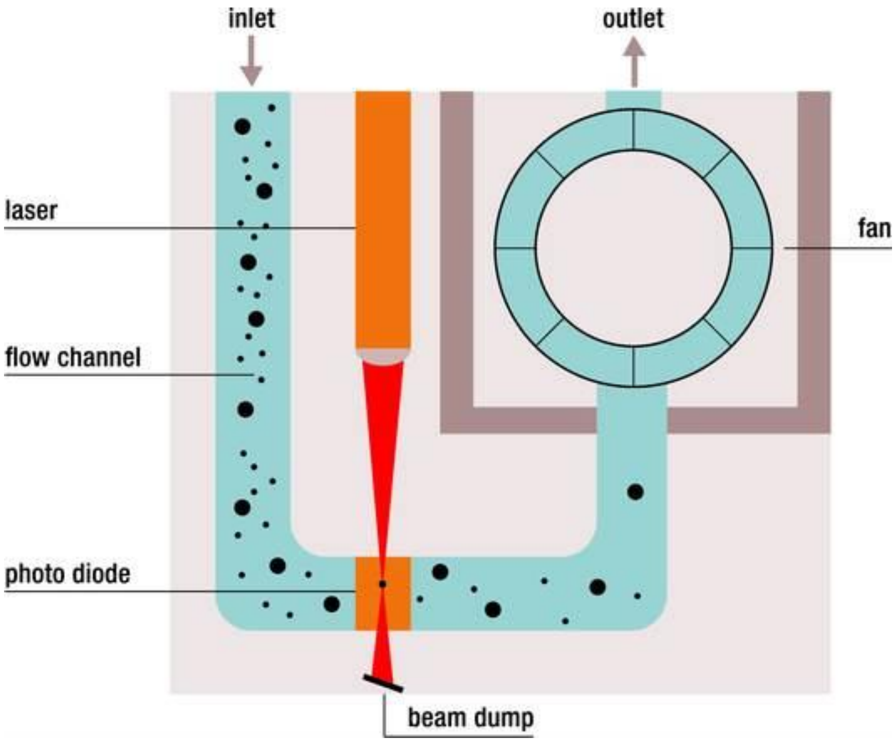
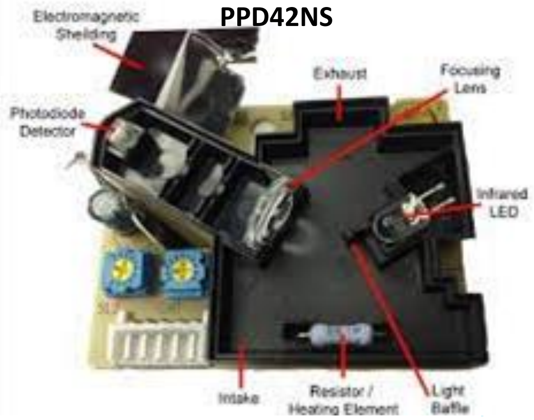
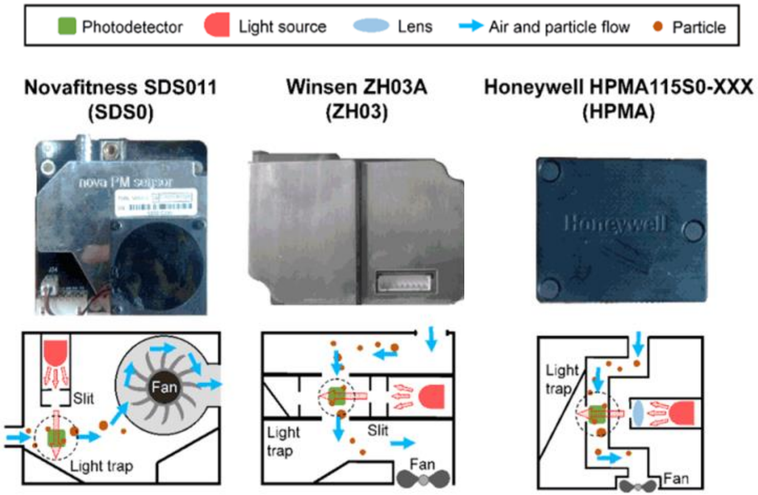
- PM optical sensor



Shinyei PPD42NS





Types of NO_2 Measurement Equipment

- Passive samplers (Palmes tubes; 2week/1month average data)

- Electrochemical sensors: real-time data

Alphasense NO_2-B43F

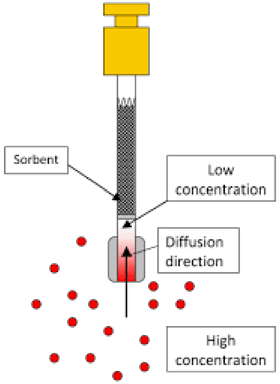
- Reference Station

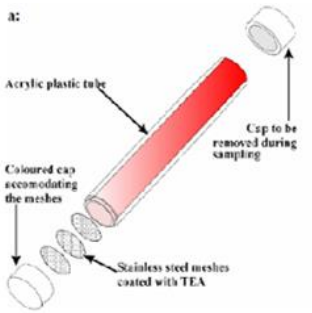
Chemiluminescence Analyser

(42i ThermoFisher Scientific)

Measurement Approach of NO_2 passive samplers

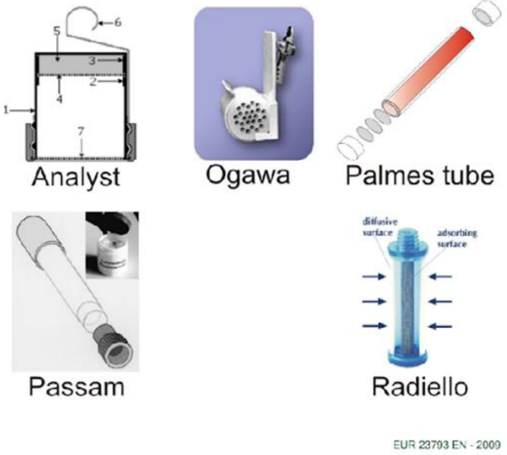
- NO_2 passive sampler (Palmes tubes)





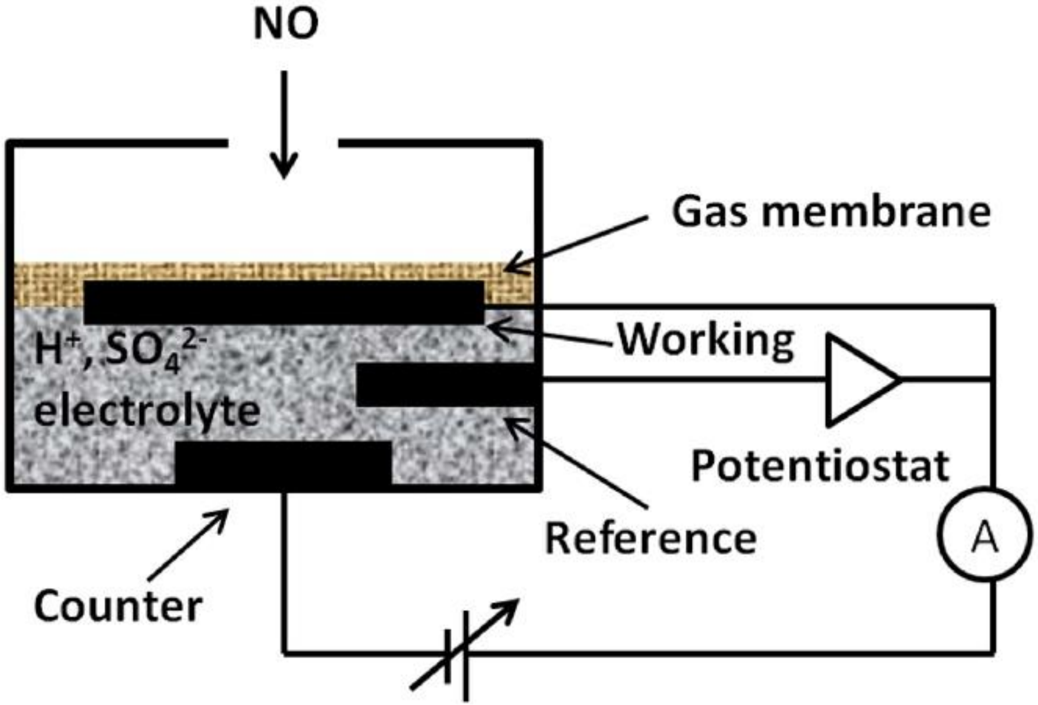
In the Palmes tubes samplers, after collection, the NO_2 concentration is analyzed via a colorimeter / spectrophotometer

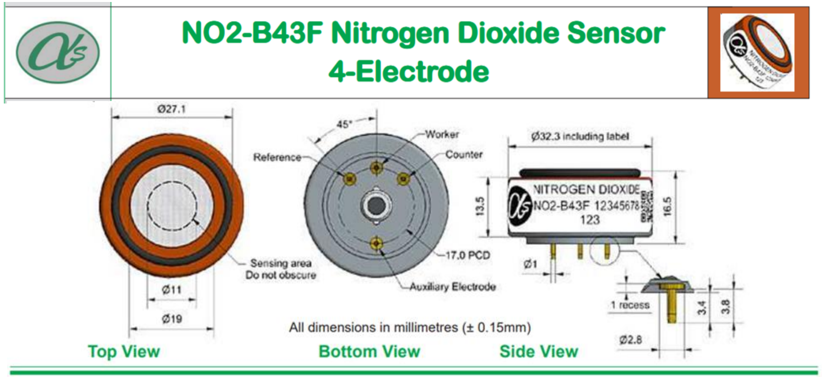
Diffusive samplers in the European Union for the monitoring of nitrogen dioxide in ambient air



Measurement Approach of NO_2 LCS

- NO_2 electrochemical sensor





Types of Black Carbon (BC) Measurement Equipment

- Light attenuation LC BC sensors

Static:

BCmeter

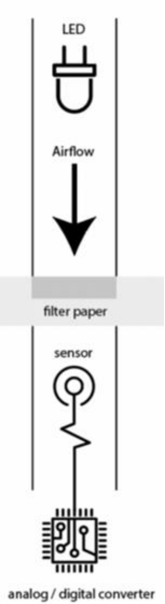
Portable:

Aethlabs

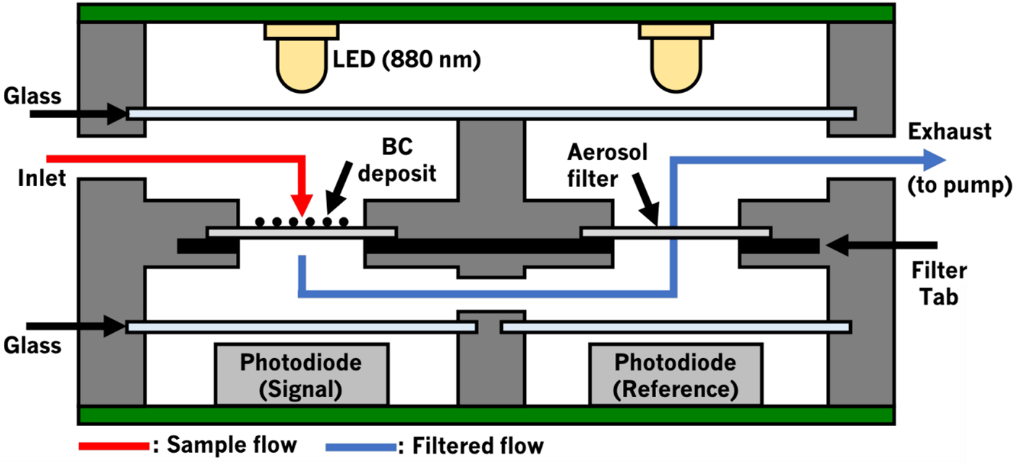
(microAeth® Model AE51)

- Aethalometer (Magee Scientific)

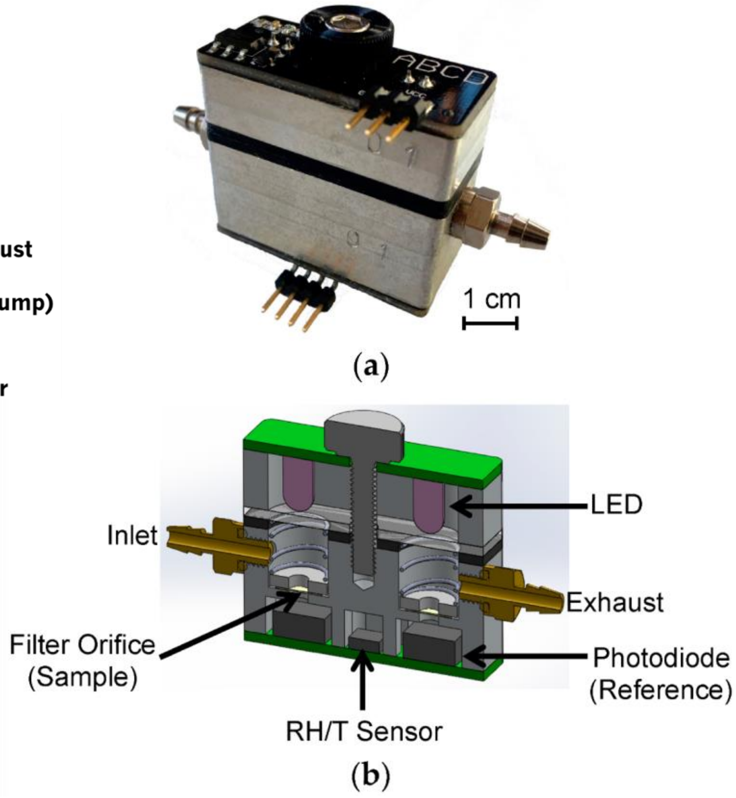
Measurement Approaches of BC LCS



Simplified working principle: BCmeter



Detailed working principle



Internal assembly

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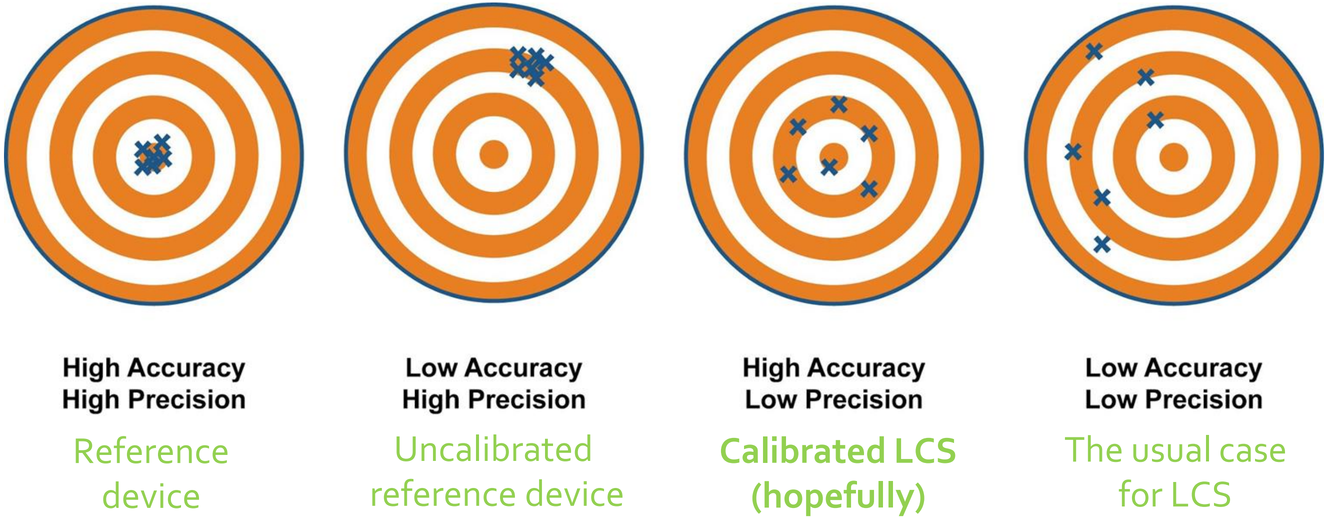
LCS Applications

- Enables spatially dense, high temporal resolution measurements of air quality to be made economically
- Beneficial in areas where the concentration of air pollutants have significant spatial gradients
- Inexpensive and can be portable, compared to reference monitoring station
- Specific use cases for sensors include outdoor monitoring in a stationary or mobile mode, indoor environment monitoring and personal monitoring

LCS response time and overall performance

- Response time
  - Time at which the output reaches a certain percentage (e.g. 95%) of its final value, in response to a step change of the input.
- Overall performance
  - Sensitivity to cross-interferences from other atmospheric pollutants, and environmental variables, such as temperature and humidity
  - Limitation of sensor longevity and long-term stability
  - Variance compared to reference monitoring stations
  - There is a limit to the performance one can expect from a (calibrated) LCS ~100€ and a reference-grade sensor ~ 100k €.

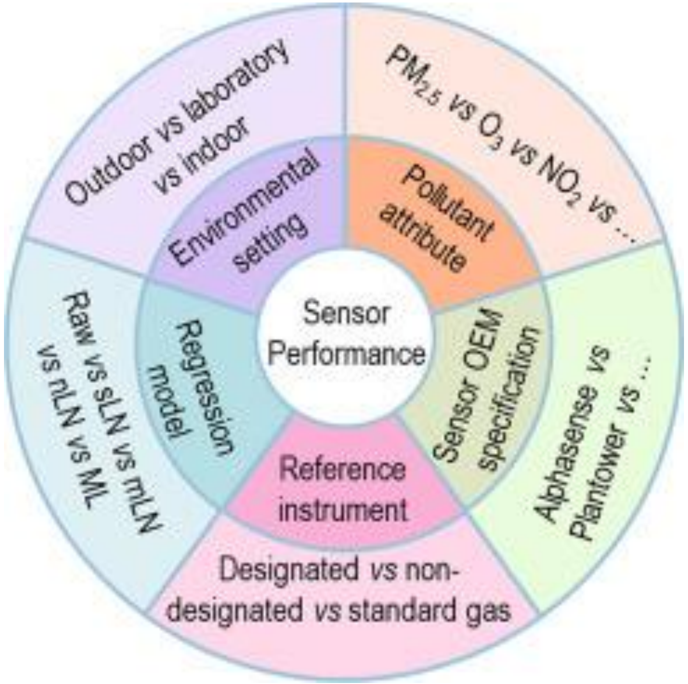


COMPAIR D5.1 Guide to Air Quality Monitoring

Chapter 3: Sensor Maintenance Training

Chapter 3: Sensor Maintenance Training

- Sensor Calibration
- Sensor Cleaning
- Sensor Inspection
- Sensor Replacement



Why do sensors need to be calibrated?

- No sensor is "perfect"

  - Two sensors from the same manufacturer production run may yield slightly different readings

  - Two sensors in similar conditions having differences in design may respond differently

  - Environmental variabilities such as temperature, shock, humidity, etc. during storage, shipments and/or assembly may result in a change in sensor response

  - Sensors may 'age' meaning their response may change over time requiring re-calibration

What is sensor calibration?

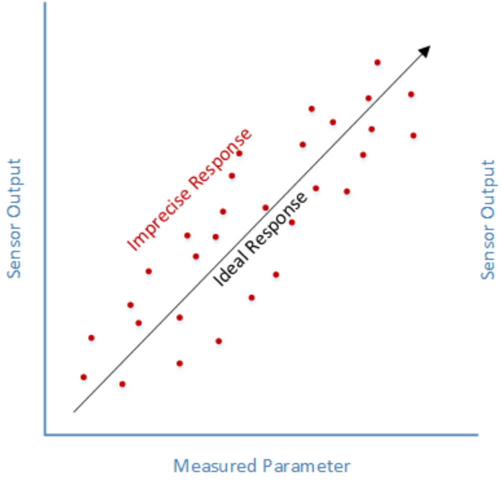
- Sensor (or device) calibration means adjustments made to the sensor to make it function with minimum deviation from official standards

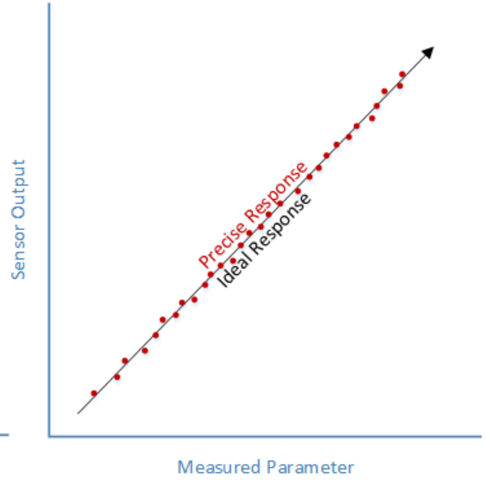
- Sensor calibration is to ensure accuracy in sensor measurements to have:

  - "precision" meaning ability to always produce the same output for the same input

  and

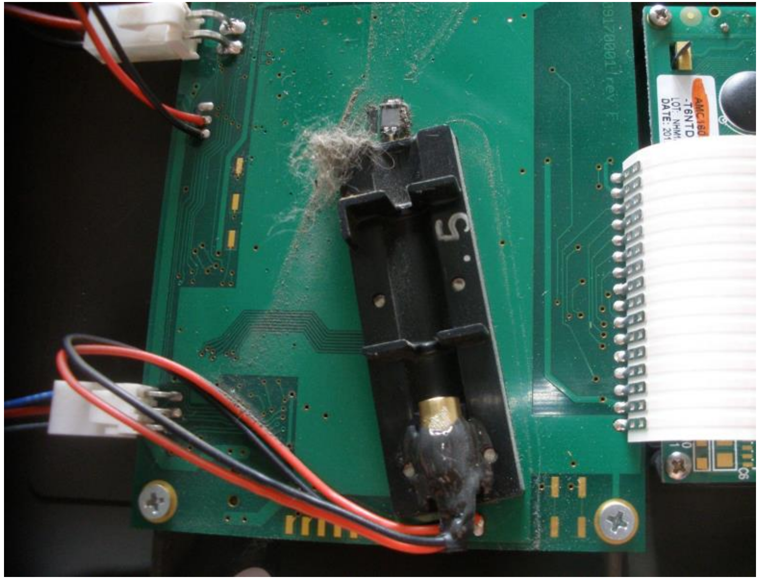
  - "resolution" meaning ability to reliably detect small changes in the measured parameter





Sensor Cleaning

- Dust accumulation on sensors, results in incorrect readings and affects product performance



Sensor Inspection

There are two ways to perform sensor inspection:

- Regular (e.g. daily) inspections to check if the sensor is measuring and if data is being processed continuously
- Periodic (e.g. monthly) inspections to check the physical condition of the sensor such as keeping dust and moisture away and ensuring no excessive rusting and corrosion

Sensor Replacement

- Sensor maintenance, inspection and cleaning can only go so far. If realignment or repairing occurs more often, it maybe time to replace the sensor or other components depending on warranty.

- Sensor manufacturers provide the expected lifespan (usually a year) of the sensor. Sensor replacement is also advised upon expiration.

COMPAIR D5.1 Guide to Air Quality Monitoring

Chapter 4: Sensor Data Collection Training

Chapter 4: Sensor Data Collection Training

- Data Collection and Calibration
- Assess data quality, patterns, anomalies
- Assess interfering chemical compounds, drift

How to calibrate sensor data?

- Step 1: Select a "Standard Calibration Reference" to calibrate against. This can be a:
  - *known concentration of measured parameter in a laboratory*
  - *reference monitoring station*
  - *calibrated sensor*

Laboratory Tests

- Step 2: Deploy the sensor to compare to the reference:
  - *Laboratory Tests - exposing sensor units to "known concentration of measured parameter in a controlled laboratory" setting*
  - *Field Tests - deployment of sensor units next to high-grade "reference monitoring stations" under realistic conditions*

Field Tests

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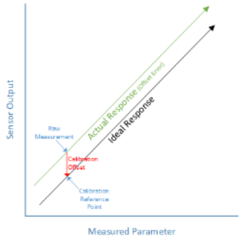
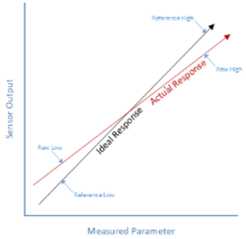
How to calibrate sensor data?

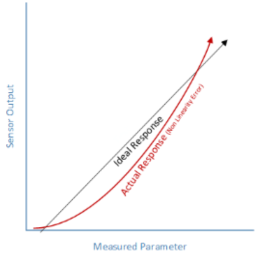
- Step 3: Determine the sensor's "Characteristic Curve", which defines the sensor's response to an input.
  - □*The calibration process maps the sensor's response to the reference's (or ideal) response.*



- Step 4: Apply the suitable calibration method:
  - □One Point Calibration *(used to correct for sensor offset (an offset means that the sensor output is higher or lower than the reference (or ideal) output)*



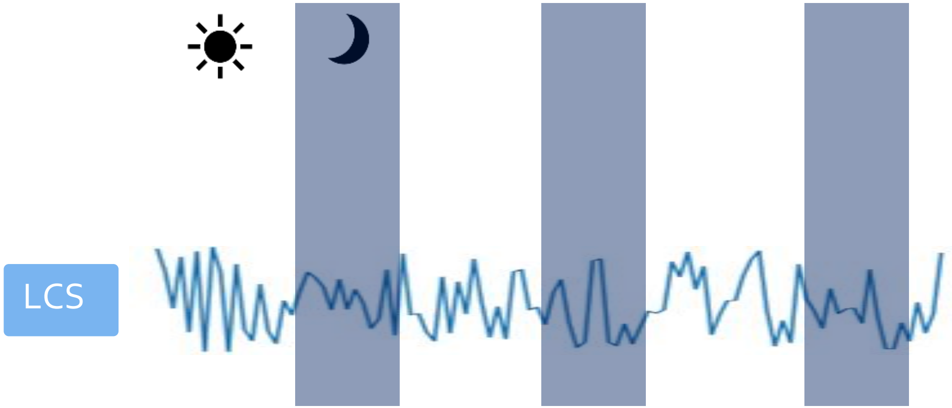
  - □Two Point Calibration *(used to correct differences in slope or sensitivity (differences in slope or sensitivity means that the sensor output changes at a different rate than the reference (or ideal) output)*



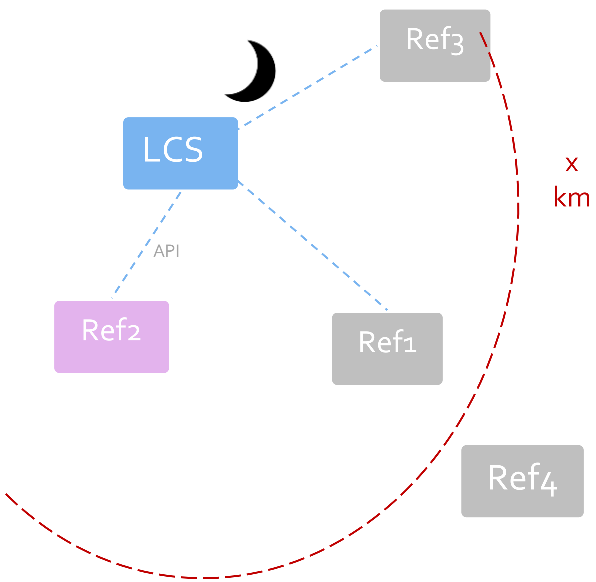
  - □Multi-Point Curve Fitting Calibration (usually the case with LCS)

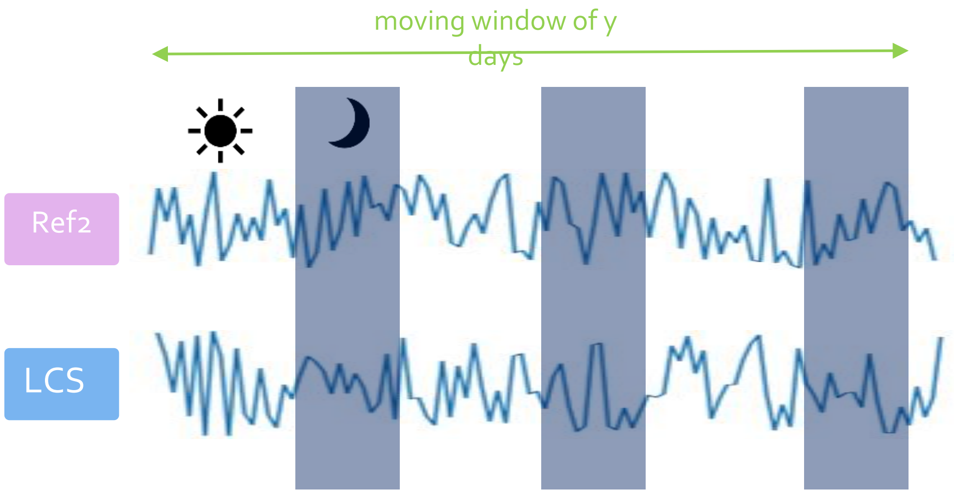
Novel calibration method: imec Distant Sensor Calibration

- imec will calibrate CompAir data using nighttime data analysis – Basics:



imec Distant Sensor Calibration - Basics





(1) Clean data (remove unrealistic values)

(2) Train (MLR) model (example: a * RAW+ b = CAL but more complex)

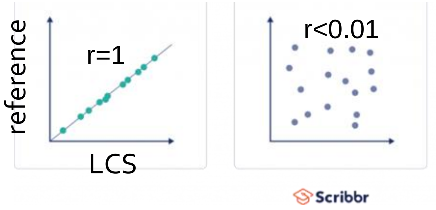
(3) Apply a, b to calibrate RAW values in real-time

Grant Agreement No. 101036563

Metrics used to quantify data quality: what do they mean?

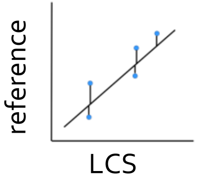
- Correlation: If "real value" increases, does measured value increase proportionally?

  Metrics: Correlation coefficient (r) , coefficient of determination (R^2)



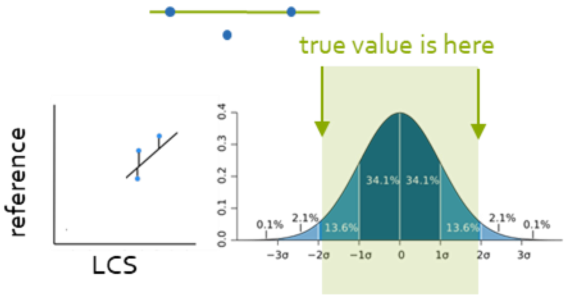
- Accuracy: How far is the measured value from "real value"?

  Metrics: Mean absolute error (MAE), root-mean squared error (RMSE), mean bias, etc.



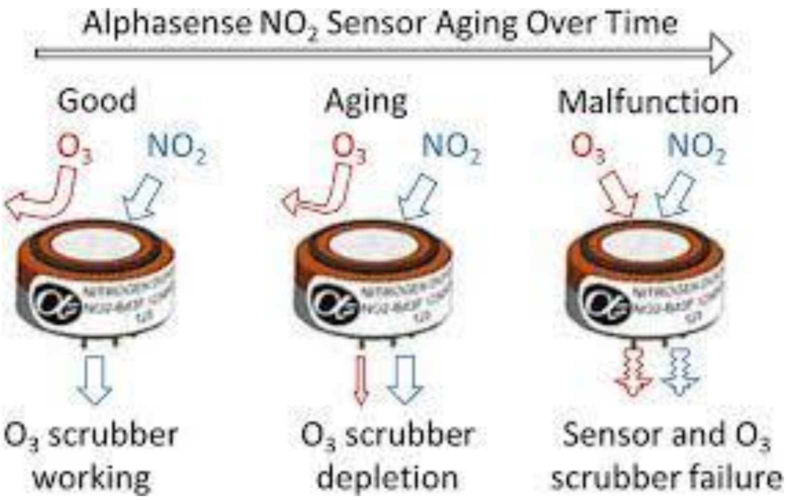
- Between-sensor uncertainty: How comparable is one LCS unit from another?

- Expanded uncertainty: If we only look at the sensor data around the limit value, what is the range within which we are reasonably confident the true value can be found?



Interfering chemical compounds, drift

- Drift is a measurement error caused by the gradual shift in a sensor's measured values over time. Drift can be caused due to:
  - Time / Sudden Shock / Environmental Changes / Vibrations / Normal Wear and Tear / Improper use / Debris Buildup / Interfering Chemical Compounds



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Chapter 5: Making sense of sensor data and its implications for research, policy and practice

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Contents

- Practice
  - Examples of experiments
- Research:
  - Steps to take when starting an experiment
- Policy:4 cases
  - Schoolstreet
  - Low Emission zone
  - Traffic Circulation plan
  - Influence Covid lockdown on air quality

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Practice

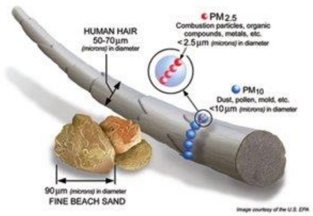
Education - Growing in experience - Measuring - Searching for solutions

Indoor air quality - experiment 1

How does my (neighbours) heater affect the air quality in my house?

What do you measure?

- Particulate matter (PM): harmful to health
- PM is a good indication for wood combustion
- Next to PM10, the finer fraction (PM2.5) is the most dangerous and thus representative of your health



When do you measure?

- Very diverse throughout the seasons - impact mainly measured in wintertime !

Indoor air quality - experiment 1

How does my (neighbours) heater affect the air quality in my house?

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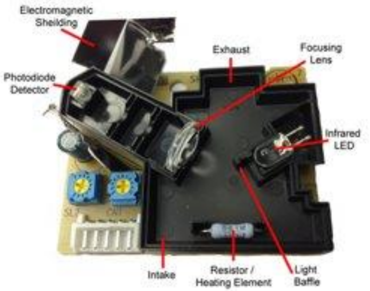
Where do you measure?

- Put the device on the back of your house where you mostly sit / you can combine with one indoor.
- Ensure a good air flow around the device.



How do you measure?

- You need an active measuring device, which measures at different times a day. because you need more than one event per day.
- With a PM sensor you collect data per minute or second.

Outdoor air quality - experiment 2

What is the impact of traffic on the air I breathe, when cycling?

What do you measure?

- Nitrogen Dioxide (NO2), is the best measure for traffic

When do you measure?

- You need to measure different moments a day- you need an active measurement method like a sensor with a fast response time.

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Outdoor air quality - experiment 2

What is the impact of traffic on the air I breathe, when cycling?

Where do you measure?

- Put the measuring device on a representative place for inhaled air
- for instance, on your backpack or your bicycle basket

How do you measure?

- Keep a logbook: weather / other important information:
- Measure while you walk or cycle and keep track of the times in the logbook
- Compare with a reference measurement (e.g. via the data portal on the together for clean air website for Flanders)

Outdoor air quality - experiment 3

What is the effect of temporarily making the street at the school gate traffic-free?

What do you measure?

- Nitrogen Dioxide (NO_2), is the best measure for traffic

When do you measure?

- Measuring before and during the introduction of the car-free school moments

Outdoor air quality - experiment 3

What is the effect of temporarily making the street at the school gate traffic-free?

Where do you measure?

- Put the measuring device on a representative place for inhaled air:
  - on an average height of a student (E.g. 1m for children, 1.5m for adults)
  - at the school gate, on the street site, on the playground, ...
  - In the classroom (relevant for exposure, but not for measuring the impact of the schoolstreet)

How do you measure?

- A sensor or a sampler - a sensor can give you a result every minute or second
- Keep a logbook: weather / other important information
- Measure while you walk or cycle and keep track of the times in the logbook
- Compare with a reference measurement

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I build a sensor - but does it work properly?

You want to know ....

- Is your sensor stable?
  - in different circumstances?
  - on a long term?
  - when there’s a high humidity?

  ...

Frequency of testing your sensor?

- Measure for at least 3 months,
- repeat the same test after 1 year: ‘aging of the sensor’
- Note that the meteo will impact your measurements too

I build a sensor - but does it work properly?

What do you measure?

- Particulate matter (PM) - for at least 3 months
- use your self-made sensor

Where do you measure?

- To be representative you measure at a height of 2.5- 4 m, this is the standard

Then compare with a measurement on the same time measured with a reference monitor, e.g. for Flanders you can look at the VMM-website or at the data portal of the Togetherforcleanair-website.

You can also look at models for more indication

I build a sensor - but does it work properly?

Precision

- To know the precision of you sensor, you need to measure if possible with 3 sensors at the same time and place.
- Are the results similar? or are there differences between the different sensors?

Then compare with a measurement on the same time measured with a reference monitor, e.g. for Flanders you can look at the VMM-website or at the data portal of the Togetherforcleanair-website.

You can also look at models for more indication

I build a sensor - but does it work properly?

Keep a logbook

- note the events in the environment, that are of interest
- note the state of the weather during the measurements
- are there outliers, and can you explain them?

you need this for the interpretation of your data

Using sensors, means also testing the sensors:

- tests in a lab (by laboratory / Institution/ ...)
- test and calibrate in the field
- calibration while measuring

-> See Chapter 4: Data Collection Training

Air quality sensor - the quality of the sensor

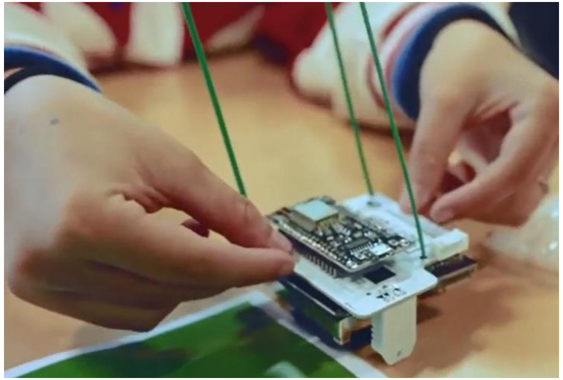
Testing and calibration of sensors

Create a web environment where everybody can be part of

Air quality experiments in schools

Toddlers are counting cars and bikes in the street

Primary school children are building measuring systems to measure air quality



Air quality experiments in schools

Instead of taking the bus (like they did before), schoolchildren now are moving safely with steps to go swimming ! This is healthier and better for the environment!

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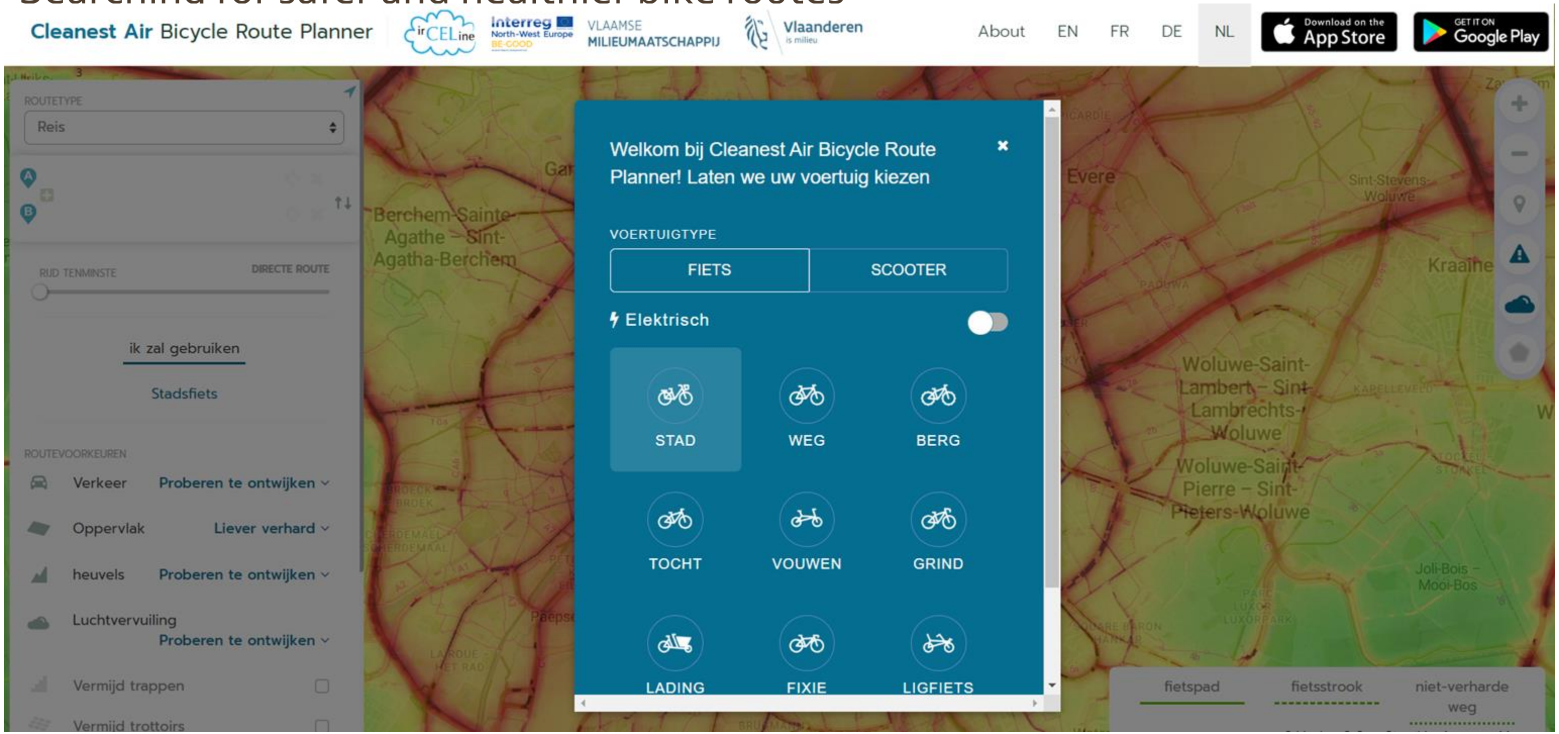
Air quality experiments in schools

Searching for safer and healthier bike routes



Air quality experiments in schools
Outdoor teaching

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Car-free street when school starts/ends

Citizen Science
How to measure particulate matter / CO_2 / NO_2

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Examples of projects done by citizens:

- Citizens measured the air quality in the neighbourhood of a harbor
- Citizens measured the air quality in buildings in function of the height

INDOOR VERSUS OUTDOOR MEASUREMENTS

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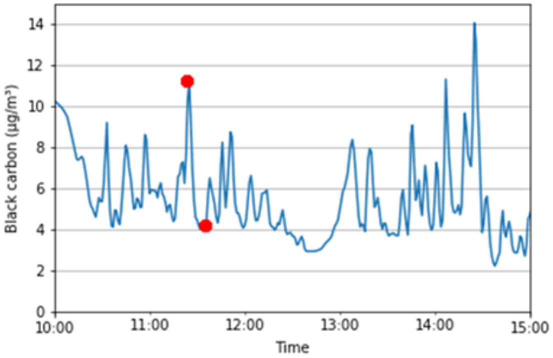
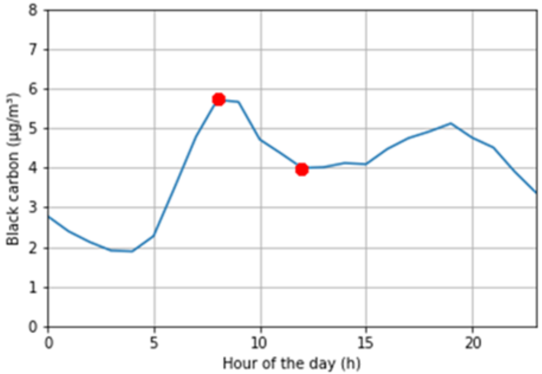
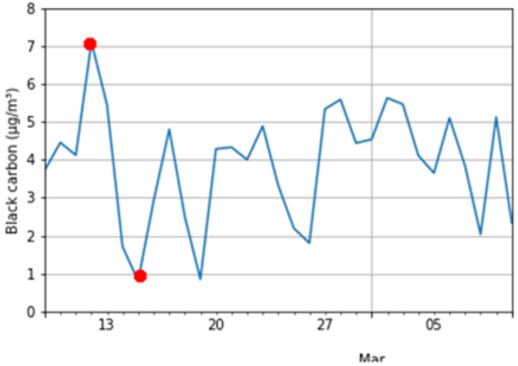
Mobile measurements

- Urban air quality => large temporal and spatial variability
- Spatio-temporal data => limited temporal resolution
- Repetitions are needed







RI URBANS

European Commission

Mobile measurements

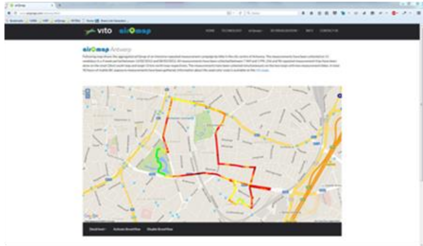
- airQmap: a tool to collect mobile **BC measurements** and process them into **street-level BC maps**.

- It contains:

1. Easy to use **measurement devices** to allow citizens to collect mobile BC measurements in a 'cost-effective' way
2. An automated **data processing** infrastructure and **visualization** to generate the BC map www.airqmap.com
3. Measurement **methodology** (data collection, data validation and aggregation)

- Has been used in different municipalities and cities

1.


2.


3.

Contents lists available at ScienceDirect

Atmospheric Environment

Mobile monitoring for mapping spatial variation in urban air quality: Development and validation of a methodology based on an extensive dataset

Joris Van den Bossche, Jan Peters, Jan Verwaeren, Dick Botteldooren, Jan Theunis, Bernard De Baets

HIGHLIGHTS

RI URBANS
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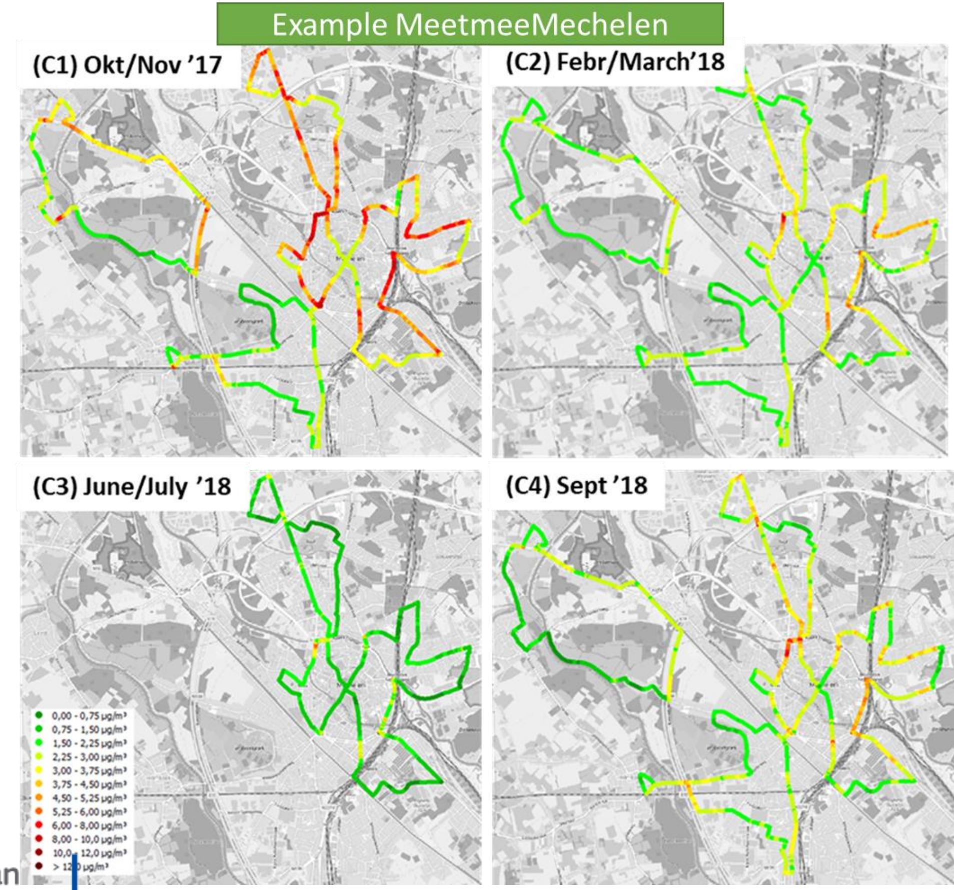
Mobile measurements

- Large differences
- Between locations
- Between seasons
- Similar pattern

Think about GDPR of participants!



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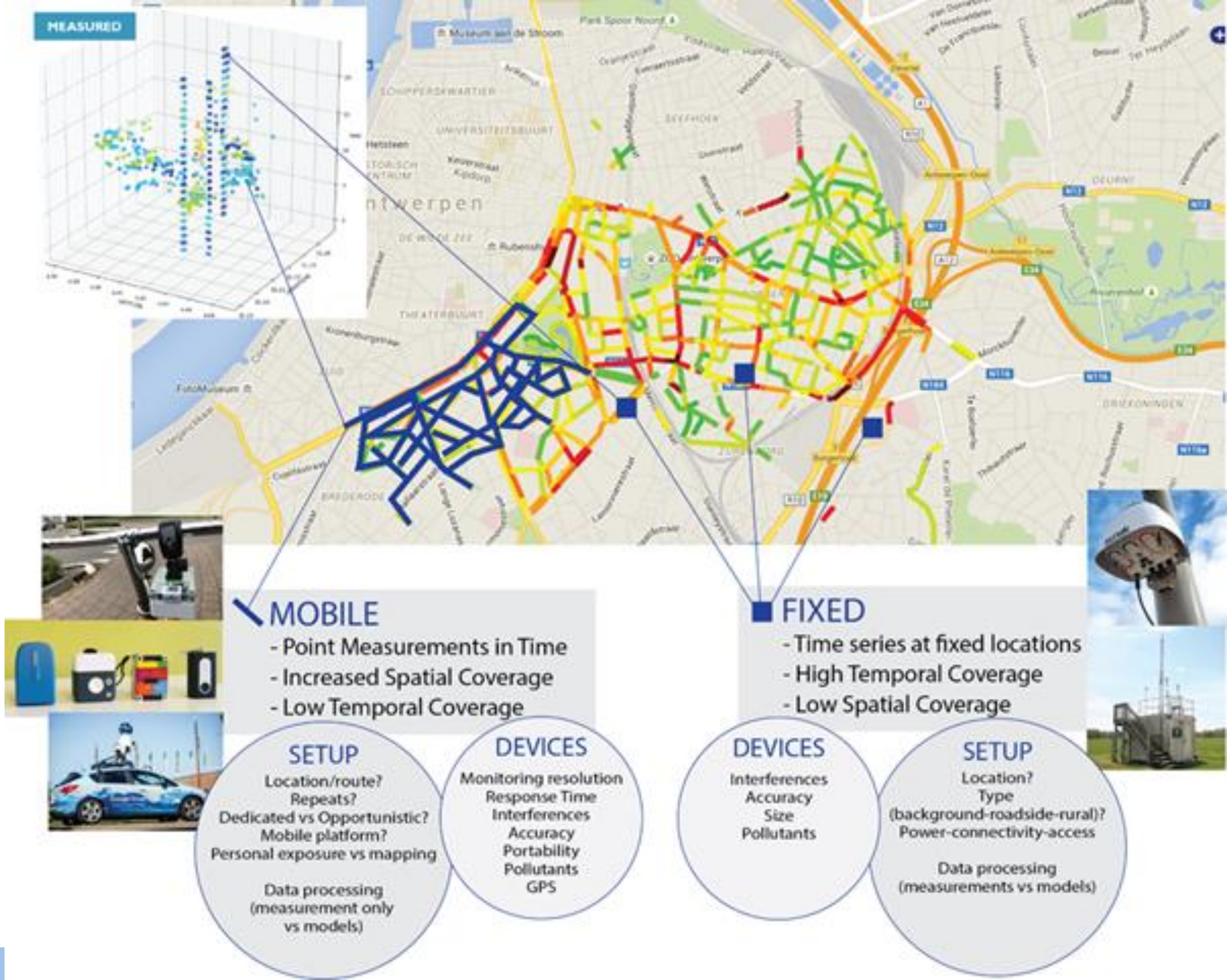
Mobile measurements



Research

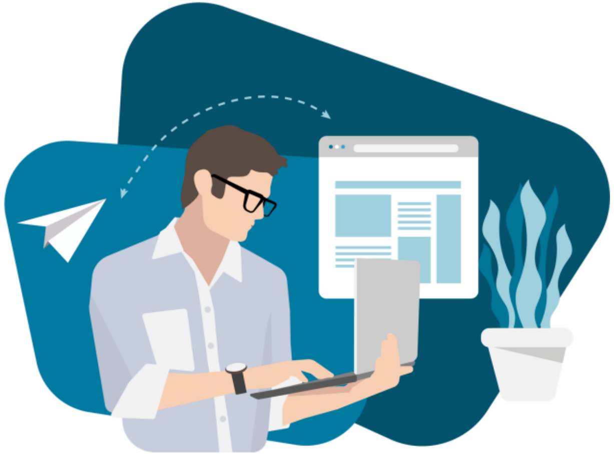
How to start a scientific experiment?

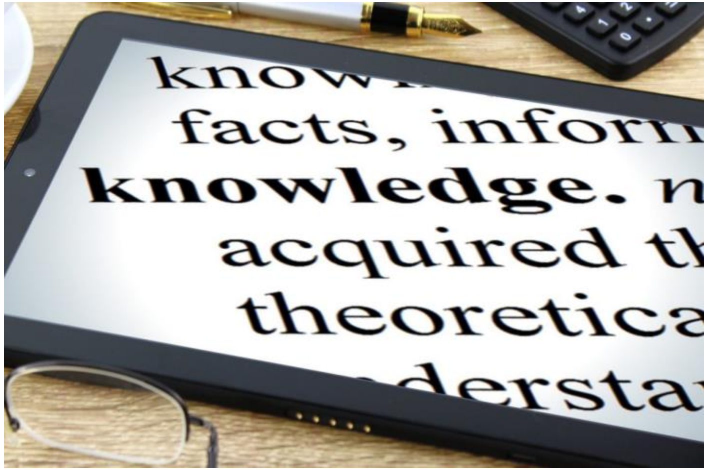
1. Knowledge gaining
2. Compose a research question
3. Experiment

Knowledge gaining

- Learn about the subject you want to investigate. This can be done via the internet or by consulting experts.
- Check what information is already available.

This knowledge can be used to formulate a solid research question.





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Compose a research question

A solid research question is accurate, concrete and measurable.

1. **What** do you want to determine and **why**?
2. **Where** and **when** will you measure?
3. **Which type of research** do you choose?
   a. Comparison (e.g. difference between the front and the back of my house?)
   b. Description (e.g. what is my exposure?)
   c. Evaluation (e.g. is a certain standard exceeded?)

E.g. I want to evaluate the air quality in my street. How is the current air quality in my street compared to the average air quality in Flanders?

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Experiment

There are several ways to measure air quality. Which device you need depends on your research question and which pollutant you want to measure.

- **Sensor** (active method)
  - Measures air quality at different times in a day. (every second, minute, 15 minutes, …)
  - You obtain a lot of data (= more detail), that can be read on a computer.

- **Sampler** (passive method)
  - Captures pollutants during a certain period.
  - You obtain 1 value at the end of that period.
  - No short-term differences
  - Cheaper

Experiment

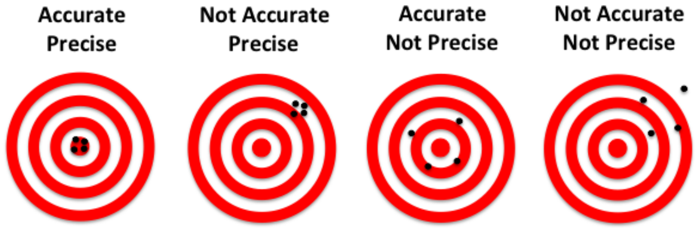
How to ensure good quality measurements?

- Check whether your experiment is feasible or not
  - Do you have sufficient resources, the right permits, etc.?
- Conduct a trial experiment in advance
  - Draw up an experimental design
- Follow your measurements accurately during the experiment
  - Is your setup still working?
  - Are your sensors still measuring?
  - Record anything that may have an impact on your measurements (logbook)
    - Weather conditions, temporary disruptions (eg road works), etc.

Experiment

Regular quality control is recommended

- **Precision**
  - Your measurements are reproducible or precise when 3 or more measuring devices of the same type give more or less the same result. If they do not, choose a different measuring device if possible or take this into account when interpreting the data.
- **Accuracy**
  - Your measurements are accurate, when they are comparable with official measurements. If you systematically measure higher or lower, you can still use your measurements if you rescale them to the 'correct' values. This process is called calibration.
- **Variability**
  - Choose the correct time interval.
    - Short time interval gives more information, but also more 'noise'
    - Check in advance how much your data varies and determine the ideal time interval



Experiment

Data analysis & interpretation

- Visualize your data
  - Helps with data interpretation
  - Clear and easy way to share your data
- Analyse your data
  - Compare with official measurement data (reference stations)
  - Check for outliers (your logbook can help to understand them)
  - R is great software for data analysis
    (certainly the OpenAIR module)
- Interpret your data
  - Discuss the results with fellow researchers

Was your research question answered?

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Policy

Schoolstreet

City Of Things

Kampenhout use-case sensornetwork

Measurements

The contribution of traffic (NO, NO_2, PM_1) was measured at the school and at a background location

Traffic scenarios

Different traffic scenarios were implemented to demonstrate the effects of traffic measures on local concentrations:

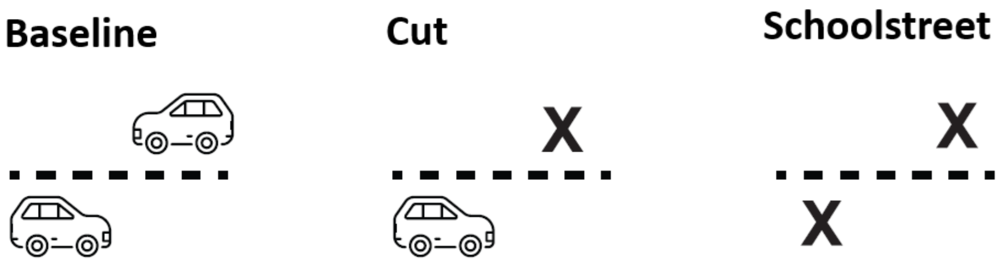
- **Baseline** = current situation
- **Cut** in one driving direction
- **Schoolstraat fully closed** for traffic

Schoolstreet

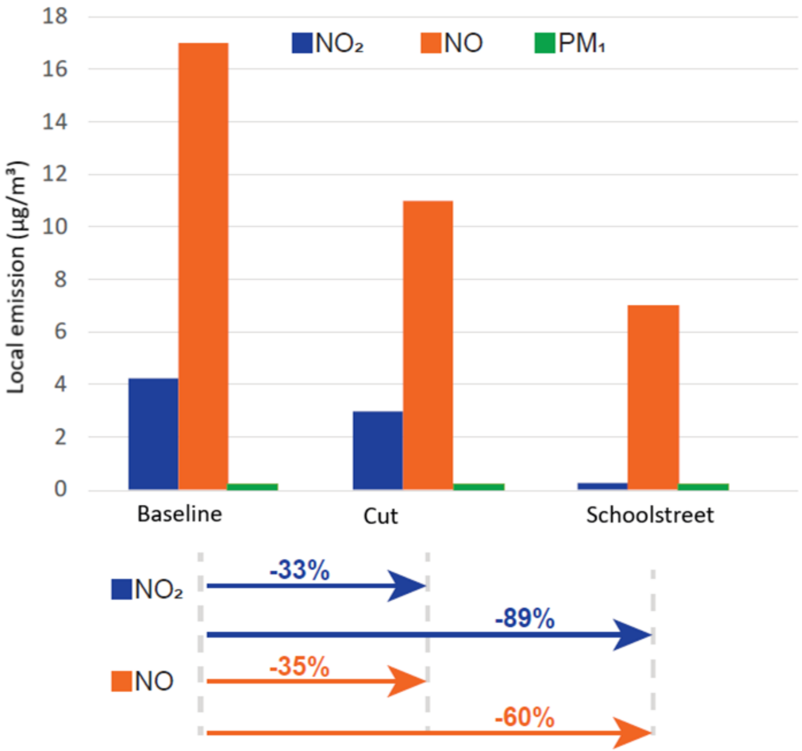
Remove one or both lanes of traffic to determine the impact on air quality

Results

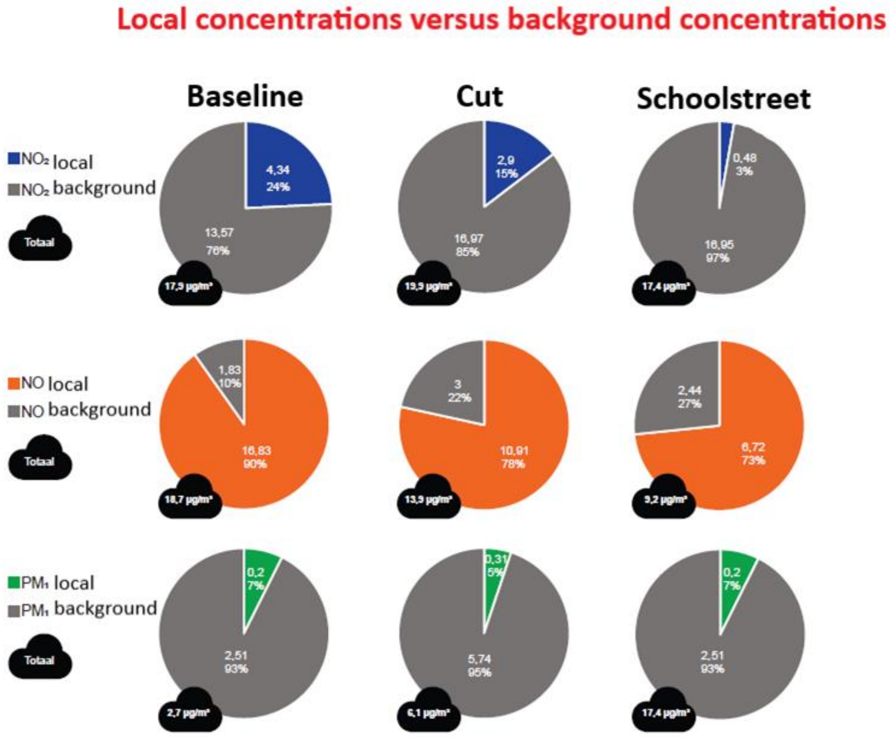
Impact measures on local concentrations

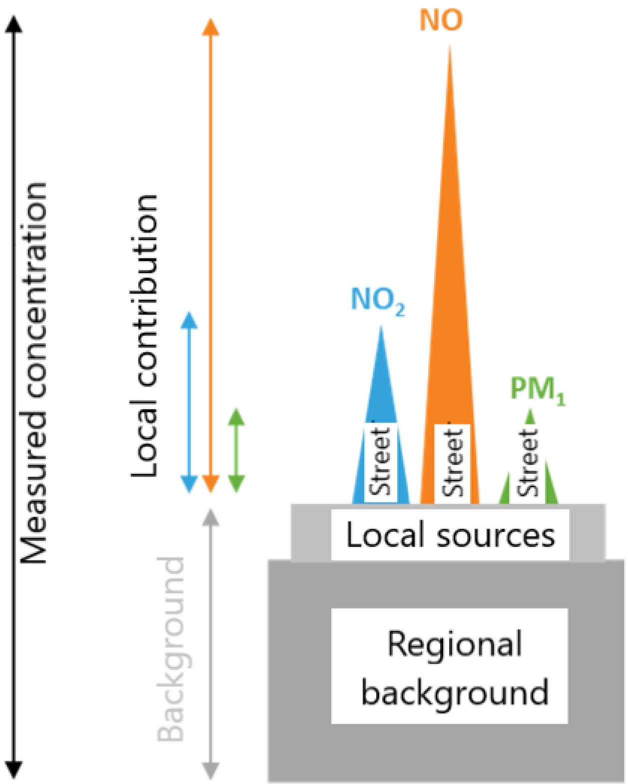


Schoolstreet



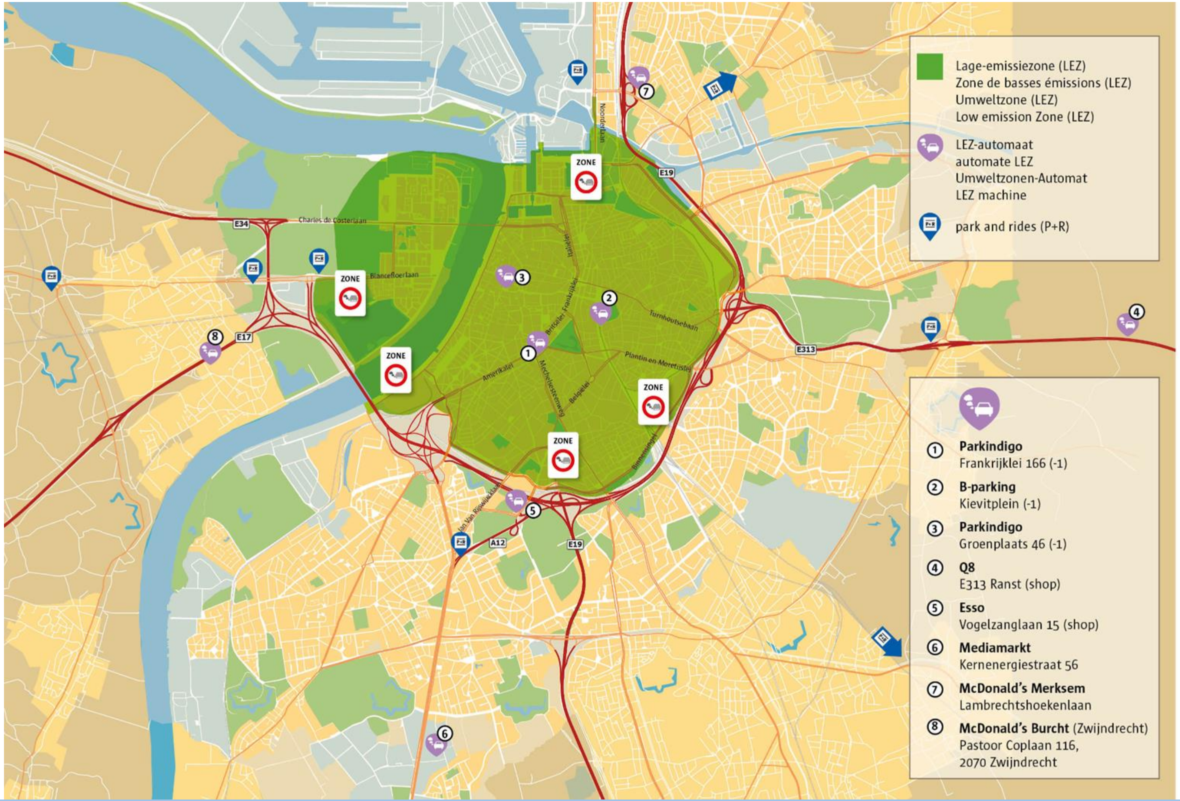
Schoolstreet





Low Emission Zone (LEZ)

E.g. Antwerp (Belgium)



Low Emission Zone (LEZ)

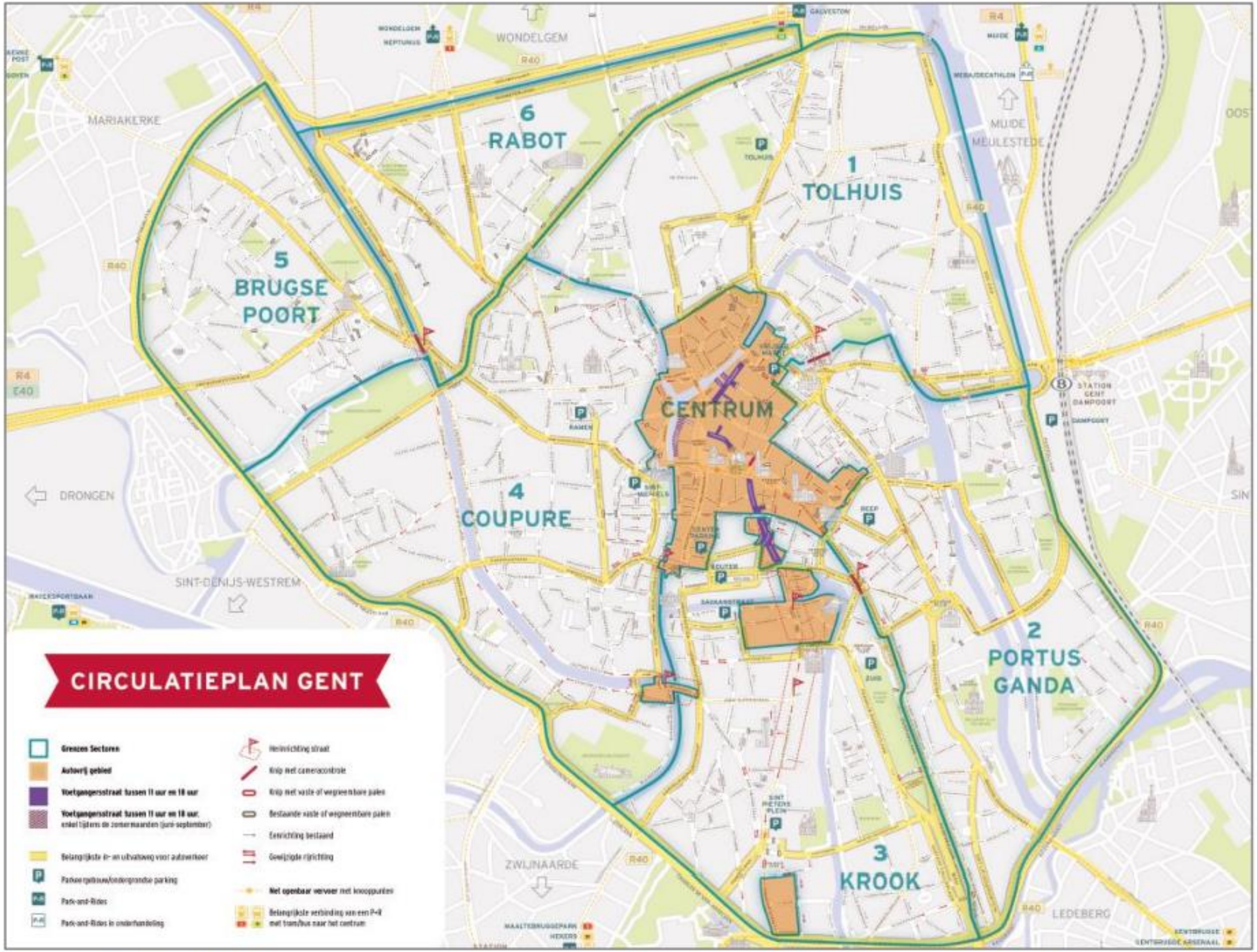
Difficult to give general, scientifically correct results on local nett effect of LEZ on NO_2 and BC concentrations since these concentrations are dependent on meteorological parameters

- The LEZ in Antwerp caused locally reduced concentrations for BC
- For NO_2 there are no clear indications that the LEZ caused additional reductions of the local concentrations

Source: https://www.vmm.be/publicaties/luchtkwaliteit-in-de-antwerpse-agglomeratie-jaarrapport-2020

Traffic circulation plan

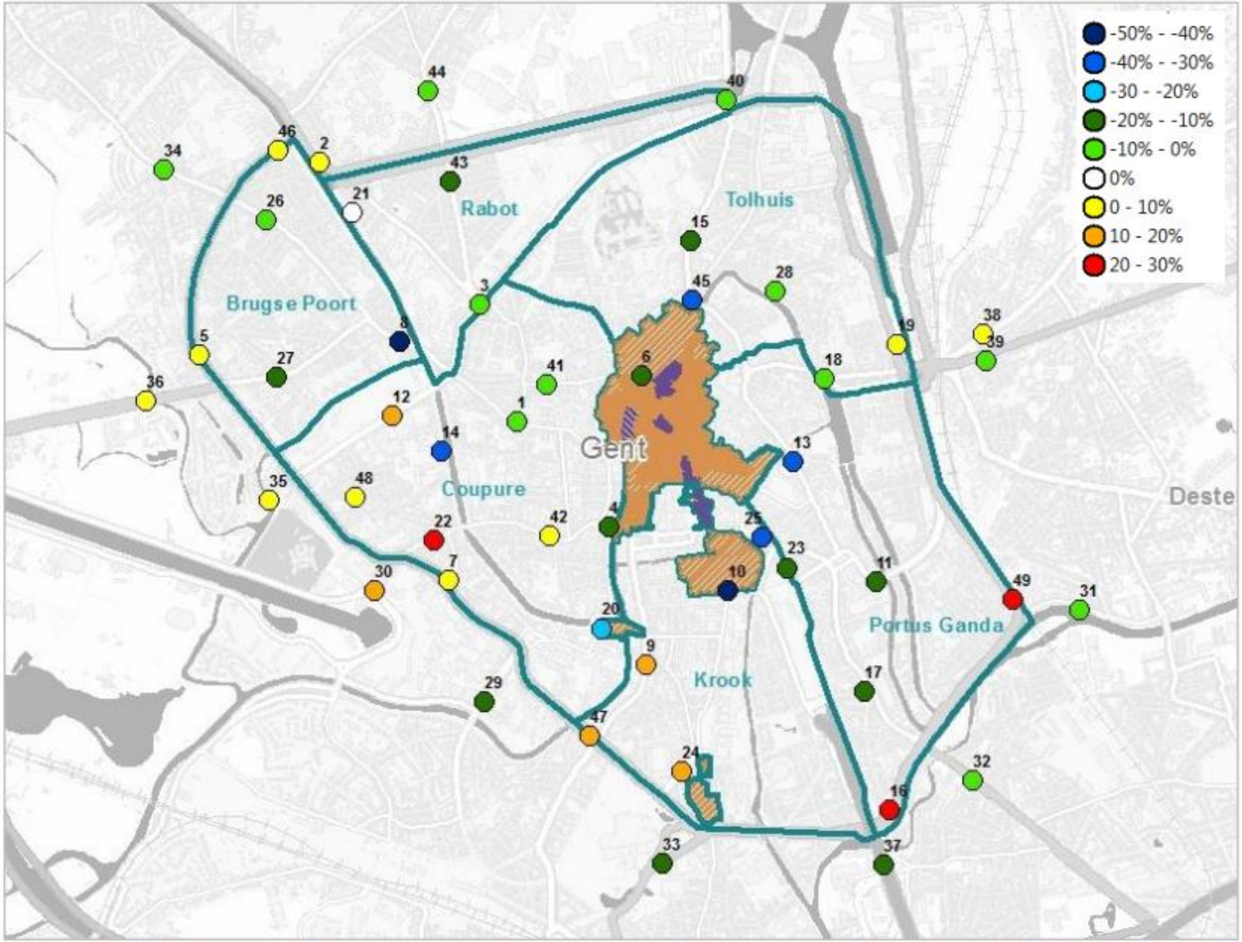
E.g. Ghent (Belgium)



Figuur 1-2 Circulatieplan binnenstad Gent ingevoerd op 3 april 2017 (Bron: Stad Gent)

Traffic circulation plan

- General trend: improved concentrations for NO2 and BC
  - Lower concentrations in city center
  - Higher concentrations on ringroad and main entrance roads
  - BUT overall decrease in NO2 and BC and less exposure.



Figuur 5-3 De berekende evolutie van de jaargemiddelde concentratie stikstofdioxide (NO_2) sinds de invoering van het circulatieplan (Bron: modelsimulaties, Stad Gent)

Influence covid lockdown on air quality

The measures that started on March 18th 2020 in Belgium to slow the spread of the covid-19 virus, had an impact on the air quality.

The net impact strongly varies depending on pollutant and location.

Two independent analyses gave comparable conclusions:

- clear reduction in NO_2 and BC
- less clear reduction in PM
- more O_3

Influence covid lockdown on air quality

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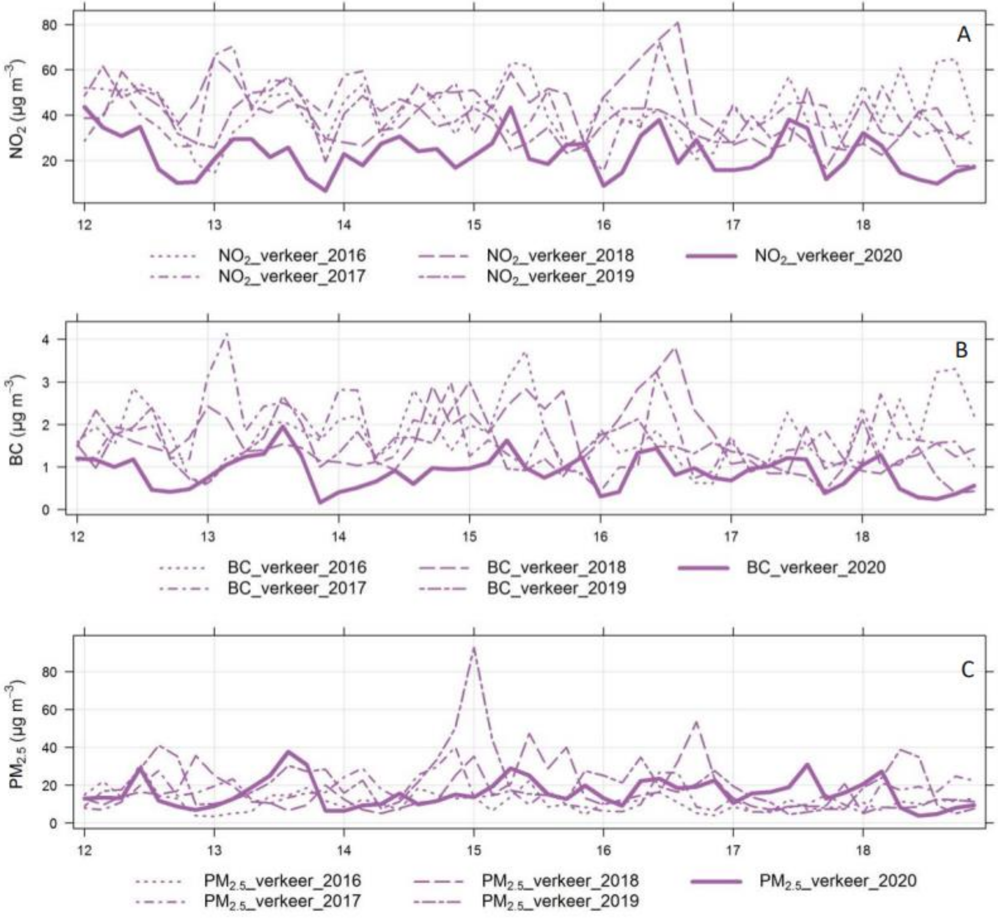
Day average concentrations for different types of locations during the covid measures compared to the same period in previous years.

(A) NO2
(B) BC
(C) PM2.5



Influence covid lockdown on air quality

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Day pattern for NO2-concentrations for different types of locations in

(A) 2019
(B) the period before the covid-19 measures