Assessment of the State Air Quality Monitoring in Georgia

Mgr. **Jáchym Brzezina**, Ph.D.
Head of Air Quality Department
Czech Hydrometeorological Institute

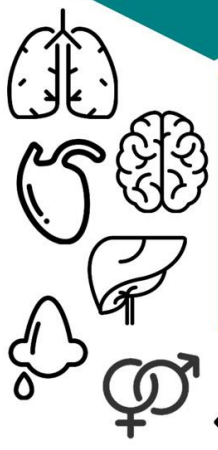
Czech Hydrometeorological Institute

ARNIKA

Importance of Air Quality

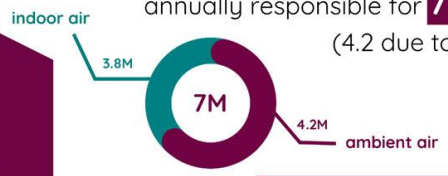
- Air quality is something everyone should be paying attention to.
- Most of the global population breaths air quality of which does not satisfy the recommendations from the World Health Organization (WHO).
- Air pollution is currently considered the world´s most important environmental threat, responsible for approximately 7 million annual premature deaths globally.

Why is air quality important?



Poor air quality has various negative impacts on many organs in the human body.

World Health Organization estimates that poor air quality is annually responsible for **7 million premature deaths** (4.2 due to poor ambient air quality, 3.8 million due to poor indoor air quality).



Approximately **91 % of global population** breathes air, in which concentration of at least one pollutant exceeds the World Health Organization recommended maximum value.

smog in Beijing (China)
Source: Lintao Zhang

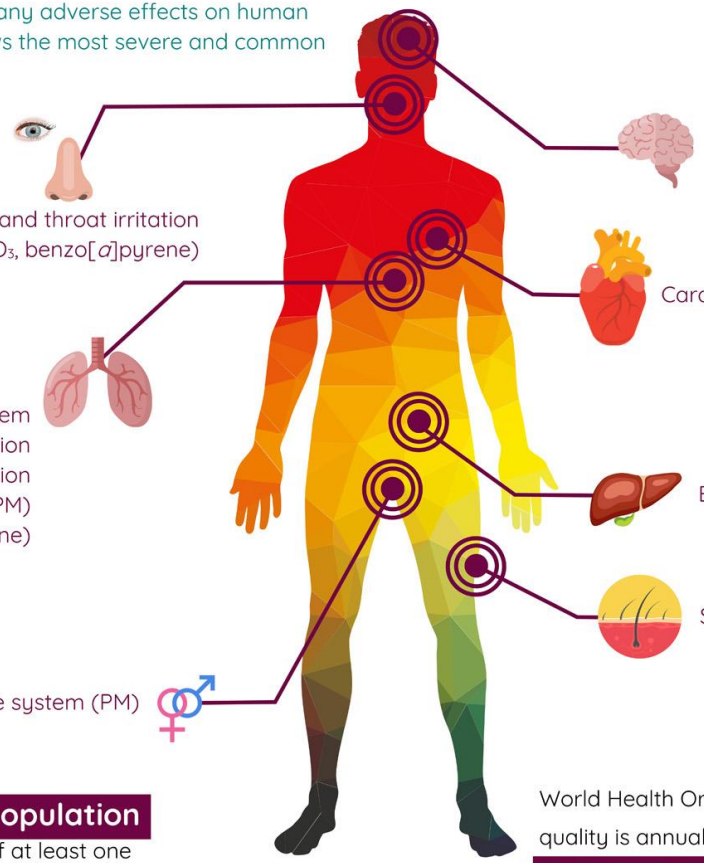
Concentration of at least one pollutant exceeds the limit values at **65.5 %** of total area of the Czech Republic (66 % of total population).

Regions where air quality limit values were exceeded in 2020.

Source: WHO, Commonwealth, UNICEF, ČHMÚ, EEA

Air pollution and human health

Poor air quality can have many adverse effects on human health. Diagram below shows the most severe and common ones.



Eye, nose and throat irritation
Breathing problems (PM, NO_2, SO_2, O_3, benzo[σ]pyrene)

Headache and anxiety (SO_2)
Effect on central nervous system (PM)

Cardiovascular diseases (PM, SO_2, O_3)

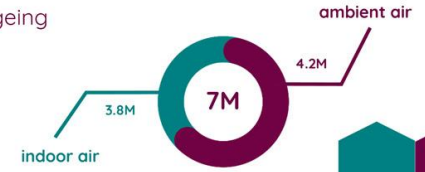
Effect on respiratory system
Irritation, inflammation and infection
Asthma and reduced lung function
Chronic obstructive lung disease (PM)
Lung cancer (PM, benzo[σ]pyrene)

Effects on liver, spleen and blood

Skin ageing

Effect on reproductive system (PM)

Approximately **91 % of global population** breathes air, in which concentration of at least one pollutant exceeds the World Health Organization recommended maximum value.



World Health Organization estimates that poor air quality is annually responsible for **7 million premature deaths** (4.2 due to poor ambient air quality, 3.8 million due to poor indoor air quality).

Sources: EEA, ERS/ATS, WHO

What to do during a smog situation?

A **smog situation** is a state of short-term significant air pollution. In this particular case, concentrations of PM_{10} particles, sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and ground-level ozone (O_3) are monitored for this purpose in the Czech Republic.

A smog situation is declared when the conditions for the declaration are met. This includes both area-wide nature of the pollution and for example in the case of PM_{10} particles the fact that the weather forecast does not make it likely that the situation will get better in the upcoming hours.

If the concentrations of pollutants are significantly higher than the threshold values for declaring a smog situation, a state of even greater pollution may be declared. In the case of PM_{10}, SO_2 and NO_2 this state is called **regulation**, for ground-level ozone a **warning**.

Nowadays, smog situations in the Czech Republic are only declared due to high concentrations of **PM_{10}** (winter smog, mostly at very low temperatures and poor dispersion conditions) or **ground-level ozone** (summer smog, on very hot, clear days). SO_2 and NO_2 concentrations no longer reach the values for declaring a smog situation in the long term.

Smog situations **do not pose an immediate threat to life!** Nevertheless, especially individuals belonging to a group of **more sensitive individuals** should follow some **recommendations** in order to **minimize** any **health complications**.

Who is a sensitive individual?

Children
Children including **infants**.

Pregnant
Sensitive individuals are not just **pregnant women**, but also the **developing fetus.**

Elderly

Chronically ill
Individuals with chronic diseases, especially of the **respiratory** and/or **cardiovascular system** (asthmatics, patients with chronic obstructive pulmonary disease etc.)

Acutely ill
Individuals **acutely ill** or shortly **after being ill**, who are temporarily weakened.

Particularly when the air quality is poor **aim to reduce pollutant emissions**. For example, take public transport instead of car and do not make open fires.

Recommendations for higher levels of air pollution

Limit your stay outdoors
You can still go outdoors (shopping, to school etc) even when pollutant concentrations are higher. However, you should try to minimize the time spent outdoors. Also consider the time of the day you go outside. When ground-level ozone concentrations are high, levels tend to be highest in the afternoon and evening. For the PM particles, highest concentrations tend to be observed during peak traffic and when people heat (morning, evening).

Reduce physical activity outdoors
Increased physical activity leads to more intense breathing, which is not desirable during poor air quality.

Ventilate briefly and intensively
There are a number of air pollution sources indoors as well and thus it is not uncommon for the air quality to be worse inside than outside. Therefore, ventilate even during elevated concentrations of pollutants outdoors! However, ventilate only briefly, but intensively. Ideally 3 to 4 times a day.

Reduce polluting the air indoors
Since prolonged ventilation is not desirable, limit indoor pollution by for example avoiding painting, varnishing, smoking etc. indoors.

Initiate treatment early and be prepared
If you experience difficulties or deterioration of your health, initiate treatment as soon as possible. Chronically ill patients who know that they are particularly sensitive to higher levels of air pollution should carry medicals with them.

Jáchym Brzezina | 2023 @jachym | www.infoviz.cz | version 1.0

Air Quality - Important aspects

- Ambient air quality station network
- Legislation
- Analysis
- Assessment
- Publication

Ambient air quality monitoring stations in Georgia

- Ambient air quality monitoring in Georgia is carried out by the National Environment Agency of the Ministry of Environmental Protection and Agriculture of Georgia
- 2014 – only one modern automated station in operation (in Tbilisi) + 3 outdated non-automated stations (also in Tbilisi)
- 2014-2017 – replacement with stations fulfiling EU standards.
  - Passive sampling in 20 municipalities
  - 4 modern fully automated stations (Tbilisi, Kutaisi, Batumi)
- 2021 – seven stationary automated stations

Air pollutants

- Particles PM_{10}, $PM_{2.5}$
- Nitrogen dioxide (NO_2)
- Sulfur dioxide (SO_2)
- Carbon monoxide (CO)
- Ground-level ozone (O_3)
- Benzo[a]pyrene (BaP)
- Heavy metals (As, Ni, Cd, Pb)
- Benzene

Meteorological parameters

Especially:

- Wind speed
- Wind direction
- Air temperature

Only available from Georgian meteorological stations – not directly measured at the ambient air quality monitoring stations.

Effect of meteorological conditions on air quality

Air quality is not only determined by the amount of emissions as such, but also by other factors. One of the most important is **meteorological and dispersion conditions**, which can have a very significant and, in some situations, dominant effect on air quality. Meteorological and dispersion conditions also tend to be the main source of **inter-annual variability** in air pollution levels.

Wind speed

Wind speed has a **very significant effect** on air quality. In general, higher wind speed contributes to lower air pollution because air pollutant disperse in the atmosphere at a greater extent upon being emitted from its source and do not accumulate.

Under some specific situations the effect of wind speed can be opposite. An example of such a situation is a wildfire or construction work – at higher wind speeds the **resuspension** of particles is more intense and they spread to the surrounding.

Precipitation

Precipitation, both liquid (eg. rain) and solid (eg. snow), has a very **positive effect** on air pollution. Especially during and after a heavy precipitation event, air pollutant concentrations tend to be low. This is due to the **washout effect** of the rainfall.

Wind direction

Wind direction determines in which direction the air pollutants will be **transported from its source**. A poor air quality at a particular place can be caused by even a very distant source and manifests itself when the wind blows in the direction from that source.

Air pollutants **can be transported thousands of kilometers** in the atmosphere. An example of such long-range transport is the Saharan dust, which can at times be detected in Europe, but also other examples of transboundary transport.

Air temperature

Air temperature has both a **direct and an indirect effect** on air quality.

The direct effect is related to the **vertical temperature gradient of the atmosphere** in the ground layer. Under normal conditions, the air temperature decreases with increasing height in this layer. The warmer air near the surface therefore naturally rises upwards and air pollutants do not accumulate near the ground. Under certain conditions (most often in the winter), a layer of warmer air, called an **inversion layer**, forms at a certain height above the surface. Now the air below this layer is cooler and therefore does not rise. Dispersion is limited and **pollution accumulates** near the ground.

The indirect effect of air temperature is the **effect on air pollution sources**. Often a very important source of pollution is heating. Cold temperatures mean higher heating intensity and thus higher emissions from heating. Air temperature also influences other sources – eg. higher emissions from vehicles during cold starts.

Solar radiation intensity

Solar radiation intensity affects **ground-level ozone concentrations**. This pollutant does not have a direct source and is only formed by reactions in the atmosphere. These reactions are known as **photochemical reactions** - they are catalyzed by sunlight. The highest concentrations of ground-level ozone are therefore observed during hot, sunny summer days with high air temperatures. It is under these conditions that the reactions giving rise to ground-level ozone are most intense.

In winter, sunlight can have a positive effect on the quality of air because it warms surfaces and can reduce the need for heating.

Example: February 2020

February 2020 is a good example of the effect of meteorological conditions on air quality. In fact, air quality this month was exceptionally good, thanks to a combination of several factors.

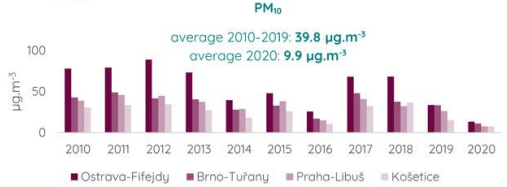
The average temperature in the Czech Republic in February 2020 was 3.7 °C, while the long-term average for 1981-2010 is -0.9 °C. A deviation of more than 4.5 °C is exceptionally high.

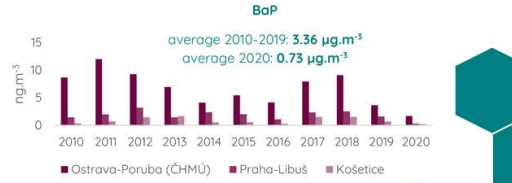
In the Czech Republic, the average rainfall in February 2020 was 78 mm, whereas in the 1981-2010 period it was only 38% - less than half.

The Czech Republic experienced two storms in February 2020 and overall it was a relatively windy month.

High temperatures, abundant rainfall and windy conditions are factors that each on their own generally contribute to good air quality. Pollutant concentrations (with the exception of ozone) tend to be highest during the winter months. In February 2020, concentrations of various pollutants at a number of stations were nearly or quite at summer month levels.

The graphs show the average February concentrations of PM_{10} particles and benzo[α]pyrene at selected stations.





Concentrations at stations in February 2020 were often tens of percent lower than the February 2010-2019 average. This improvement is due to the influence of meteorological and dispersion conditions.

Data source: CHMI

Stations in May 2023

- Batumi (BTUM) – traffic station
- Tbilisi (TSRT) – traffic station
- Tbilisi (KZBG) – traffic station
- Tbilisi (VRKT) – traffic station
- Tbilisi (AGMS) – background station
- Rustavi (RST18) – background station
- Kutaisi (KUTS) – traffic station

Stations in May 2023

- 4 stations located in the capital of Tbilisi (population 1.184 mil.)
- One station in Batumi (pop. 204 000)
- One station in Kutaisi (pop. 147 600)
- One station in Rustavi (pop. 125 100)

All of the above represent the largest cities in Georgia. They are therefore all of the type of urban or suburban. No automated professional stations are located in rural areas.

Legislation

Threshold values are in line with the European threshold values for air pollutant concentrations.

PM2.5 limit has been changed to 20 ug.m^{-3} in 2020. This change was also implemented in Georgia.

Pollutant	Limit value	Averaging period	Number of allowable exceedances per year
Sulphur dioxide (SO_2)	350 µg · m^{-3}	1 h	24
	125 µg · m^{-3}	24 h	3
Nitrogen dioxide (NO_2)	200 µg · m^{-3}	1 h	18
	40 µg · m^{-3}	1 year	
PM_{10}	50 µg · m^{-3}	24 h	35
	40 µg · m^{-3}	1 year	
$PM_{2.5}$	25 µg · m^{-3}	1 year	
carbon monoxide (CO)	10,000 µg · m^{-3}	max. daily 8h moving average	
benzene	5 µg · m^{-3}	1 year	
ozone (O_3)	120 µg · m^{-3}	max. daily 8h moving average	25 (for a three-year averaging period)
lead (Pb)	500 ng.m^{-3}	1 year	
arsenic (As)	6 ng.m^{-3}	1 year	
cadmium (Cd)	5 ng.m^{-3}	1 year	
nickel	20 ng.m^{-3}	1 year	
benzo[*a*]pyrene (BaP)	1 ng.m^{-3}	1 year	
manganese dioxide (MnO_2)	1 µg · m^{-3}	24 h	

Data presentation

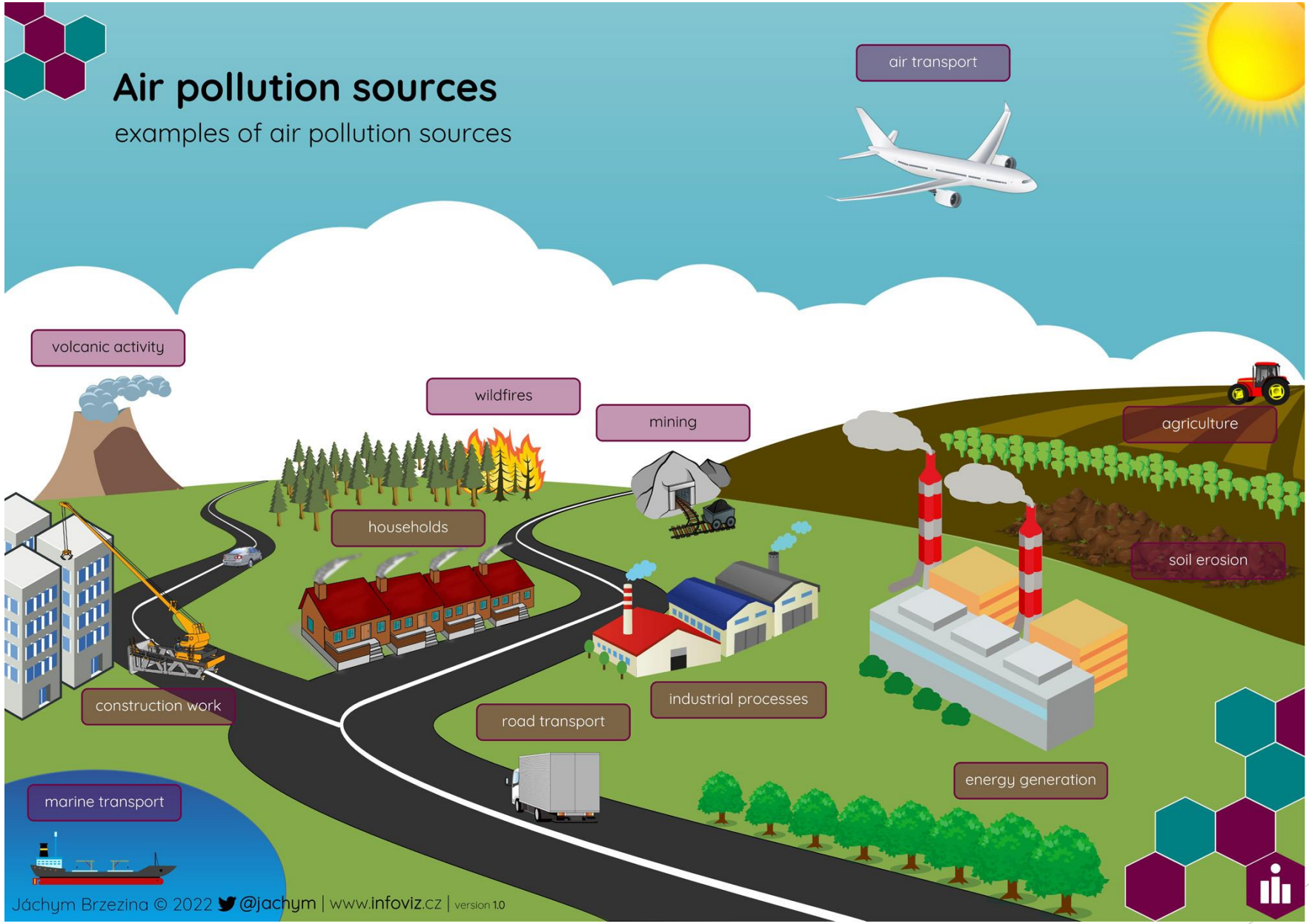
- Data is presented using an interactive map. Markers in the map are colored based on the actual value of the current concentration. Various filters can be applied to the map (location, pollutants etc.).
- Current air pollutant concentrations are available at https://air.gov.ge
- Historical data from the ambient air quality automated monitoring stations is available at https://air.gov.ge/reports_page
- This webpage allows downloading historical data from all the automated stations in a daily, monthly and annual reports. Daily report includes hourly data, monthly report daily averages.

Strengths of the monitoring

- Threshold values – the threshold values, averaging periods and number of allowable exceedances per year are in accordance with the values used in the EU.
- Monitored pollutants – the monitored pollutants include those that are of highest importance.
- 24/7 monitoring – ambient air quality monitoring is performed by automated stations in a 24/7 regime, providing hourly values of the various monitored pollutants at each station
- current data presented in a clear manner via an interactive filterable map with color-based value encoding
- historical up-to-date data is publicly available at the government website. Daily reports are available for previous day, monthly reports for previous month.
- historical data is available in a machine-readable Excel format.

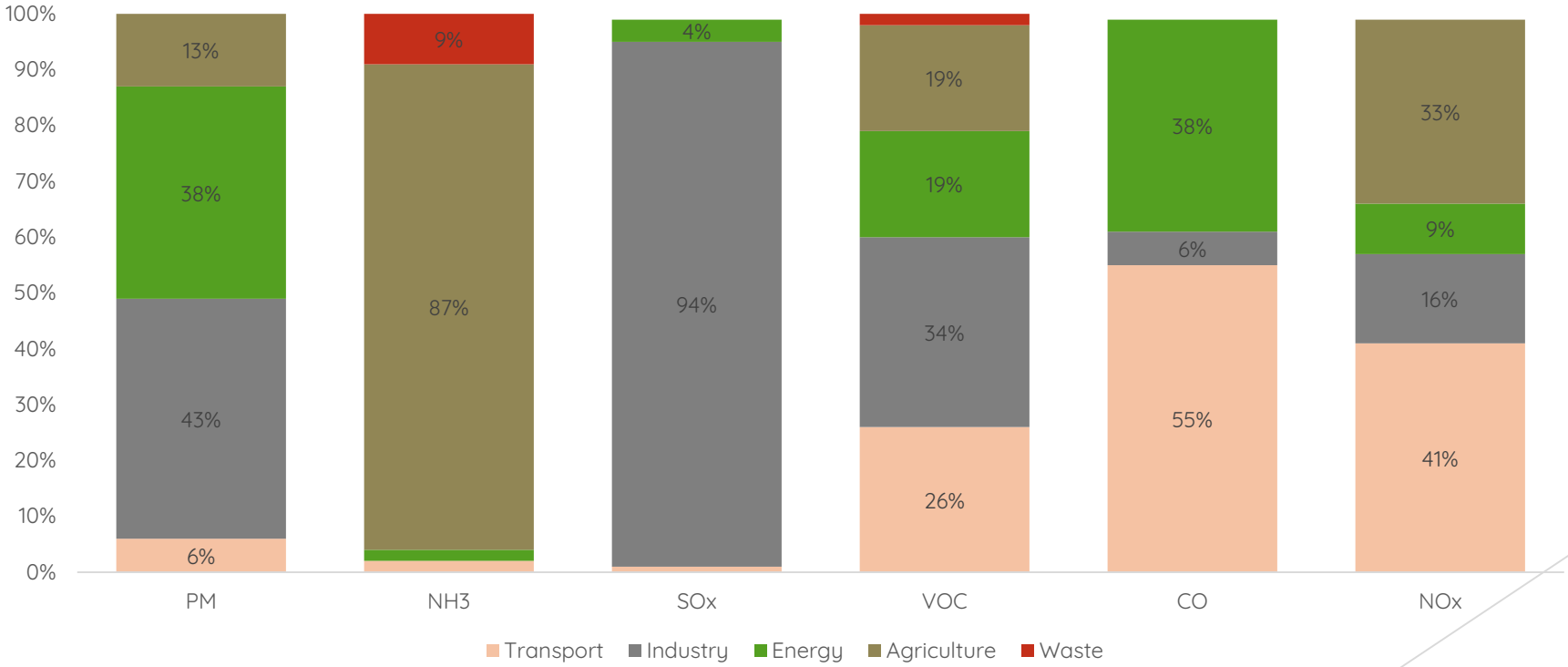
Weaknesses of the monitoring

- station network only includes 7 automated stations. more than half of which are located in the capital of Tbilisi. This means the representativeness of these stations for the country as a whole is limited.
- all available automated stations are located in the largest cities of the country. No information about air quality is therefore available from smaller towns, from villages and from remote, rural locations.
- over 70 % of the automated stations are traffic stations, which provide information about concentrations near major roads. Very little is therefore known about the background concentrations and there is therefore a very limited knowledge of what the concentrations are like in the majority of areas in the country
- annual reports are only available up to year 2017. Links for annual reports 2018 and later are broken.
- Historical data files do not include units, which is particularly problematic given the fact they are not the same for all the pollutants (all in $\mu g.m^{-3}$, carbon monoxide in $mg.m^{-3}$).
- longest interval for historical data download is one month, thus downloading data for a particular year means one has to download 12 files and then merge them into one document
- meteorological data is not monitored at the ambient air quality stations – particularly information about wind speed and direction at the measuring site is very valuable in the identification of potential pollution source


Air pollution sources
examples of air pollution sources
air transport
volcanic activity
wildfires
mining
agriculture
households
soil erosion
construction work
industrial processes
road transport
energy generation
marine transport
Jáchym Brzezina © 2022 @jachym | www.infoviz.cz | version 1.0

Air pollution sources in Georgia

As for the anthropogenic sources, the most important emission sectors are industry, transport, energy and for ammonia agriculture. The particular shares of the various sectors differ for different pollutants. The chart below shows the share of economy sectors from total emissions of various air pollutants, as provided by the Ministry of Environmental Protection and Agriculture of Georgia.



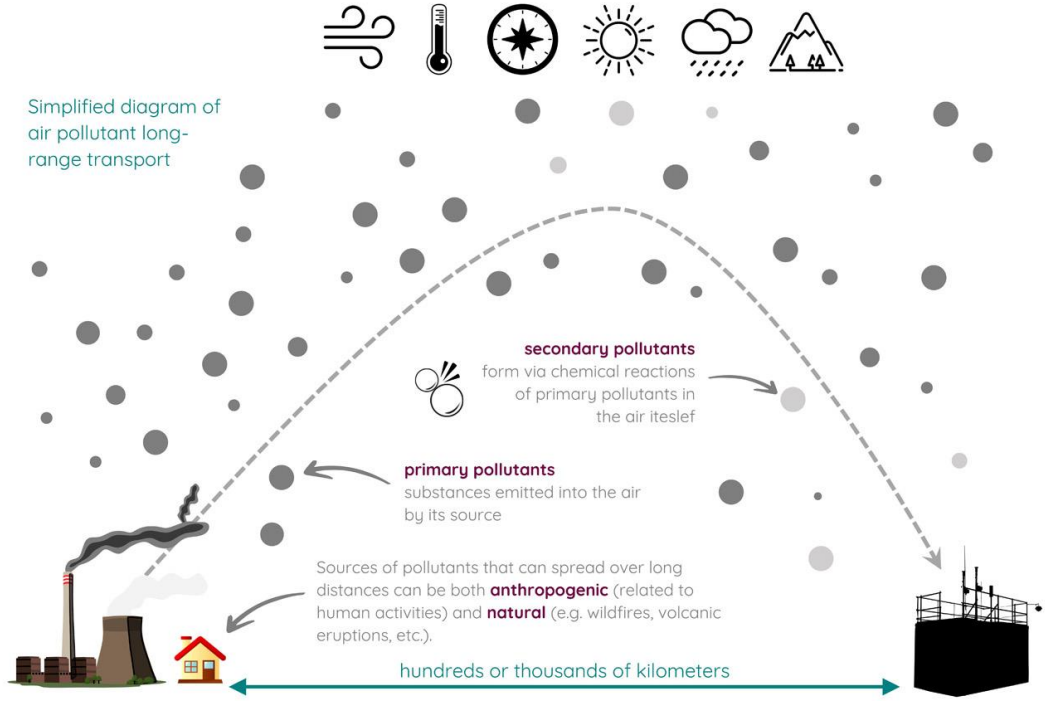
Air pollution sources

- The categorization is very general, in reality, there are more emission sources, for example in cities, especially those that are developing, construction works can be a significant contributor towards PM emissions.
- Data from the four-year period 2014-2017 show that PM emissions remain more or less constant in absolute values, though changes can be observed in the sector shares – energy sector emissions are decreasing, industry sector emissions are increasing. There is a minor increase in nitrogen oxide emissions due to the increasing number of vehicles in the country. It should, however, be noted that there is not a linear relationship between the number of cars and emissions of NOx. The number of cars is increasing faster because newer cars have lower exhaust emissions and vehicle fleet rejuvenation thus helps to decrease emissions per vehicle.

Air pollutant long-range transport

The air has knows no boundaries. If there are elevated concentrations of a particular pollutant in a particular location, **it does not mean that the source of that pollution has to be somewhere nearby. When pollutants are emitted from a particular source, they spread (disperse) into the surrounding area, and at the same time they may react with each other in different ways in the air**, giving rise to different types of pollutants. Long-range transport refers to the dispersion of substances through the air to the surroundings over a longer distance, with a threshold of > 100 km being the most commonly used.

Simplified diagram of air pollutant long-range transport



Factors affecting the dispersion of airborne pollutants from their source

The dispersion of substances in the air depends on a number of factors, including:

- wind speed and direction
- solar radiation intensity
- vertical temperature gradient in the atmosphere (eg. temperature inversion)
- precipitation
- emission source height above the ground
- terrain
- air pollutant type
- mass and size of the particle

Estimation of the nature and significance of long-distance transport

Assessing the nature and significance of long-range transport of pollutants is a very complex issue. Specific models are used which take into account a number of factors, theoretical knowledge of regional and local air flow, knowledge of meteorological and dispersion conditions, the nature and location of air pollution sources in specific locations, knowledge of air pollutant reactions, etc.

Example of long-range transport

- transport of Saharan dust over to Europe

Air quality in 2022

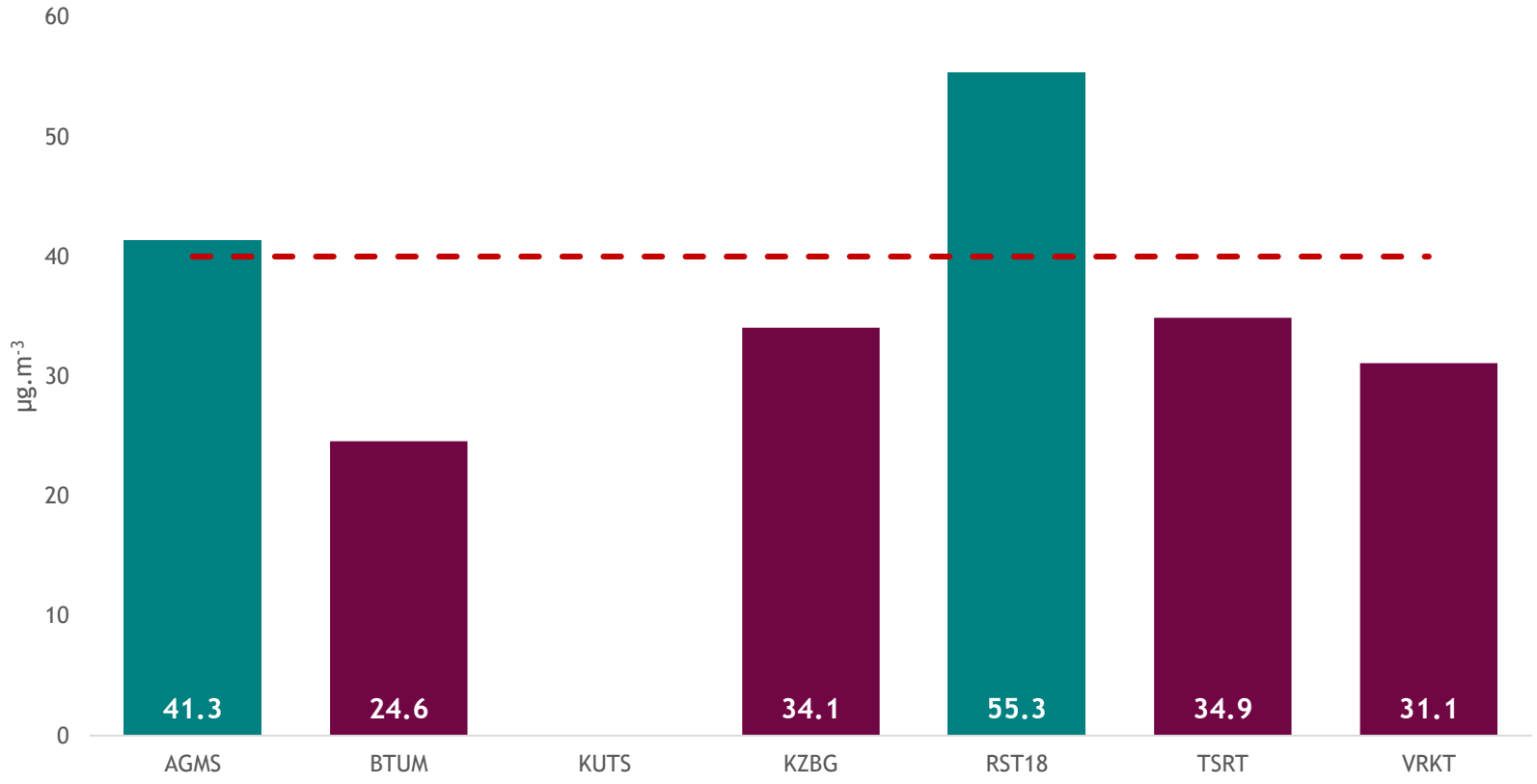
- Monthly files with daily average concentrations of various pollutants were downloaded for all the automated ambient air quality stations and all months of the year 2022 from the website of the National Environmental Agency of Georgia at https://air.gov.ge/reports_page . The data is not verified.
- Apart from the actual data values, an important factor in air pollution assessment is data availability. It is important for the assessment that there is a certain minimum data availability for the data to be representative and comparable with the threshold values for ambient air pollutant concentrations.
- In order to be able to assess annual means and number of exceedances per calendar year, there should be data for at least 90 % of days per year (data can be missing for a maximum of 36 days per year). If for a significant portion of the year there is no data, the annual mean and number of exceedances could be biased.

Data availability in 2022

Station	NO2	SO2	PM2.5	PM10	O3	CO
KUTS	60.6 %	63.0 %	56.4 %	56.4 %	48.0 %	-
TRST	98.4 %	92.3 %	97.0 %	97.0 %	98.9 %	98.9 %
KZBG	96.7 %	97.0 %	96.2 %	96.2 %	97.0 %	97.0 %
AGMS	99.2 %	98.9 %	98.6 %	98.6 %	99.2 %	-
VRKT	98.9 %	97.0 %	98.4 %	98.4 %	98.6 %	98.6 %
RST18	96.7 %	98.6 %	99.2 %	99.2 %	100.0 %	84.9 %
BTUM	97.5 %	98.6 %	98.1 %	98.1 %	97.0 %	97.5 %

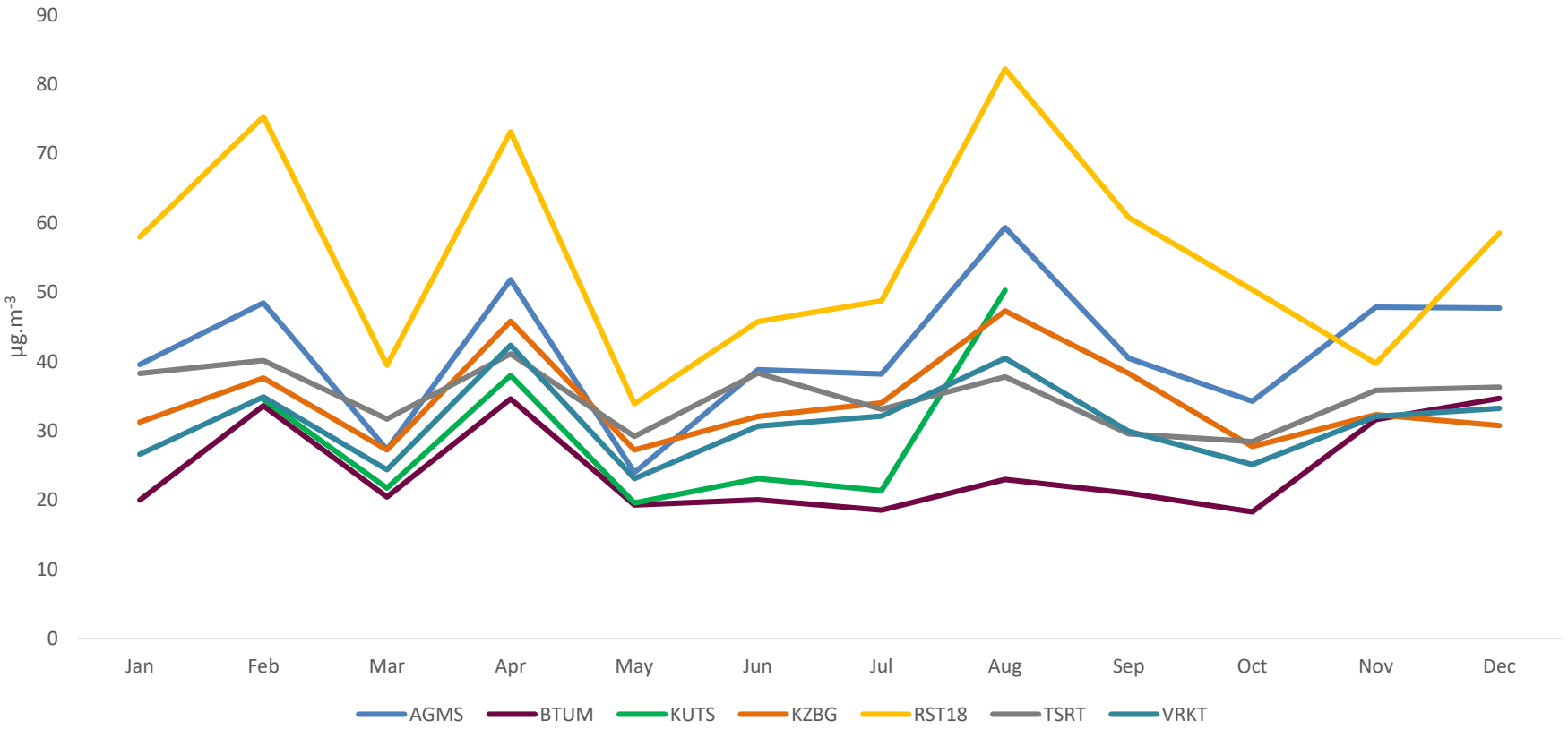
Suspended particles PM_{10}

The bar chart below shows annual mean values of suspended particles PM_{10}. Traffic stations are shown in purple, background stations in green.



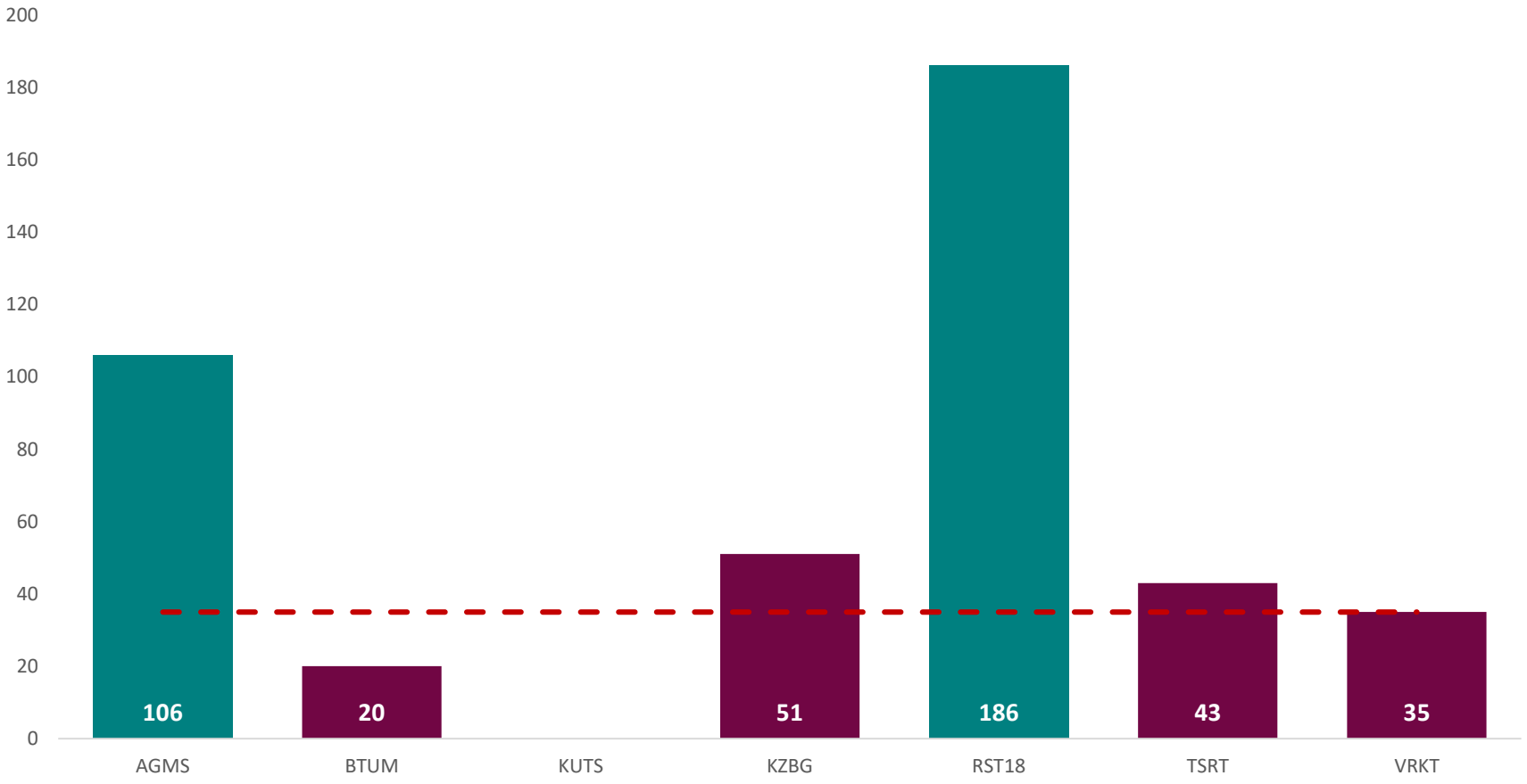
Suspended particles PM_{10}

The monthly variation in 2022 is shown at the chart below, which shows monthly average concentrations of PM_{10} for all the stations assessed.



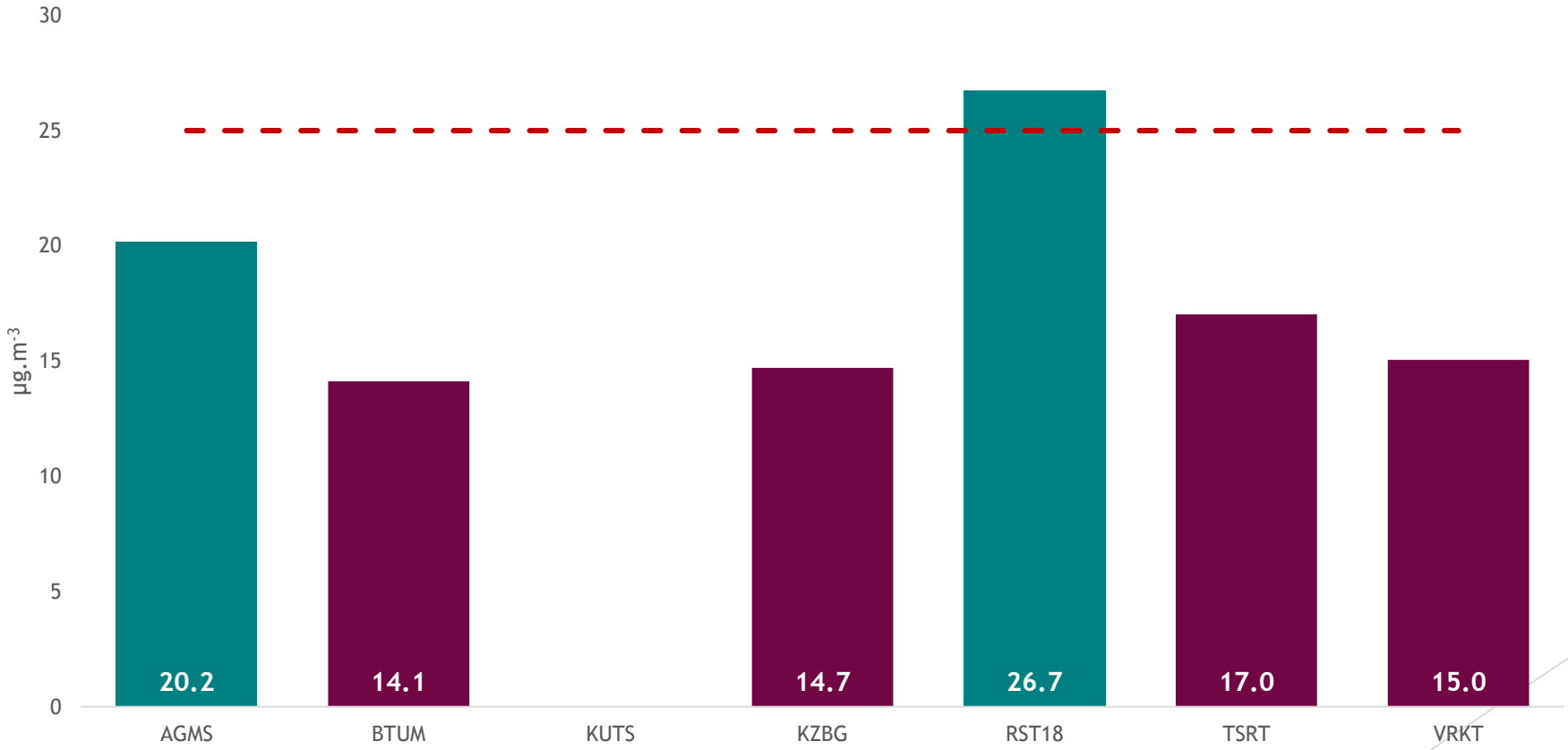
Suspended particles PM_{10}

For the suspended particles PM_{10} there is also a limit value set for 24h concentration (50 $\mu g.m^{-3}$), which is considered exceeded if the number of exceedances per calendar year is higher than 35. The chart below shows the number of exceedances of the 24h limit value for PM_{10} in 2022.



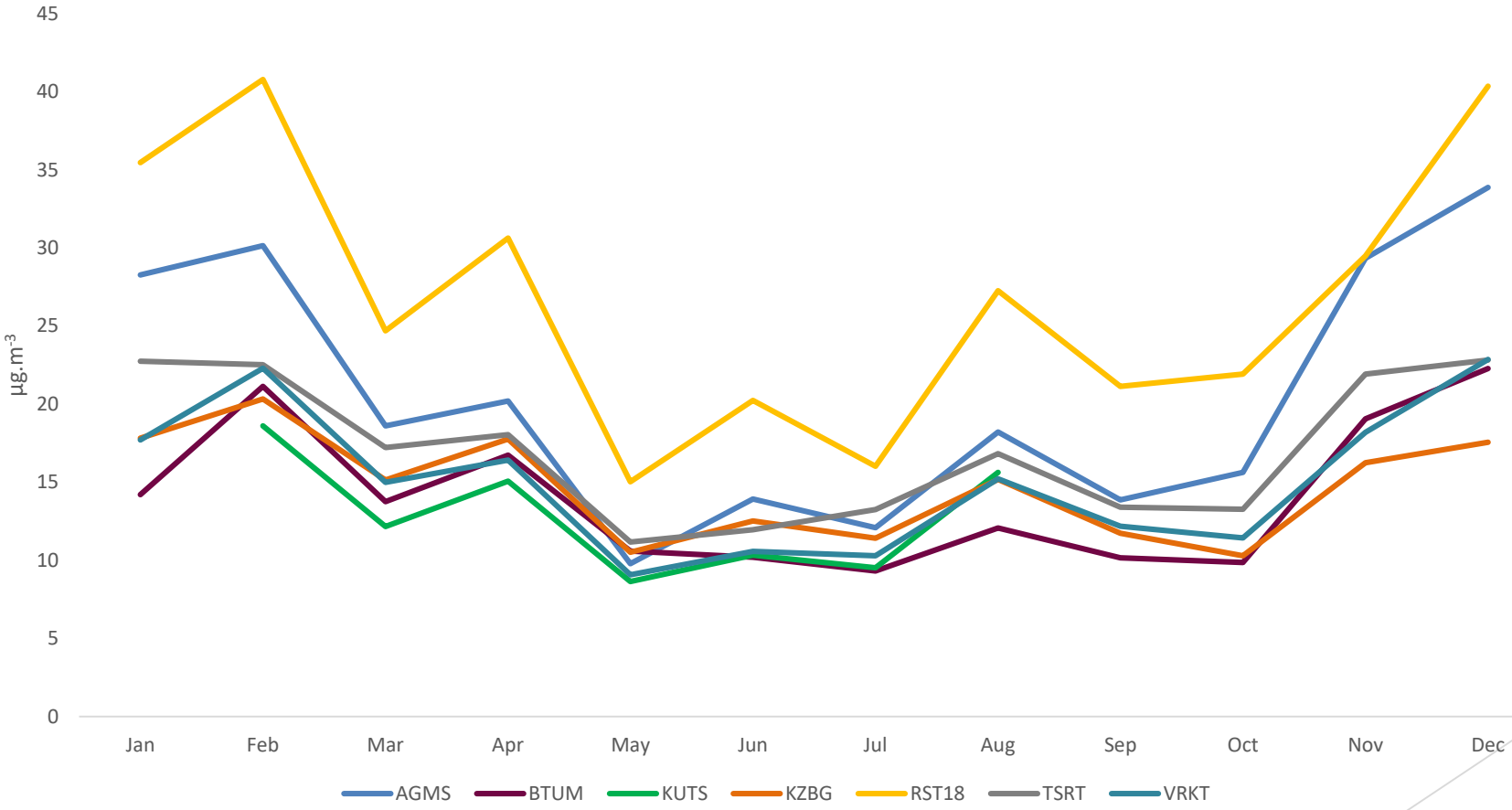
Suspended particles $PM_{2.5}$

The bar chart below shows annual mean values of suspended particles $PM_{2.5}$. Traffic stations are shown in purple, background stations in green.



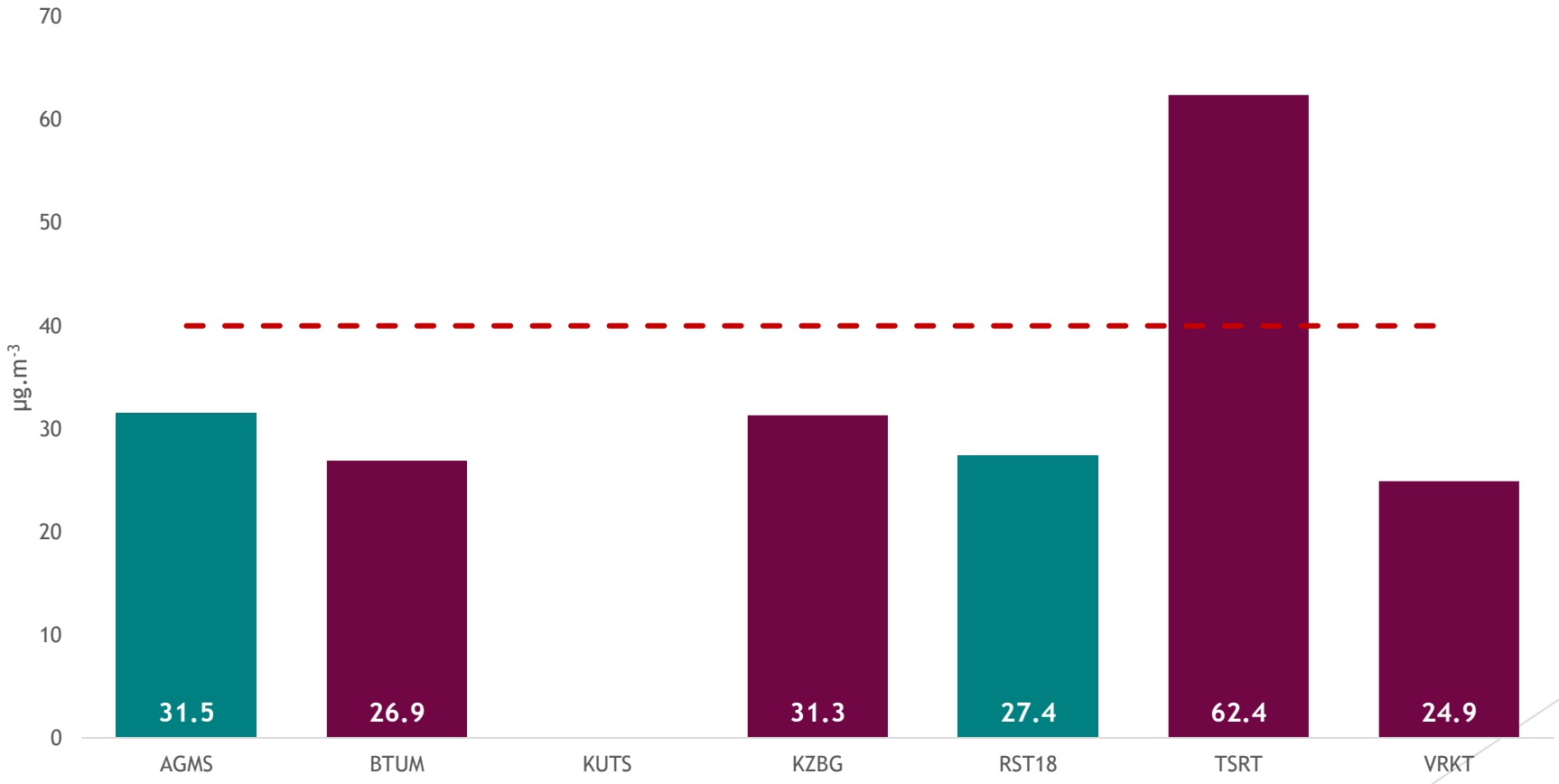
Suspended particles $PM_{2.5}$

The monthly variation in 2022 is shown at the chart below, which shows monthly average concentrations of $PM_{2.5}$ for all the stations assessed.



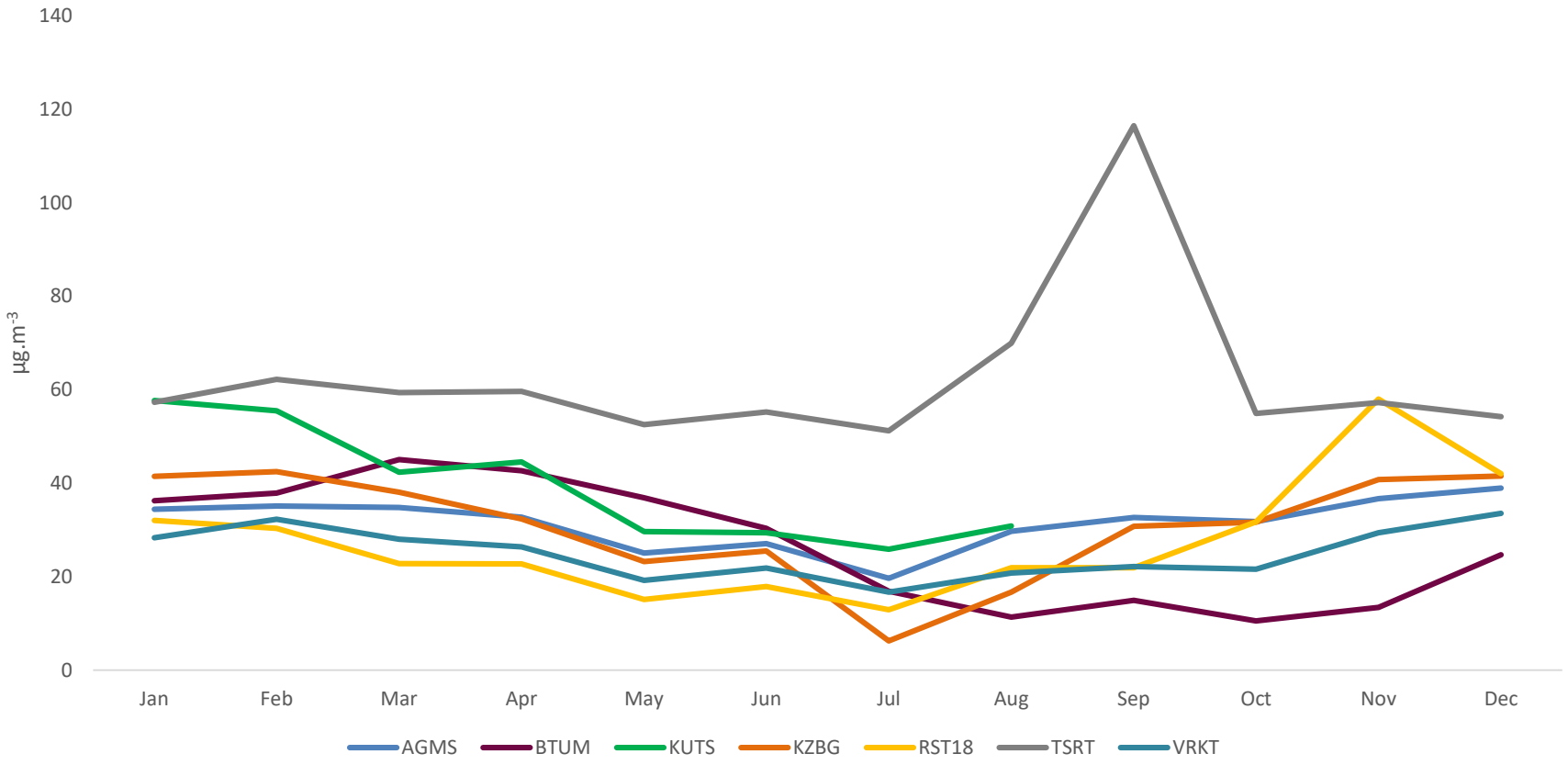
Nitrogen dioxide (NO_2)

The bar chart below shows annual mean values of nitrogen dioxide. Traffic stations are shown in purple, background stations in green.



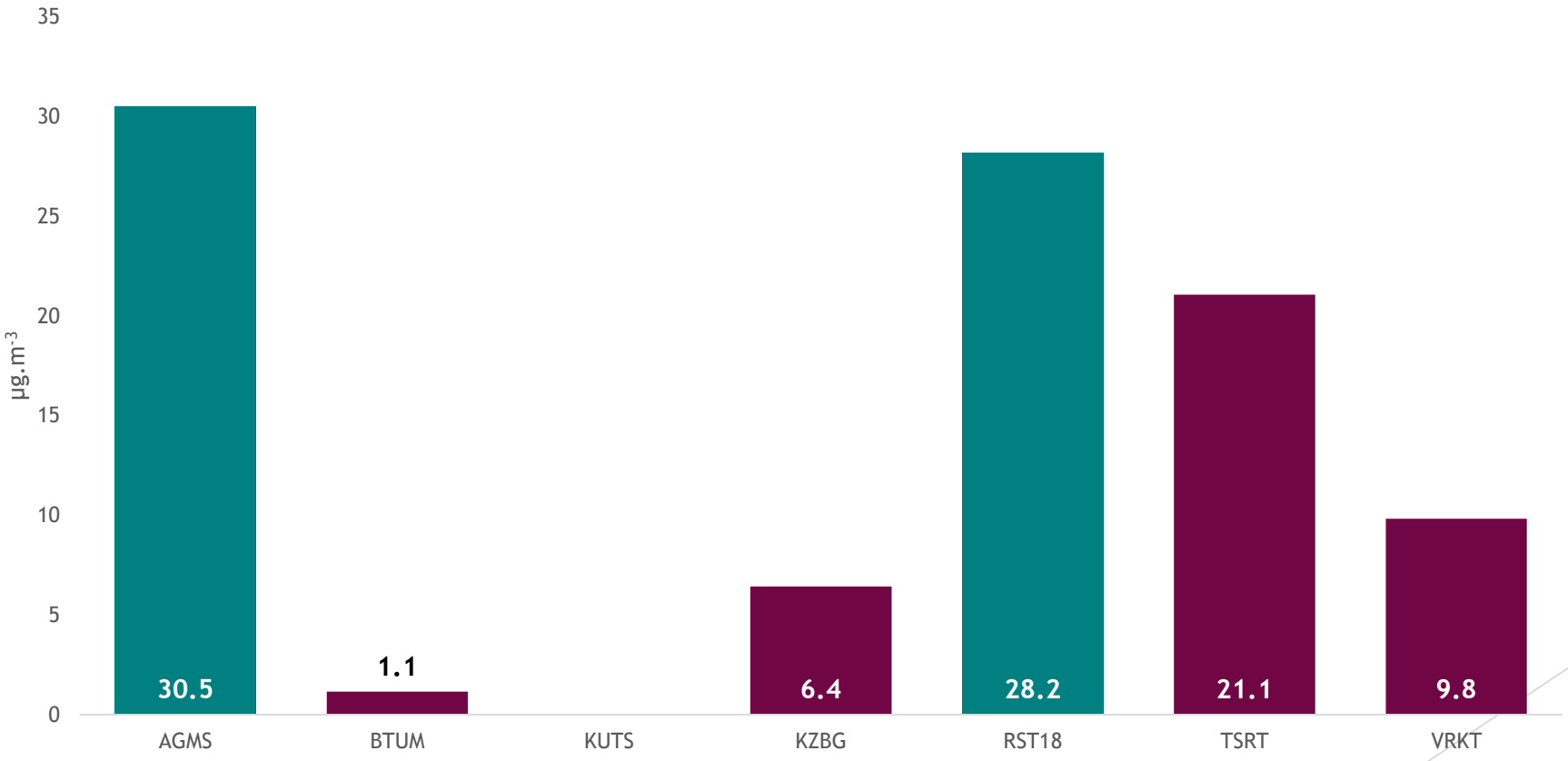
Nitrogen dioxide (NO_2)

The monthly variation in 2022 is shown at the chart below, which shows monthly average concentrations of NO_2 for all the stations assessed.



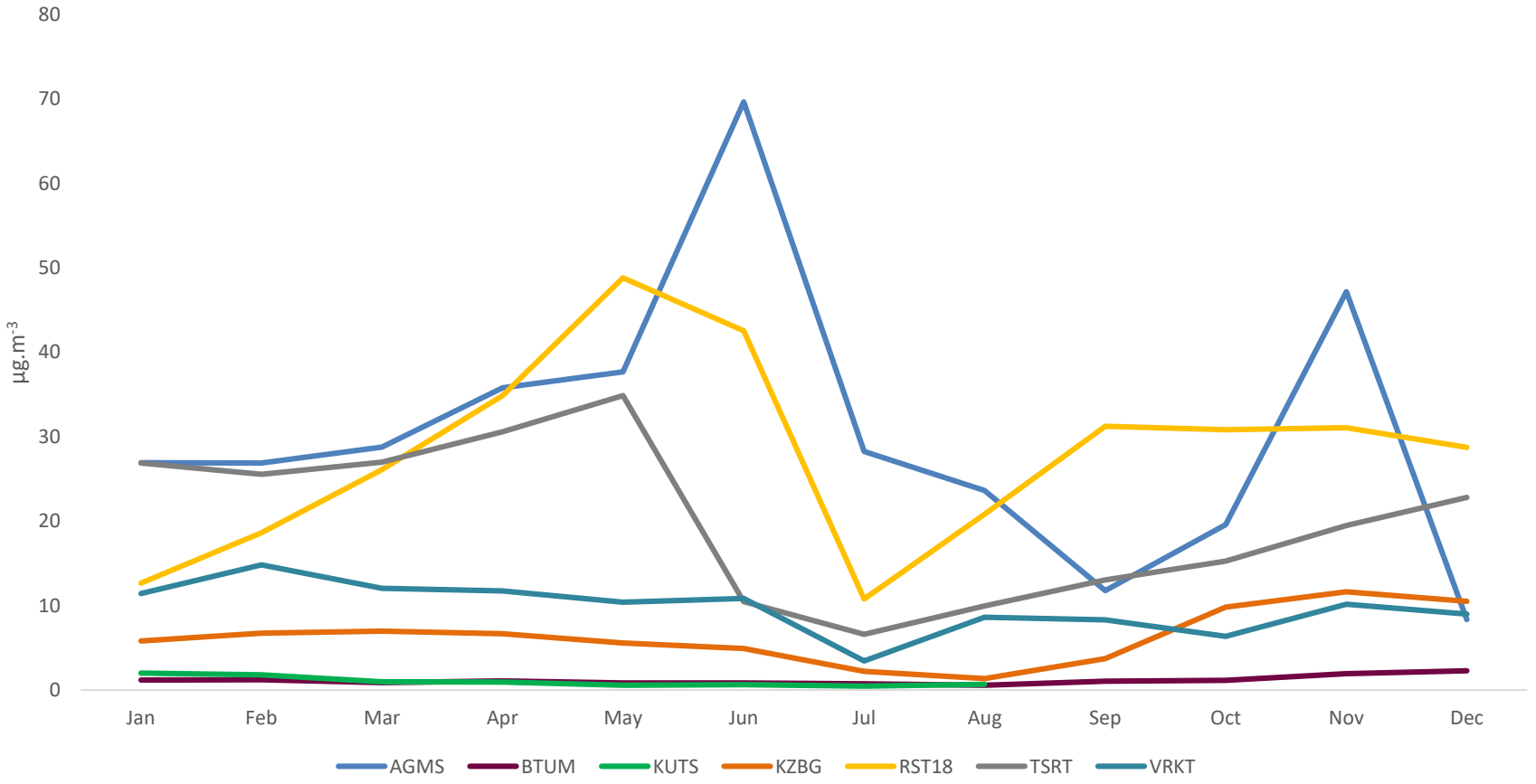
Sulfur dioxide (SO_2)

The bar chart below shows annual mean values of sulfur dioxide. Traffic stations are shown in purple, background stations in green.



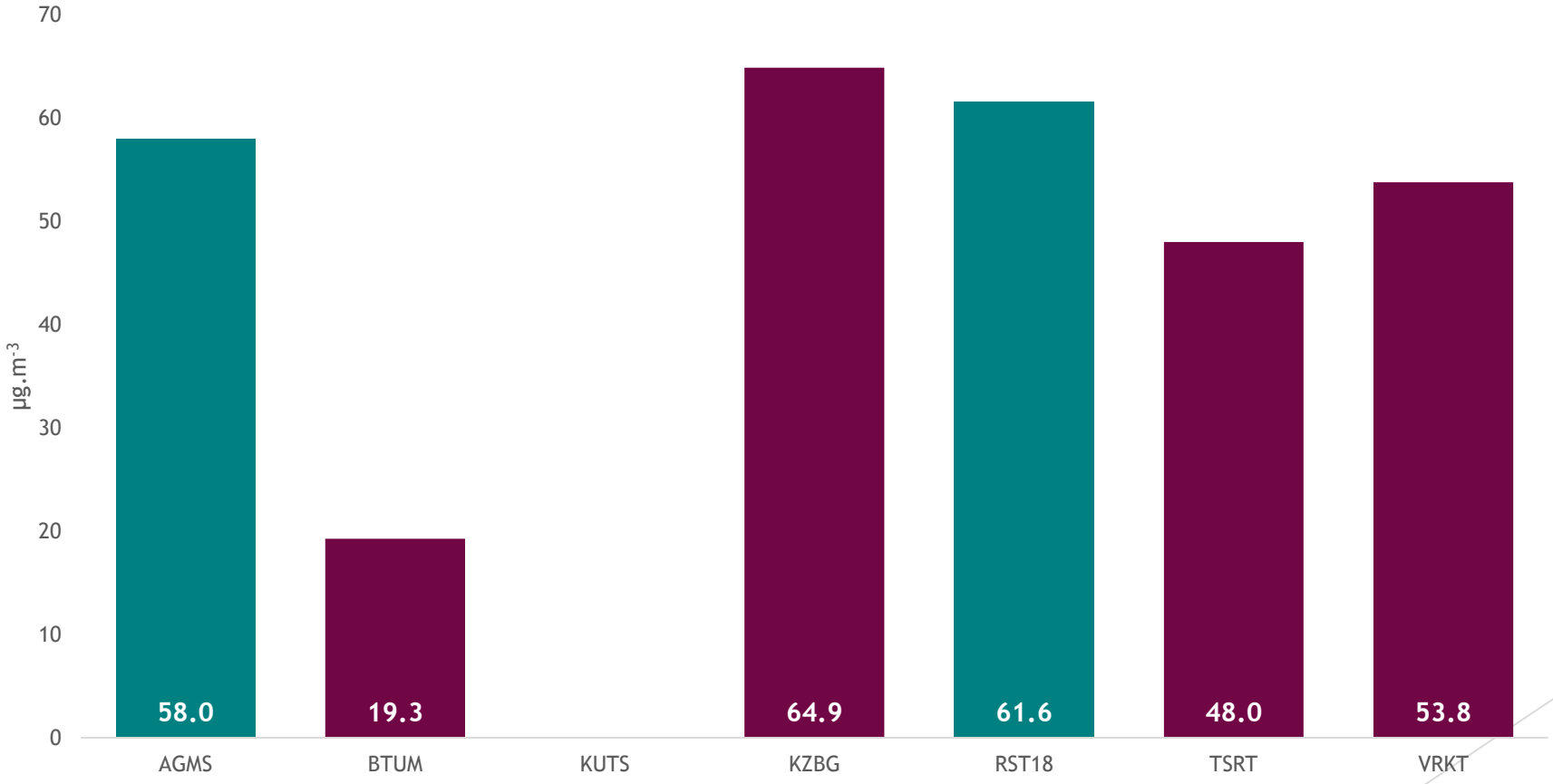
Sulfur dioxide (SO_2)

The monthly variation in 2022 is shown at the chart below, which shows monthly average concentrations of SO_2 for all the stations assessed.



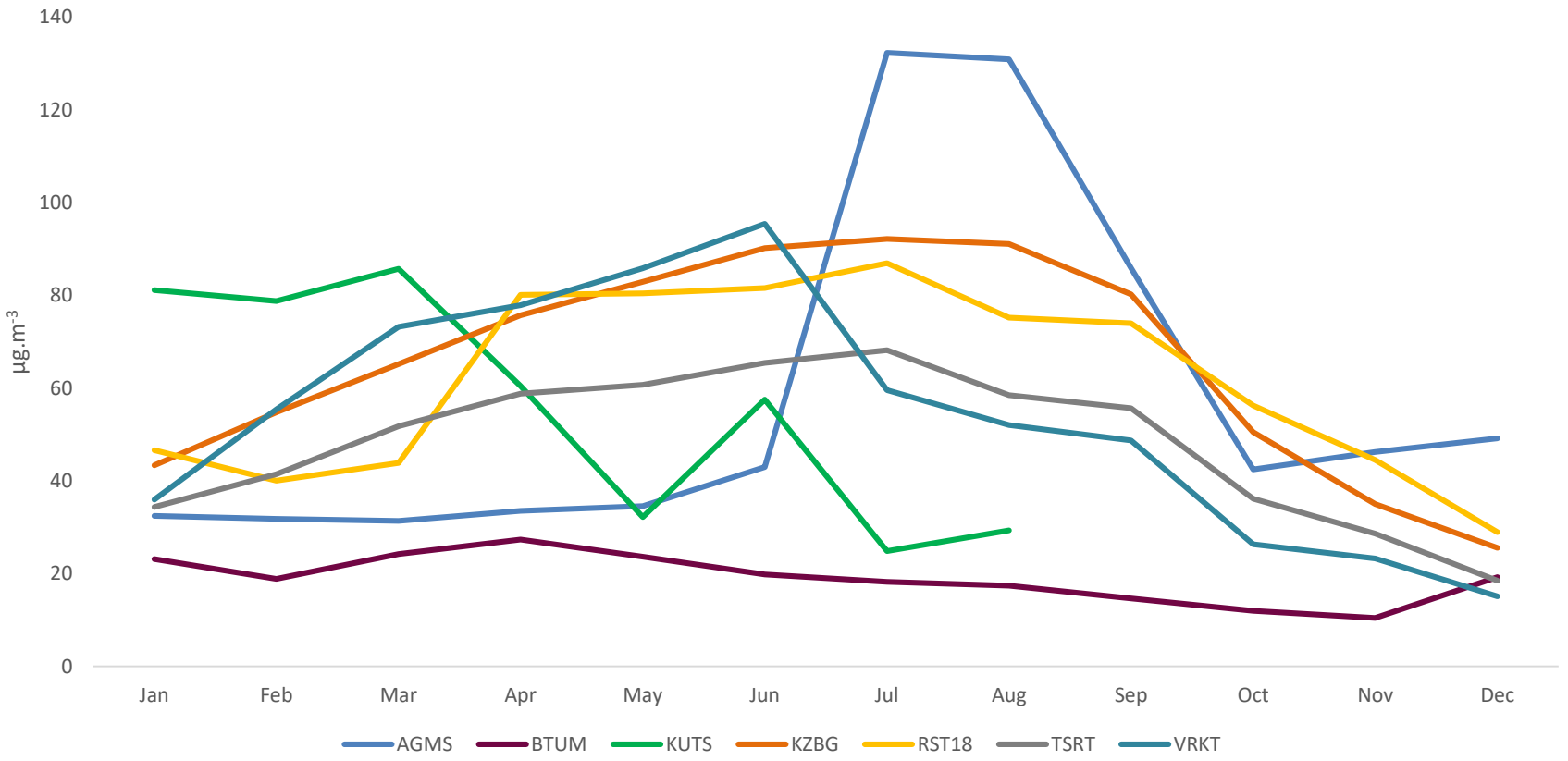
Ground-level ozone (O_3)

The bar chart below shows annual mean values of ground-level ozone. Traffic stations are shown in purple, background stations in green.



Ground-level ozone (O_3)

The monthly variation in 2022 is shown at the chart below, which shows monthly average concentrations of O_3 for all the stations assessed.



Monitoring in the Czech Republic

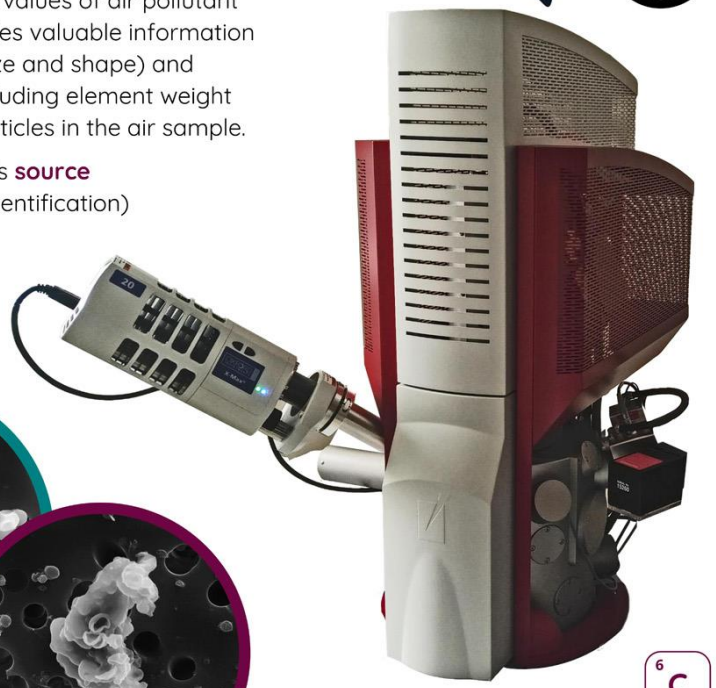
- >200 stationary automated stations
- Background/traffic/industrial; urban/suburban/rural
- EU threshold values
- Tabular reports, graphical reports, interactive reports, emission inventories
- 6 regional offices
- Focus on problematic pollutants (BaP, $PM_{2.5}$)
- Special-purpose measurements
- Scientific work in the field of air quality

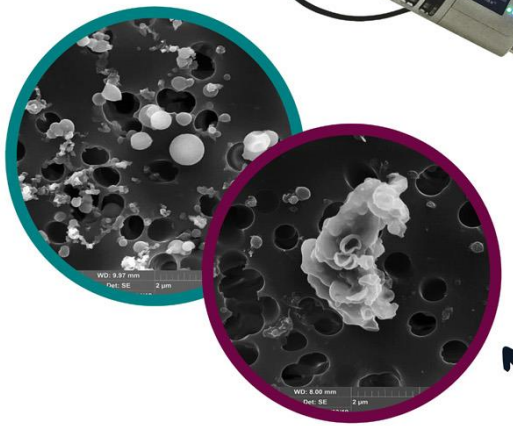
Particle analysis of ambient air using a scanning electron microscope

A **scanning electron microscope (SEM)** can be used to **analyze particles** in the air. It is a complementary method, which does not allow determination of absolute values of air pollutant concentrations, but provides valuable information about the morphology (size and shape) and chemical composition, including element weight ratios, in the individual particles in the air sample.

Main goal of this method is **source apportionment** (source identification) of those particles.

Example of a scanning electron microscope, in this case the Tescan MIRA3 model.





Particles in the air sampled on a polycarbonate filter as seen by a scanning electron microscope. Source: CHMI

Size

Size of a particle is on of the factors that can help to identify its source.

Particles emitted from combustion processes tend to be very small, in contrast mechanically generated particles (soil erosion, agriculture etc.) tend to be larger.

Shape

Shape of a particle is on of the factors that can help to identify its source.

Particles emitted from combustion processes are usually regular-shaped (round). Mechanically generated particles are often irregularly shaped.

Also soot particles often have a unique and identifiable shape.

Chemical composition

A major advantage of the particle analysis is the possibility to determine the ratio of the individual chemical elements in each individual particle.

Knowledge of the weight ratios of elements and their combination in each particle, is a very significant and useful information in the process of its source identification.

Jáchym Brzezina © 2022 @jachym | www.infoviz.cz | version 1.0

Conclusion

Overall it could be said that Georgian air pollution monitoring system is on a good track. Implementation of European threshold values and methodologies of measurements is a major step forward. Another very positive fact is the expansion of the station monitoring network, which originally consisted of just one automated station. Now there is seven stations with hourly data.

What can also be seen as highly desirable are online data publicly available on the web, in a clear and cohesive manner. Data can also be downloaded from the past in various format. Public has the opportunity to monitor current air quality and has all data available to them.

There are, however, several factors that could be improved.

Recommendations

- Station network limited to major cities – no information is available from professional stations in other areas
- For some of the pollutants for which threshold values are set, no data is available nor online neither in the historical data section (either it is not being monitored or it is not being published).
- While historical data can be downloaded and are up-to-date, they are all labeled as “not verified data”, even if they are several years old. It can therefore be recommended to make sure proper validation is done and the unverified data from the past is replaced with verified data in the section where historical data can be downloaded.

Recommendations

- At some of the stations there were very high values of the number of exceedances of the 24h limit for suspended particles PM_{10}. At one of the stations the limit was exceeded more than half of the days in the year, while the allowable number of exceedances is just 35. In cases of such major exceedance of the limit value, the sources of this pollution should be identified and maximum effort made to improve the air quality at that particular location. Limit values are also exceeded for example for SO_2 and NO_2.

Thank you for your attention

Mgr. Jáchym Brzezina, Ph.D.

Head of Air Quality Dpt., Czech Hydrometeorological Institute

jachym.brzezina@chmi.cz

Czech Hydrometeorological Institute

ARNIKA