Volume XXVII, 52 – No.1, 2025, DOI: 10.35116/aa.2025.0009

AIR QUALITY AND HEALTH CONDITION

Hélia NÉMETHOVÁ, Jan ZÝKA
Pan-European University, Spálená 76/14, Nové Město, 110 00, Prague, Czech Republic
**Corresponding author.* E-mail: helia.nemethova@peuni.cz

Abstract. Air quality is a hot topic every century, especially today when the traffic density increases and there are more industries and cars in every city. Filters for air cleaning exist, but this is not always enough. Considering all these factors, it is crucial to monitor air quality, which is based on air quality index metrics. Air quality mainly impacts sensitive persons, but if the index metrics reach higher values, the impact can be significant even for healthy people. The most common contaminants are PM 2.5, PM10, and O3. They can primarily damage the lungs, alveoli, airways, and vessels. They can also cause severe allergic reactions and irritation. The level of concentration and health condition depend on it.

Keywords: air pollution, air quality, air quality index, ecosystem, environment

1. INTRODUCTION

Every century, especially nowadays, when the traffic density—air or road traffic—is high, it is essential to monitor air pollution. Air condition is really an actual topic every century. Air pollution can be harmful to our health and significantly impacts the immune system. Some countries and cities have a higher level of air pollution than others. The air can contain a variety of pollutants—for example, a mixture of solid particles (dust, pollens), liquid droplets, gases, smoke, etc. The composition of air pollution can vary greatly, depending on the Earth's surface, ambient air, location, factors regarding traffic density, and many other factors. The quality of the air is closely related to the production of CO2 emissions. CO2 and greenhouse gas emissions impact the ozone layer and climate change. There is a massive discussion between car and airplane emissions. This article also briefly compares the emissions produced in transportation. Based on the environment, we can divide air pollution into indoor and outdoor (ambient air) pollution. Air quality is also closely linked to the global ecosystems and climate of the Earth. This article discusses air quality generally, range of impact on health condition, analyses the type of pollution, and investigates the air quality above the five biggest European cities based on the population from the "World population review" page to 2025—Istanbul, Moscow, Paris, London, Madrid; and above the three central European capital cities—Budapest, Prague, and Bratislava. [1] The second chapter analyzes air quality—the type of air pollutants and their effects on health and the environment. The third chapter discusses about the emission production in transportation – especially in aviation based on the EASA and Eurocontrol reports. The fourth chapter investigates and analyzes air quality above the most populated towns and central European capital cities. The fifth chapter – Discussion, evaluates the inquiry, and the last one concludes. The article mostly uses methods like analysis, comparison, and characterization. Pictures, maps, and tables are used for better understanding and visualization.

2. AIR POLLUTION AND QUALITY OF THE AIR: AN OVERVIEW

The EPA – United States Environmental Protection Agency sets National Ambient Air Quality Standards for six common air pollutants - known as *"criteria pollutants"*:

- **ground-level ozone (O3)**
- **particle pollution/ particulate matter (PM10 and PM2.5)**

- **carbon monoxide (CO)**
- **sulphur dioxide (SO2)**
- **nitrogen dioxide (NO2)**
- **lead**

These pollutants are found all over the world. They are harmful to humans and the environment and can cause property damage. Ground-level ozone and particle pollution are the most widespread health threats. [2]

2.1. Ground-level ozone

Generally, ozone is a gas composed of 3 atoms of oxygen and occurs in the Earth´s upper atmosphere – stratosphere, but at ground level too. The stratospheric ozone is a protective layer and shield from the ultraviolet rays. Ground-level ozone is harmful and belongs to the most common and detrimental air pollutant. The ground-level ozone is created by chemical reactions between NOx (nitrogen oxides – nitric oxide (NO) and nitrogen dioxide (NO2), mainly formed during the combustion of fossil fuels) and VOC (volatile organic compounds). The contributing factors for formation are sunlight and heat (see Figure 1). [2]

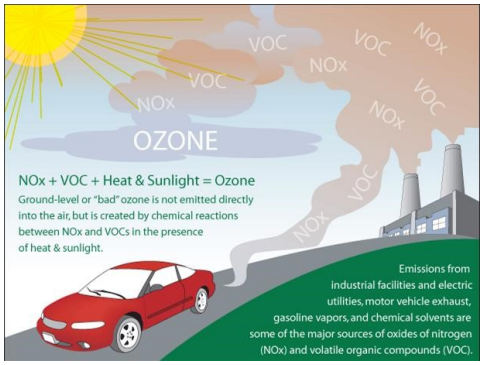


Figure 1 Ground-level ozone formation [2]

The ground-level ozone has an impact on the environment. It can affect fauna, flora–sensitive vegetation, and the ecosystem. The most sensitive plant species are black cherry, quaking aspen, tulip poplar, white pine, ponderosa pine, and red alder. The most harmful effects on these plants are:

- reducing photosynthesis
- slowing the plant´s growth
- increase the risk of diseases, damage from insects.

Due to the above-mentioned facts, it has the following effect on the ecosystem:

- changes to the specific assortment of plant species
- changes to habitat quality and water, nutrient cycles. [2]

People with asthma and a weak immune system are the risky groups. Depending on the level of O3 pollution and exposure, the primary and most frequent health problems that can occur are the following:

- coughing and scratchy throat
- difficult to breathe deeply, which can cause pain during breathing
- inflame and damage the airways – can cause the muscles to constrict and trap air in the alveoli, which leads to shortness of breath emphysema), and then hyperventilation (see figure 2)
- lung infections, diseases, asthma, allergic reaction, chronic bronchitis [2]

These effects can even be in healthy people, but these effects can be severe in people with health problems – asthma, allergic and immune system issues.

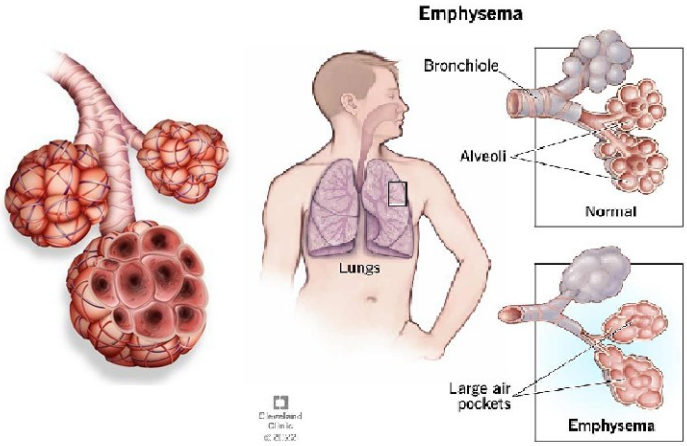


Figure 2 Emphysema [2,3]

2.2. Particle pollution/ particulate matter (PM10 and PM2.5)

PMs are tiny solid particles and liquid droplets in the air. It can include nitrates, sulfates, metals, organic chemicals, soil or dust, and allergens (fragments of pollen or mold spores). They have short-term and long-term effects on health. Short-term exposure—duration: hours and days—can cause irritated eyes, nose, and throat, asthma, lung diseases, chronic bronchitis (chronic obstructive pulmonary diseases—COPD), heart attacks, arrhythmias, respiratory problems, cardiovascular issues, and skin irritation. The long-term exposure – duration: years – reduced lung function, cardiovascular and respiratory diseases, functional problems, increased rate of disease progression, alveoli damage, eye irritation (inflammation, katarakta), skin irritation, and allergic reaction.

Based on the size of the particles, we can divide them into PM10 and PM2.5:

- **PM10** particles with a diameter of less than 10 micrometers can pass through the throat and nose and enter the lungs. They mainly affect the heart and lungs.
- **PM2.5** particles with a diameter of less than 2.5 micrometers are tiny and can penetrate the lungs, airways, heart, and bloodstream. Many times, PM10 also includes PM2.5. [4]

2.3. Carbon monoxide (CO)

CO is a poisonous gas that we can´t see, smell, or taste. It arises during engine exhausts (car, boat, or aviation). Barbeques, charcoal briquettes, outdoor heaters, gas lanterns, tools with gasoline engines, and portable generators are common sources of CO.

Symptoms of CO poisoning are the following:

- headache
- nausea
- stomach pain, vomiting
- weakness, dizziness
- fainting, confusion, tiredness
- loss of consciousness
- seizure
- permanent brain injury
- in several cases death. [4]

2.4. Sulphur dioxide (SO2)

SO2 is a highly reactive gas, formed by fossil fuel combustion at industrial facilities, naturally during volcanic eruptions.

Sulphur dioxides:
- irritate the lining of the nose, throat
- expand existing respiratory illnesses like asthma or allergic reaction
- exacerbate the cardiovascular diseases
- narrowing of the airways, which leads to shortness of breath, and due to this may occur hyperventilation, which can lead to headache and loss of consciousness
- can cause asthma attacks.

2.5. Nitrogen dioxide (NO2)

NO2, like SO2, is a highly reactive gas formed by emissions from motor vehicles and industry. A high concentration can be found near highways and roads, but indoor sources like cigarette smoke can also produce it. NO2 contributes to the formation of O3.

Nitrogen dioxide is a respiratory irritant. It increases lung infection in people with asthma, worsens asthma symptoms (causing more frequent asthma attacks), and can cause airway inflammation.

2.6. Lead

Lead emission varies greatly by location and area. The major sources are metals and ore processing, piston-engine aircraft operating, and manufacturers.

Lead has a serious impact on the human body and health. Blood distributes lead through the body to the bones, where it accumulates and can cause severe issues depending on the level of exposure.
It can affect the nervous system, kidney function, immune system, reproductive organs, and cardiovascular system. It mainly affects the blood's oxygen capacity—it has a higher linkage to haemoglobin than to oxygen. The haemoglobin transfers less oxygen, which can lead to hypoxia and blood intoxication.

All the above-mentioned pollutants have a big impact on health, mainly on the cardiovascular and immune systems, asthma, and lungs. It is important to monitor the level of air conditioning in different countries. Due to the fact that this is an actual, relevant topic and has a high level of importance, there are many articles with similar topics, like:

- "Gaps and future direction in research on health effects of air pollution" [8]
- "Clearing the air: A systematic review of studies on air pollution and childhood brain outcomes to mobilize policy change" [9]
- "Review of scientific research on air quality and environmental health risk and impact for PICTS" [10]

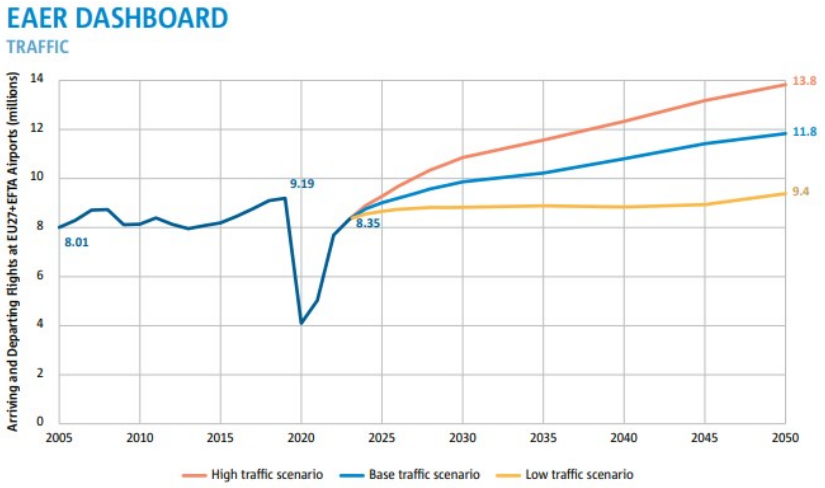
3. EMISSION PRODUCTION

CO2 emissions from transportation are also a key contributing factor to air quality degradation. Cars and planes produce the most CO2, which enhances greenhouse effects and causes health problems.

Based on the Eurocontrol and EASA data analysis, CO2 emissions come from just 6% of flights (most of them long-haul flights). The production of CO2 emissions also depends on other factors like aircraft type, flight duration, meteorological conditions, airports, flight routes, FL, operational procedures, delays, and unexpected operation limitations.

"Along with all other economic sectors, aviation finds itself at a crossroads in its decarbonisation transition with increasing pressure to deliver against agreed environmental goals and challenges due to supply chain issues delaying fleet renewal as well as the premium price of Sustainable Aviation Fuel and limited production capacity." [11]

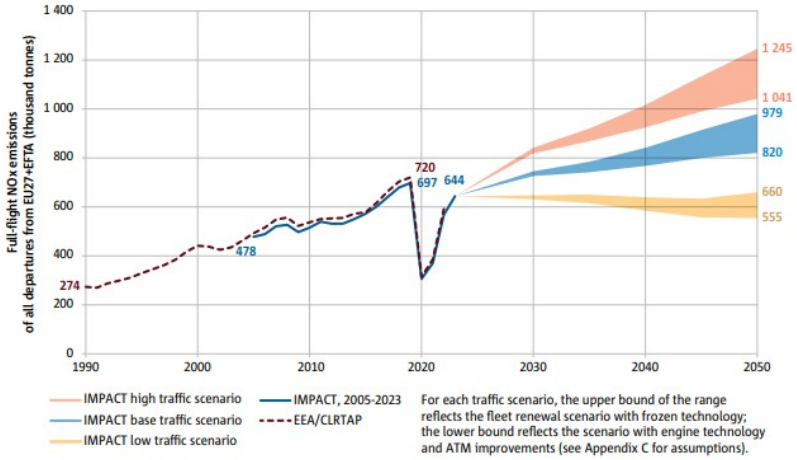
The 4th European Aviation Environmental Report provides information and an overview about current progress and the situation related to emission production and flight numbers (see Figures 3 and 4).



Indicator	Units	2005	2019	2023	2030[3]
Number of flights[4]	million	8.01	9.19	8.35	9.9
Passenger kilometres[5]	billion	777	1 459	1 375	1 683
Number of city pairs served most weeks by scheduled flight		5 368	7 991	7 695	N/A

[3] Base traffic scenario
[4] All departures and arrivals in EU27+EFTA.
[5] All departures from EU27+EFTA.

Figure 3 ARR and DEP flights indicator [11]



Indicator[9]	Units	2005	2019	2023	2030
Full-flight CO_2 emissions[10]	million tonnes	109	147	133	144
Full-flight 'net' CO_2 emissions[11]	million tonnes	109	114	108	139
Full flight NO_x emissions[10]	thousand tonnes	478	697	644	726
Average fuel consumption[10]	litres fuel per 100 passenger kilometre	4.8	3.5	3.3	2.9

Figure 4 Full-flight CO_2 emission [11]

Figure 3 demonstrates the flight number (DEP and ARR) overview in 2005, 2019, and 2023, and a forecast for 2030. Figure 4 reflects the CO2 emissions.

The graph is divided into three base scenario impacts: high traffic scenario, base traffic scenario, and low traffic scenario. In 2023, the full-flight net CO2 emission was 108 million tonnes, the lowest among the three analysed years—2005, 2019, and 2023. However, for 2030, the expectation is that emissions production will rise. [11]

According to the EASA report, the average mass of CO2/PAX km was reduced to 83 grams in 2023, which is equivalent to 3.3 l of fuel per 100 PAX km. “In 2023, flights departing from EU27+EFTA AD emitted 133 million tonnes CO_2, which is 10% less than in 2019.” [11]

Eurocontrol states in the report:

“Meeting the ReFuelEU Aviation supply mandate for sustainable aviation fuels could the net CO_2 emission by at least 65 million tonnes (47%) in 2050.” [11]

Based on the facts and analysis from the EASA report, NOx emissions have grown faster than CO2 emissions in aviation since 2005, and there is an expectation that this trend will continue without further improvement in engine technology. [11]

4. AIR QUALITY MONITOR IN REAL-TIME

This section discusses real-time air quality index and shows in tables the values and levels of air quality based on the World Air Quality Index and Air Quality Scale, available on page “Waqi – World´s Air Pollution: Real – time Air Quality Index”. [5]

The Air Quality Index (AQI) measures the six types of air pollutants – PM2.5, PM10; O3; NO2; SO2; and CO. All measurements are based on hourly readings: for example AQI report at 10 AM means that the measurement was from 9 AM to 10 AM. The AQI scale is for indexing the real-time pollution on the map, and it is based on the US EPA standard.

The AQI scale is in Table 1.

AQI	*Air Pollution Level*	*Health Implications*	*Cautionary Statement (for PM2.5)*
0-50	Good	Air quality is considered satisfactory, and air pollution poses little or no risk	None
51-100	Moderate	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.	Active children and adults, people with respiratory diseases, such as asthma, should limit prolonged outdoor exertion.
101-150	Unhealthy for Sensitive Groups		Members of sensitive groups may experience health effects. The general public is not likely to be affected. Active children and adults, people with respiratory diseases, such as asthma, should limit prolonged outdoor exertion.
151-200	Unhealthy		Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects. Active children and adults, people with respiratory diseases, such as asthma, should limit prolonged outdoor exertion. Everyone else, especially children, should limit prolonged outdoor extertion.
201-300	Very Unhealthy	Health warnings of emergency conditions. The entire population is more likely to be affected.	Active children and adults, people with respiratory diseases, such as asthma, should avoid all outdoor exertion; everyone else, especially children, should limit outdoor exertion.

300+	Hazardous	Health alert: everyone may experience more serious health effects.	Everyone should avoid all outdoor exertion.

Table 1 AQI scale [5]

The following Figures and Tables show the situation worldwide in April between the 15th and 16th of April and compare the min and max values. **On the 16th of April**, at 16:00 UTC hour, the real-time situation is the following (see Figure 5):

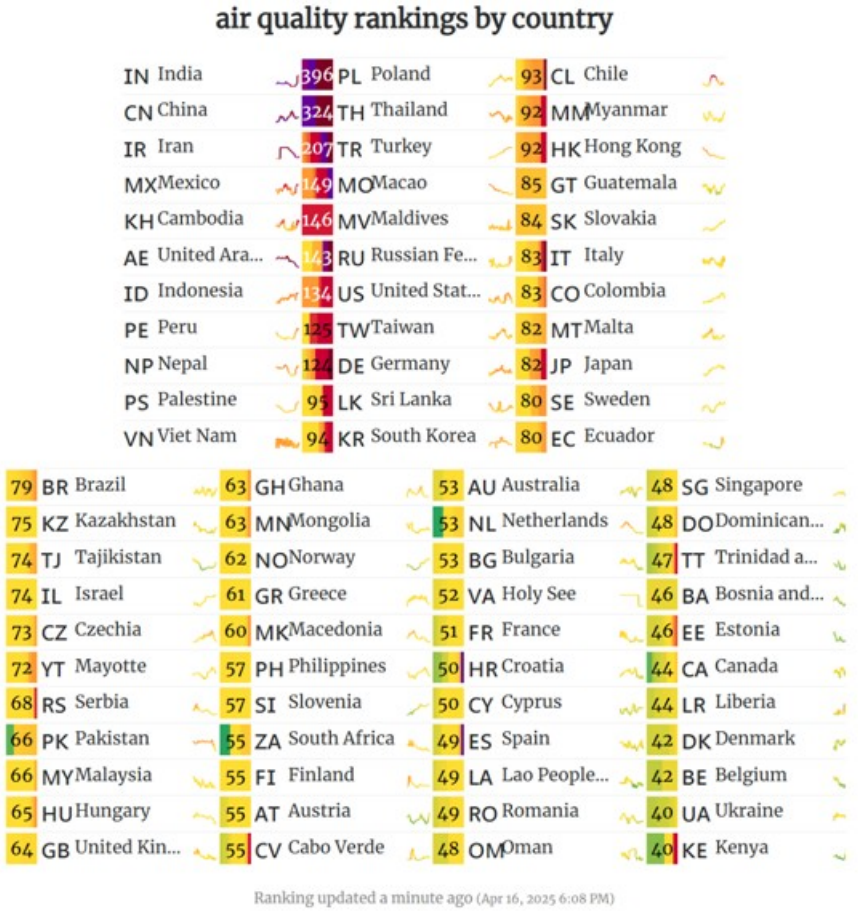


Figure 5 AQI rankings by country [5]

Figure 6 shows that the worst air quality is in India (divided into districts in India – see Figure 6) where the AQI on the AQI scale is between 200 +.

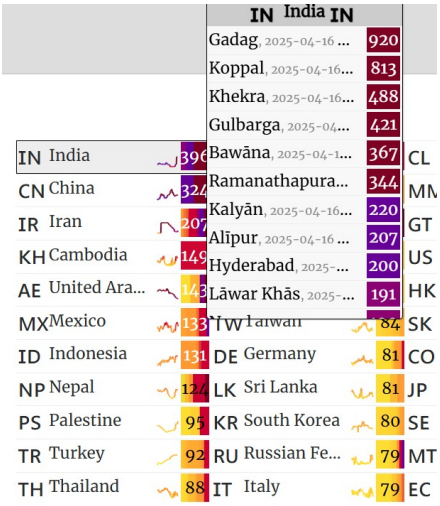


Figure 6 AQI index in India [5]

Figure 7 describes the real-time AQI situation monitored **at 16:30 UTC on the 16th of April (the last uptades are in LOC time zones)**. The cities were chosen based on the World Population Review page – the five most dense European cities:

- Istanbul with population 16 236 700
- Moscow – 12 737 400
- Paris – 11 346 800
- London – 9 840 740
- Madrid – 6 810 530

The last three cities are the capitals of the central European states – Hungary (Budapest with 1 782 240 population), Czech Republic (Prague with 1 353 296 population), and Slovakia (Bratislava with 443 679 population). Air quality is deeply related to the city´s population density because industries and traffic can negatively impact air quality. Figure 5 shows values related to air quality from 15 April to 16 April. It shows a real-time air quality index, temperature, air pressure, humidity, and wind dates, and information about pollutants with maximum and minimum values. All cities have an AQI index green – Good, and there is no cautionary statement.

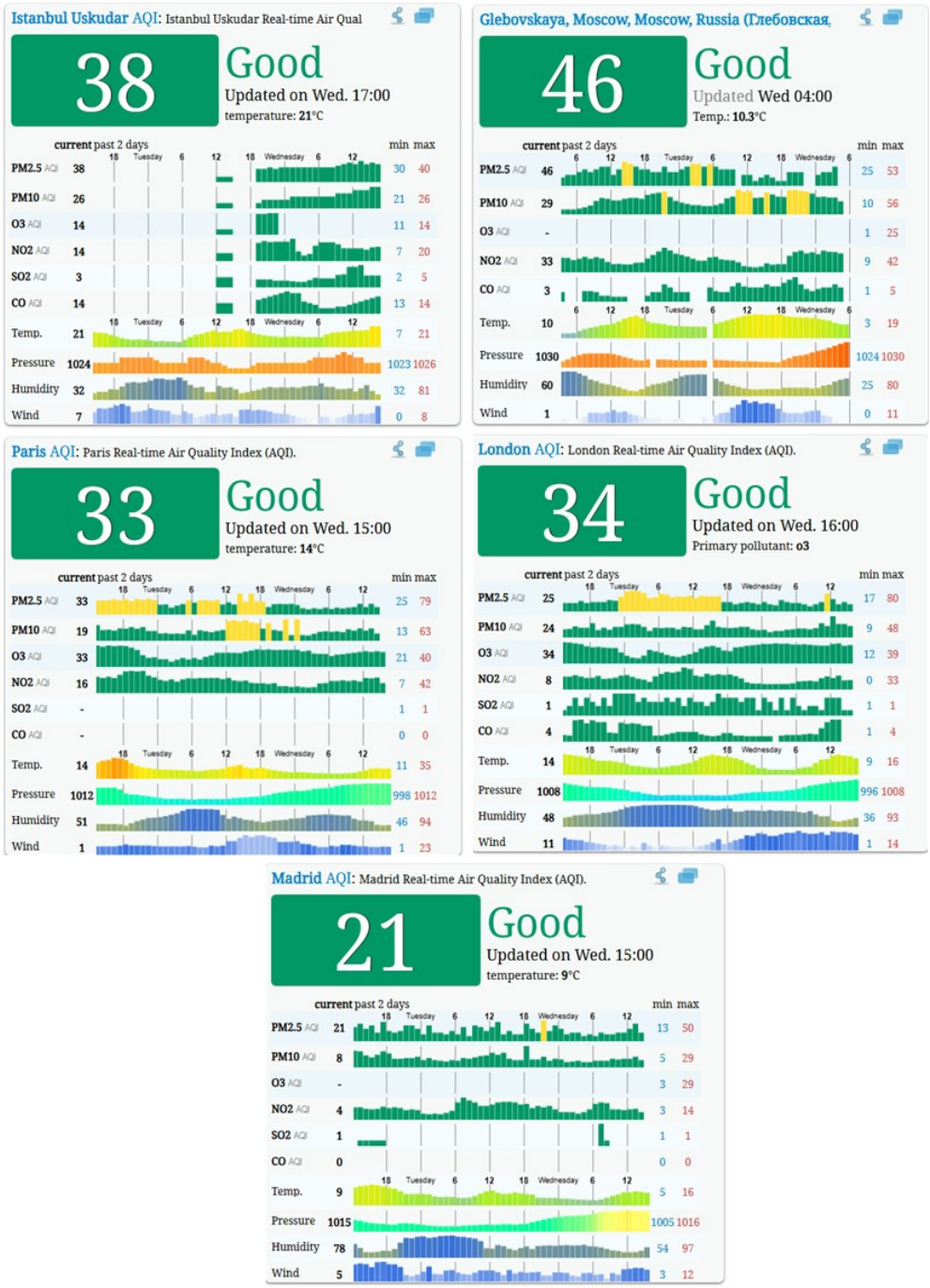


Figure 7 AQI index – Istanbul, Moscow, Paris, London, Madrid [5]

Figure 8 describes the real-time AQI index in central European capitals **between 16:00 and 17:00 UTC on April 16th (the last updates are in LOC time)**. Of the three cities—Budapest (Hungary), Prague (Czech Republic), and Bratislava (Slovakia)—Prague has the worst air quality index at this date. The second row is the air quality forecast for the next four days. The information is from the observation station for all cities, which had the worst values and AQI index—where the pollutant concentration is the highest.

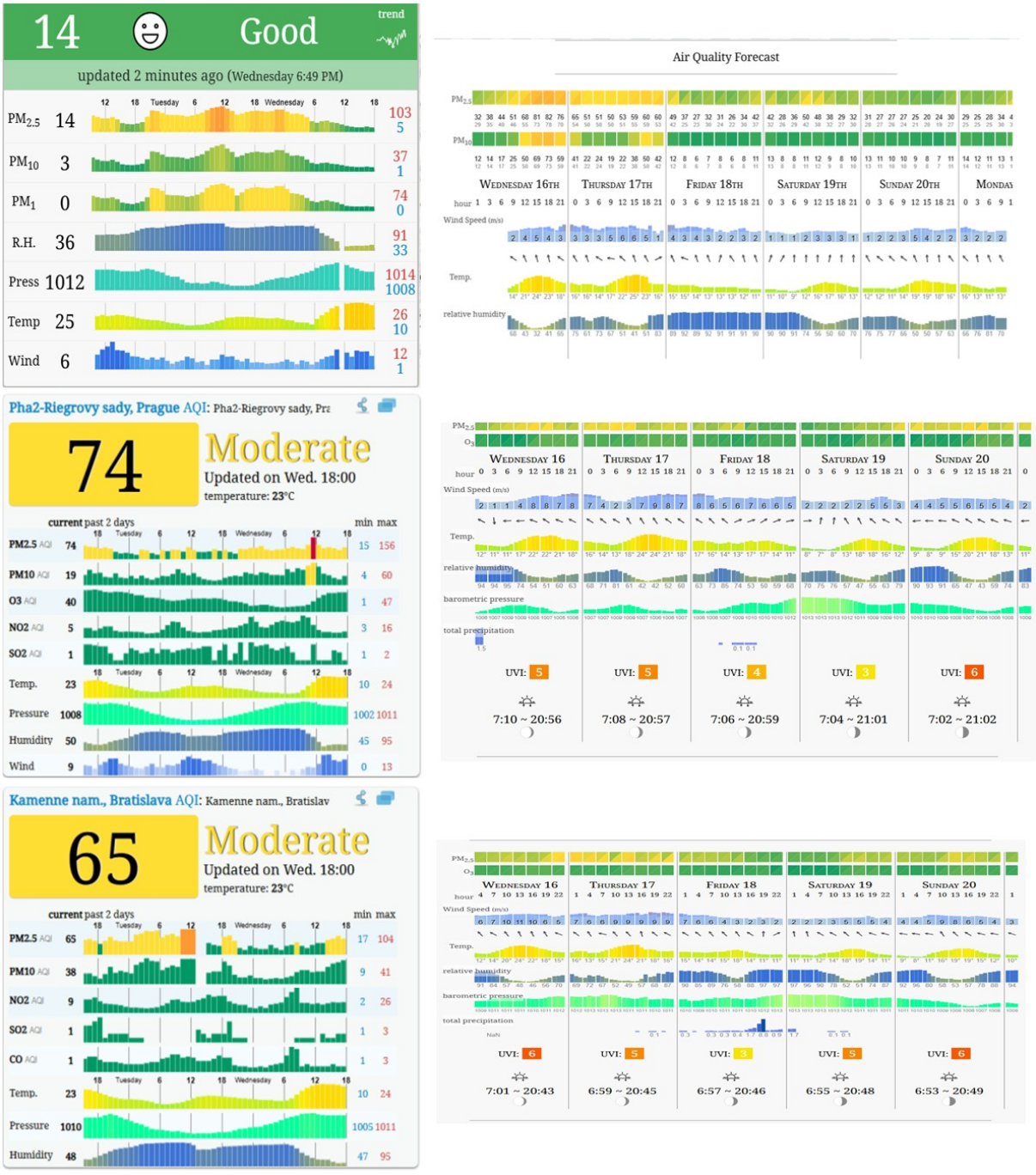


Figure 8 AQI index and forecast – Budapest, Prague, Bratislava [5]

Prague and Bratislava are in the yellow category, which means that there are cautionary statements (see AQI index scale – Table 1). In Prague, the AQI index is 74. Most of the pollutant types are PM2.5 with maximal values 156. The maximum value is 156, which belongs to the 4th category (red) – unhealthy air pollution level. The cautionary statement for PM 2.5 is for everyone – should limit outdoor activities or wear a mask. In Bratislava, the maximum value is 104 for PM 2.5. This value belongs to the orange category – unhealthy for sensitive groups. Generally, for healthy people, it shouldn´t be a threat. In all cases, the prevailing contaminants are PM2.5 and PM10.

5. DISCUSSION

In Chapter 4, based on the actual values related to 16th April, Prague and Bratislava were the most polluted cities of the eight monitored towns on this day. Both are located in central Europe. The values can vary daily, but the actual day monitoring is essential for health care. Air quality monitoring is essential for planning outdoor activities, sports activities, and vacations. If someone suffers from severe allergic reaction or asthma, there is a possibility of changing location or taking part in a vacation abroad where the air quality is at a green level. Good. The air quality often depends on the prevailing wind, precipitation, and meteorological conditions at this location. There may be no industries around the place, and the area is in the forest. Nevertheless, the air quality is bad. It is often caused by wind or meteorological conditions, where particles blow from distances. Air pollution can be caused by humans (most frequent cases), natural bushfires or forest fires, and volcanic activity (for example, Etna). Air pollution caused by humans is permanent and can be more dangerous than natural. Natural causes have lasted for weeks, but human causes (industries, cars, engines, etc.) have lasted for years, leading to permanent air pollution. The last figure (Figure 9) demonstrates the low air quality above Europe on the map (at 17.04.2025, 15:00 UTC hour).

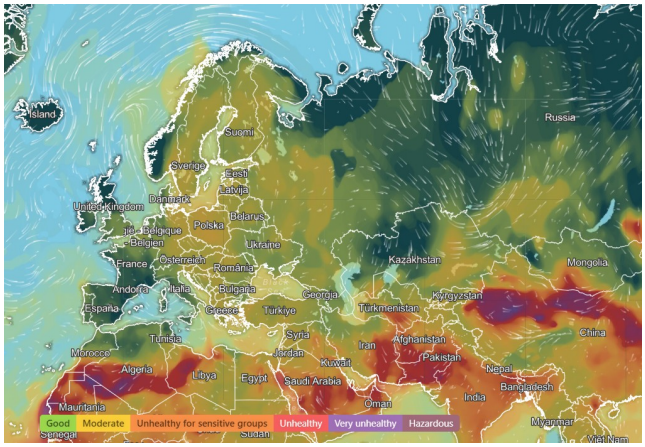


Figure 9 AQI map above Europe at 17.04.2025, 15:00 UTC [6]

6. CONCLUSION

Air pollution is a global problem. Tiny invisible particles in the air are dangerous not only for sensitive people, but the high concentration is harmful for healthy people, too. The tiny droplets enter our bloodstream, penetrating our cells and organs, and can damage the lungs, heart, and brain. This can lead to severe diseases and health issues. The level of contamination differs depending on the country, location, the number of industries around, and the meteorological conditions. The location, such as a basin, mountains, or beach, can often be significant. Meteorologically, wind is the factor that contributes the most to spreading air and its pollutants. If industries and dense towns are near the location, the wind can blow the pollutants into the air for long distances. It causes decreasing air quality in locations where there could be clear air. Bushfires or volcanic activities are the most common natural threat to air quality. Page "Clean air fund" states, that: "8.1 million premature deaths annually are attributed to air pollution – that is more than tobacco smoking. It´s the second leading cause of premature deaths worldwide, primarily due to non-communicable diseases. Air pollution is also the second biggest cause of death of children under five, after malnutrition." [7]

The above statement confirms that this topic is highly actual and often underrated. People who live in highly contaminated areas have a greater risk of severe respiratory diseases, asthma, allergies, chronic obstructive pulmonary disease (COPD), infection, eye irritation and inflammation, pneumonia, and many others.

The easiest ways to improve air quality are:

- to reduce pollutants by the fact that installing air filtration,
- to plant trees
- to reduce the felling of trees
- to care more about global climate change, which increases the concentration of CO2 and ozone damage.

Figure 10 demonstrates how wind and bushfires badly affect air quality. We can see that low air quality is above the continents and deserts or where the ozone layer is thicker, but better air conditions are above the oceans, forests, and low-density areas.

A

B

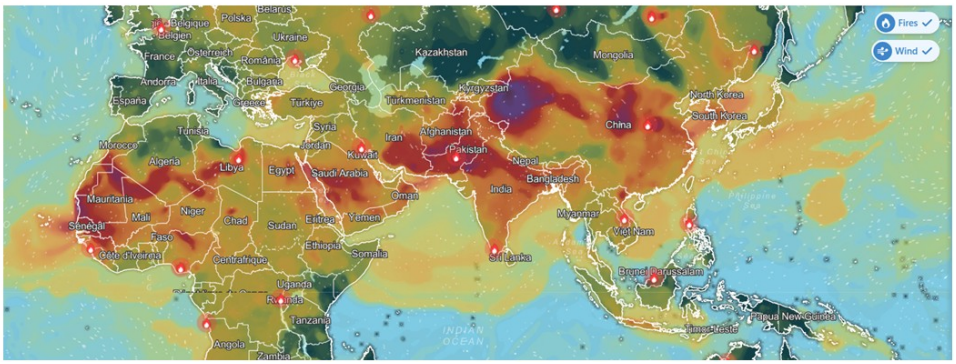


Figure 10 AQI map at 18.04.2025, 09:00 UTC [6]

7. LITERATURE LIST

References

Websites:

[1] *World population review*. European Cities by Population 2025. Available at: https://worldpopulationreview.com/cities/continent/europe

[2] *EPA United States Environmental Protection Agency*. 2025. Available at: https://www.epa.gov/air-quality-management-process/managing-air-quality-air-pollutant-types ,

[3] *Cleveland Clinic*. Emphysema. 2025. Available at: https://my.clevelandclinic.org/health/diseases/9370-emphysema

[4] *NSW Government* – NSW Health. Particulate matter (PM10 and PM2.5). 2025. Available at: https://www.health.nsw.gov.au/environment/air/Pages/particulate-matter.aspx
https://www.health.nsw.gov.au/environment/Pages/copoisoning.aspx

[5] *WAQI*. World´s Air Pollution: Real-time Air Quality Index. 2025. Available at: https://waqi.info/#/c/4.18/8.145/2.2z,
https://aqicn.org/city/turkey/istanbul/uskudar/mthm,

[6] *IQAir*. Switzerland. 2025. Available at: https://www.iqair.com/air-quality-map

[7] *Clean Air Fund*. London. 2025. Available at: https://www.cleanairfund.org/theme/health/?gad_source=1&gbraid=0AAAAAo23RUcB1VL10h9Is9Xv9Xp0tQe35&gclid=EAIaIQobChMIion35pDhjAMVDqODBx0BwwNAEAAYASAAEgLU5_D_BwE

Journals:
[8] Ruzmyn Vilcassim,George D. Thurston. Gaps and future directions in research on health effects of airpollution. *eBioMedicine.* 2023. Vol. 93. July.
[https://www.sciencedirect.com/science/article/pii/S2352396423002335]
[9] Anna M. Parenteau § et al. Clearing the air: A systematic review of studies on air pollution and childhood brain outcomes to mobilize policy change. *Developmental Cognitive Neuroscience.* 2024. Vol. 69. October. [https://www.sciencedirect.com/science/article/pii/S1878929324000975]
[10] Hilly J.J. & et al. Review of scientific research on air quality and environmental health risk and impact for PICTS. *Science of the Total Environment.* 2024. Vol. 942. No. 10 September.
[https://www.sciencedirect.com/science/article/pii/S0048969724037756]
[11] EASA § Eurocontrol – European Aviation Environmental Report 2025. European Environment Agency; ISBN 978-92-9210-26-9
[https://www.eurocontrol.int/publication/european-aviation-environmental-report-2025]

Received 05, 2025, accepted 06, 2025