



Air Quality Programs

Lecture Notes

Author(s)/Organisation(s):

Anders Östman (Novogit AB)

License



<https://creativecommons.org/licenses/by/4.0/>

Version

Version 2.0

Date: 2025-04-29

Learning outcomes

At the end of this lecture, the learner is expected to be able to

- Explain motives for the European Clean Air Policies
- Describe basic components of the EU Ambient Air Quality Directive
- Describe actions which might reduce air pollution in cities
- Describe basic structure of current and future air quality monitoring networks.



Expected competences when entering the lecture

- No specific pre-requisites required.

Summary

The topic of this lecture is air quality and how this type of issues is addressed by EU and related policies. Air quality measures are described as well as monitoring strategies at EU level. EU network for providing near real-time measurements of air quality is also described. The lecture is an introduction to the assignment on sensor alarms of air quality monitoring.

Expected Workload

9 slides with course learning content, 1 classroom hour, 0.1 ECTS (ECVET)

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

With the support of the Erasmus+ Program of the European Union Strategic Partnerships N° 2021-1-SE01-KA220-VET-000028000

Revision History:

Revision	Date	Author(s)	Status	Description
0.1	2023-10-20	A. Östman	Final Draft	Lecture ready for review
0.2	2024-02-13	A Östman	Final Draft	Update based on reviewers' comments
1.0	2024-04-04	A Östman	Public version	Final adjustments
1.1	2025-01-20	A Östman	Final	License change and new EU directive added
2.0	2025-04-29	A Östman	Final	Updated EU logo and disclaimer. Edited by T. Näslund



Co-funded by
the European Union



Contents

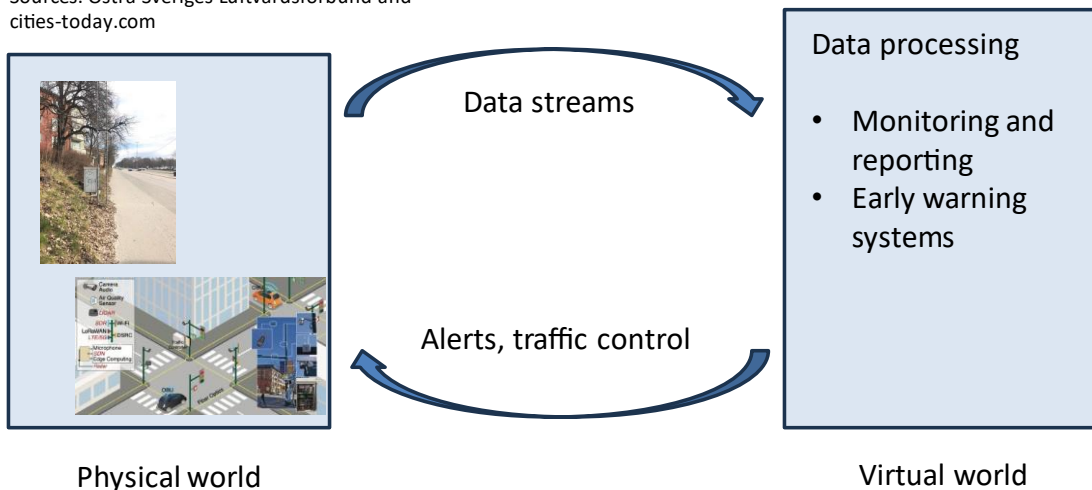
Air quality networks and digital twins	5
EU Clean Air Policy	6
European Ambient Air Quality Directive	7
PM2.5 limits, current situation	8
PM2.5 limits, EU targets	9
Improving air quality in cities	10
EEA Air Quality Download Services	12
Swedish Air Quality Monitoring Network	13
Local initiatives	14
References	15

Air quality networks and digital twins

Air Quality Programs

Air quality networks and digital twins

Sources: Östra Sveriges Luftvårdsförbund and cities-today.com



4

In the previous lecture on sensor network standards, focus was on the sensors and how to access their measurements. In this lecture we will focus on how to use the data and for what purposes, with a specific focus on air quality data.

Limits of air pollutants are specified in various European and national regulations. Data from sensors are collected and processed and presented in various status reports. The number of sensors in a city is often quite limited, ranging from one up to a few. If pollution thresholds are exceeded, actions need to be implemented. This process is often quite slow and the typical status reports are usually issued once a year.

Due to recent developments in sensor technologies, the price and availability of different sensors measuring air quality has improved considerably, although the accuracy of the sensor readings may be reduced. As an example, IKEA is selling air quality sensors to be used in Smart Home solutions. Consequently, several cities are considering using air quality networks to continuously assess the air quality and to control the traffic. Alerts may then be sent to travellers to take alternative routes or to switch the mode of the vehicle to electric mode.

But before we go deeper into this subject, let's have a look at the underpinning air quality norms.

EU Clean Air Policy

Air Quality Programs



EU Clean Air policies

- 300 000 premature deaths caused by fine particulate matter annually
- EU target: 55 % reduction by 2030
- Economic cost of air pollution more than 330 B€
- Zero pollution vision for 2050
- Main policies
 - Air quality standards (Ambient Air Quality Directive) – thresholds for air pollution
 - National Reduction Commitments (NEC Directive)
 - International Cooperation (Sustainable Development Goals)
 - Air pollution from key sectors (EU regulations) - energy, transport, agriculture, industry, waste etc.

5

Air quality has improved in the European Union (EU) over the last decades. Since 2000, the EU's GDP grew by 32% while emissions of the main air pollutants decreased by 10% to 70% depending on pollutant. However, in most Member States, the quality of life of EU citizens remains hampered, as air quality standards are still not being met. The situation is especially severe in urban areas, where most Europeans live (EC, 2018. A Europe that protects: Clean Air for All). In 2021, 300,000 premature deaths were estimated due to fine particulate matters in Europe alone, having an annual cost of more than 300 B€

Several EU initiatives have been initiated, aiming to reduce the air pollution. In 2008, the Ambient Air Quality Directive was adopted, specifying thresholds for different types of air pollutants. Other complementary EU legislations have also been implemented for instance related to air pollutions from specific sectors like road transport, energy etc.

The Ambient Air Quality Directive was revised in late 2024, where targets of air pollutants are adjusted to better harmonise with international (and stricter) air quality norms. These changes are also in line with the zero-pollution vision, where a continuous reduction of air pollutants is specified.

European Ambient Air Quality Directive

Air Quality Programs



European ambient air quality directive

- 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
- Rules for assessment of ambient air quality in relation to sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter, lead, benzene and carbon monoxide
 - Thresholds
 - Procedures
 - Density of sampling points
- Air Quality Plans
- Information and reporting
- Implementation, penalties etc

6

The European Ambient Air Quality Directive came into force in 2008. It is dealing with the major air pollutants of that time, and it specifies thresholds for concentrations, procedures for measuring air quality, density of sampling points and many other things. The directive was updated in December 2024 and it shall be implemented in the national legislations within two years.

It can be noted that carbon dioxide is not listed as a toxic air pollutant. But since CO₂ is important for the climate change policies, separate additional monitoring schemes have been developed for CO₂ and related greenhouse gases like methane (CH₄).

The directive also demands the member states to report their air quality on an annual basis. These reports are collected by the European Environmental Agency (EEA) and published on the EEA web site. This reporting scheme is also implemented at a national level and consequently, political decisions are taken on an annual basis, in best cases. But since new technologies allow for better and more frequent information, other actions may also be considered. These are however not reflected in the current legislations. But, as mentioned earlier, the ambient air quality directive has been revised and will enter into force by the end of 2026..

PM2.5 limits, current situation

Air Quality Programs

PM 2.5 limits, current situation

- PM2.5 (Particular Matters 2.5 μm) = Particles (aerosols) having maximum size of 2.5 μm .
- WHO (2021)
 - 24-hour average: 15 $\mu\text{g}/\text{m}^3$, not to be exceeded more than 4 times in any calendar year
 - Annual average: 5 $\mu\text{g}/\text{m}^3$
- Air Quality Directive (2008) – measurements at fixed stations in urban areas
 - Annual average: 17 $\mu\text{g}/\text{m}^3$
- Air Quality Directive (2024)
 - Meet the WHO guidelines by 2050
 - Thresholds to be met by 2026 and 2030

7

One example indicating that the current Air Quality Directive is getting outdated is the stipulated concentration thresholds for the air pollutants. We will here have a closer look at the concentration thresholds for one key pollutant, namely Particular Matters 2.5 (PM2.5). Particular Matters are small particles, often called aerosols. In this case, their maximum size is 2.5 micrometres. Breathing in unhealthy levels of PM2.5 can increase the risk of health problems like heart disease, asthma, and low birth weight.

When specifying limits, like the upper threshold of concentration of air pollutants, one must balance the costs of implementation with the health impact. In 2008, the EU considered that an annual average of 17 $\mu\text{g}/\text{m}^3$ was an appropriate upper level of PM2.5 concentration. Many countries then specified national guidelines, based on this European directive.

In 2021, the World Health Organisation specified other appropriate levels, this time entirely based on impacts on human health, based on scientific studies. As you can see on the slide, the upper limits are far less as compared to the EU directive from 2008. As an example, the annual average of PM2.5 concentration is from a human health perspective specified as 5 $\mu\text{g}/\text{m}^3$, in contrast to the 17 $\mu\text{g}/\text{m}^3$ as specified in the Air Quality Directive.

This together with other initiatives, have led to a revision of the Air Quality Directive, which now has been completed.

PM2.5 limits, EU targets

Air Quality Programs

PM 2.5 limits, EU targets

- WHO (2021)
 - Daily average $< 15 \mu\text{g}/\text{m}^3$
 - Annual average $< 5 \mu\text{g}/\text{m}^3$
- Air Quality Directive (2024)
 - By December 2026, annual average $< 25 \mu\text{g}/\text{m}^3$
 - By January 2030, daily average $< 25 \mu\text{g}/\text{m}^3$
 - By January 2030, annual average $< 10 \mu\text{g}/\text{m}^3$
 - By 2050, aligned with WHO
- Alert threshold, daily average = $50 \mu\text{g}/\text{m}^3$
- Exposure Reduction obligations, based on three-year averages

8

The overall goal of the new Air Quality Directive is that we should align with the WHO specifications by 2050. To reach this goal, a stepwise approach has been specified. These steps are also specified in the new Air Quality Directive, implying that the member states must include it in their national legislations.

The monitoring of air quality is based on sensor readings at specific monitoring stations. To reduce the impact of statistical outliers, the sensor readings are averaged in space and time. The temporal averaging is for instance specifying daily averages, yearly averages and also there-years average. But there is also sometimes a spatial averaging, based on single station, stations within a city or stations within a larger region. In our case, we will only look at the temporal average. More details about the air quality monitoring indicators are specified in the appendices of the directive.

If we look at the annual average of PM 2.5, the current directive from 2008 specifies an upper limit of $17 \mu\text{g}/\text{m}^3$ (see previous slide). However, by 2026, the annual average should not exceed $25 \mu\text{g}/\text{m}^3$. This is an increased level, indicating that the level from 2008 might be too optimistic. But by 2030, the annual average should be down to $10 \mu\text{g}/\text{m}^3$ and by 2050, fully aligned with the WHO specifications.

There are also other thresholds specified in the directive, for instance when alerts have to be made and to whom as well when exposure reduction obligations kick in. The legal reduction obligations indicate the importance of having a good monitoring system for air quality data.

Improving air quality in cities

Air Quality Programs



Improving air qualities in cities

- Road traffic was responsible for 56% of NO_x emissions and 23% of PM_{2.5} emissions in Paris (2018). Other important PM_{2.5} emission sources are heating (wood, oil, ...), nonroad mobile machineries (NRMM) (construction machineries, inland shipping etc) and industrial sites.
- Air quality planning (no common tool for assessing the impact of air quality plans). Better modelling and forecasting tools required
- Air quality monitoring (hot spots, micro sensors, smart home (IKEAVindriktning))
- Air quality management
 - Planting trees,
 - Redirecting and regulating traffic
 - New vehicles (electrical, Euro 6 etc)
 - Low emission zones (LEZ), Zero emission zones (ZEZ)
 - Alerts to hybrid vehicles to switch to electric mode

8

If look specifically at PM_{2.5}, we notice that the major problems are in the cities. And the major reason for this is road traffic. But energy consumption (heating) is also a major factor, at least at a European level.

But what to do? Unfortunately, we have a few scientific problems to address first. The first one is that it is currently quite difficult to estimate the air quality impact of different activities and plans. We need better modelling and forecasting tools. Modelling means here that “if we do this, then this will happen”. And forecasting means also “if we don’t do anything, this will happen”.

The current system of air quality monitoring stations is based on the Air Quality Directive from 2008. This monitoring strategy was based on monitoring hot spots, which means places where high concentrations of air pollutants are expected. Due to the decrease of acceptable thresholds, induced by the WHO, additional monitoring stations might need to be established. In addition, we have a development within the sensor technology sector and smart homes. Monitoring PM_{2.5} concentration is also of interest for people wishing to improve their own inhouse environment. Consequently, companies like IKEA are selling equipment (sensors and software) which allows their customers to monitor their inhouse air quality. In contrast to IKEA tradition, you don’t have to put the pieces together yourself. It’s all delivered in one single box 😊.



If we then look specifically what you can do about road traffic, which is one major source of reduced air quality, the following actions can be identified, seen from an urban planner point of view.

1. Redirection of traffic is one obvious way to start with, where we reduce the traffic around the hot spots. To what degree that reduce the entire emission of PM_{2.5} needs to be investigated.
2. The usage of newer car models will certainly reduce the amount of emissions. Electrical cars have in principle no emissions of PM_{2.5}. There are also new regulations of engines coming up, such as committing to the Euro 6 standard for fuels.
3. There is also a possibility to establish zones where certain types of vehicles are not allowed to drive.
4. In case thresholds are exceeded, alerts can be sent to travellers, requesting them to take alternative routes or to switch to electrical mode.
5. Planting trees do not reduce the emissions from the traffic, but it has other positive impacts on the air quality.

It should however be noted, that although some solutions exist, there are no standardised way of estimating their overall impact on the air quality, by applying this type of measures.

EEA Air Quality Download Services

Air Quality Programs

 Co-funded by the European Union

EEA Air Quality Download Service

Air Quality Download Service

Filters
Filter to download specific data

Countries:

Cities:

Pollutants:

Datasets:

☒ List of URLs

[Metadata](#)
[Vocabulary](#)
[Documentation](#)

Download Service provides access to air quality measurements time series. You can filter and download the verified data (E1a) reported by countries by 30 September each year for the previous year and the most recent unverified data transmitted continuously (Up To Date/UTD/E2a).

The selected time series will be downloaded as zipped Parquet files. Each file contains a complete time series at a monitor location (Sampling Point), the filename corresponds to the identifier (localid) of the Sampling Point. Verified and UTD time series for the same Sampling Point are provided in separate files.

The measurement start and end time indicated the Parquet files for hourly data and variable (var) measurements are converted to UTC+1 time zone, daily values are instead delivered in the time zone reported by countries. Monitoring site metadata can be downloaded using the metadata link at the bottom of the page. Additional information on data elements presented as controlled codes can be accessed using the vocabulary link at the bottom of this page.

Data extracts are limited to 300MB. If more is needed, please use the "List of URLs" checkbox to download the data afterwards.

Source: <https://discomap.eea.europa.eu/map/fme/AirQualityExport.htm>

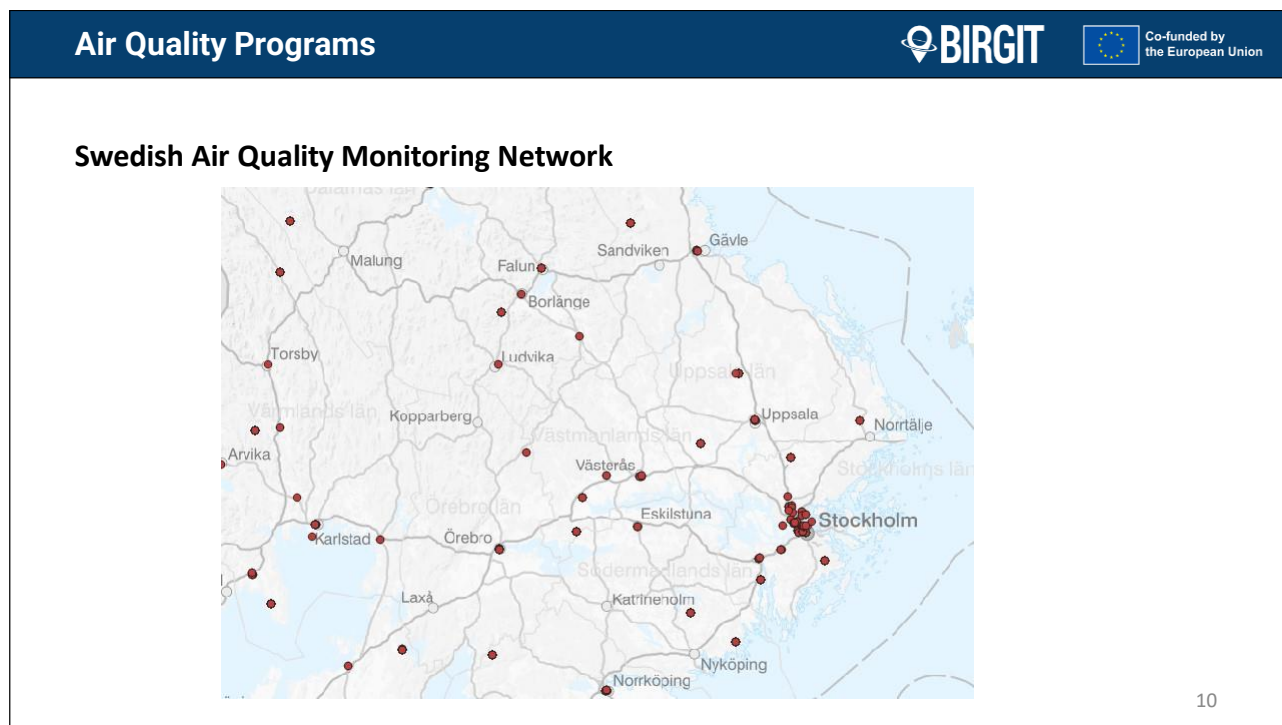
9

- Search for air quality data in any country / larger city
- Data reported by countries by 30 Sept each year
- Data available in Apache Parquet files (open-source file format)

The Air Quality Service provided by the EEA provides a good overall reference for the progression of air quality measurements performed in the EU member states. It is based on the annual reports from the member states and contains for instance detailed daily data from different monitoring stations. Links to data sets are provided in a CSV file, but the daily data is provided through an open source file format named “Parquet”.

These data sets are more suitable for following up the implementation measures carried out by the member states. The data sets are less suitable for smart city or digital twins purposes.

Swedish Air Quality Monitoring Network



According to the Air Quality Directive, each European member state must establish a national network of air quality monitoring stations. The Swedish network is managed by the Swedish Environmental Protection Agency, but it is operated by subcontracting agreements. Anyway, the data from these monitoring stations are made available through OGC WMS, WFS and SWE services. This means that we can monitor the air quality in many Swedish cities in near real-time. However, the density of the sensor network is limited and many cities have only one (or in some cases none) monitoring stations for air quality.



Local initiatives

Air Quality Programs



Case study: City of Bristol

Source: <https://www.smartcitiesworld.net/news/bristol-reports-10-per-cent-improvement-in-air-quality-9811>



- National government directed city of Bristol to reduce NO₂ pollution
 - Cleaner cars reduced fee for entering the inner city
 - Modernized public transportation
- 170 air quality monitoring stations established (off-line)
- After 1 year, 10 – 15 % reduction in NO₂ pollution

11

City of Bristol is an example of how local authorities may address the issue of bad air quality. The city was, by the national government, directed to reduce the NO₂ pollution in the city as fast as possible. This dictate was based on the annual reporting of the air quality.

The city then decided to implement a number of measures, for instance establishing road tolls with reduced fees for cleaner cars and to modernize the public transportation system. In addition, several air quality monitoring stations were established. These stations were however not connected to on-line readings, so they had to be visited one by one.

The air quality measurements showed that the measures being implemented had an effect and that a 10 % reduction in NO₂ pollution could be observed.



References

EC, 2008. 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. <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0050>

EC, 2018. A Europe that protects: Clean Air for All. <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018DC0330>).

EC, 2023. EU Clean Air Policy. https://environment.ec.europa.eu/topics/air_en.

EC, 2024. Directive (EU) 2024/2881 of the European Parliament and of the Council of 23 October 2024 on ambient air quality and cleaner air for Europe. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:L_202402881

EEA, 2022. Sources and emissions of air pollutants in Europe. <https://www.eea.europa.eu/publications/air-quality-in-europe-2022/sources-and-emissions-of-air>

EuroCities, 2022. Hope is in the air (quality). <https://eurocities.eu/wp-content/uploads/2022/04/Eurocities-policy-statement-on-air-quality-AAQ-directives.pdf>

SmartCitiesWorld, 2024 Bristol reports 10 percent improvement in air quality. <https://www.smartcitiesworld.net/news/bristol-reports-10-per-cent-improvement-in-air-quality-9811>

WHO, 2021. Global Air Quality Guidelines. <https://iris.who.int/handle/10665/345334>.