Supplementary Information of the Air Pollution Dataset

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Where does the data come from?

The data comes from **Tehran**, the capital of **Iran**.

Characteristics of the study area

Tehran, the capital of Iran, is located at 35.69°N latitude and 51.42°E longitude, with an elevation of 1200 meters above sea level, nestled in the southern foothills of the Alborz mountains. These mountains act as a natural barrier, preventing the dispersion of pollutants to the north. The city's complex geography, combined with low wind speeds for much of the year, leads to the accumulation of air pollutants, especially $PM_{2.5}$, in the atmosphere. Temperature inversions during colder months trap pollutants near the ground, particularly in the southern plains. Winds in Tehran primarily blow from the west and southwest towards the east and northeast, carrying pollutants from industrial and densely populated areas to other parts of the city. Tehran's semi-arid climate, with an average annual rainfall of 250 millimeters and a yearly temperature of 18°C, along with rapid population growth, industrial expansion, and heavy traffic, has turned it into one of the most polluted megacities in the world (Emadodin et al., 2016).

Study period

From 00:00 on January 1, 2019, to 23:00 on December 31, 2022.

How many variables are there in this dataset?

There are 9 variables: nitrogen dioxide (NO_2), particulate matter with a diameter less than 10 micrometers (PM_{10}), humidity, temperature, pressure, dew point temperature, wind direction in the X direction, wind direction in the Y direction, and particulate matter smaller than 2.5 micrometers ($PM_{2.5}$).

Geographical location map of the study area

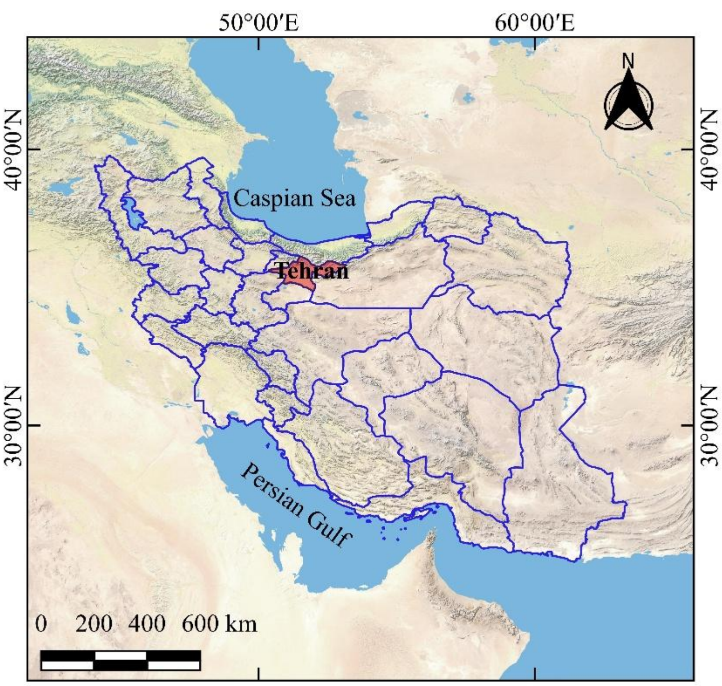


Fig. 1a. Study area,

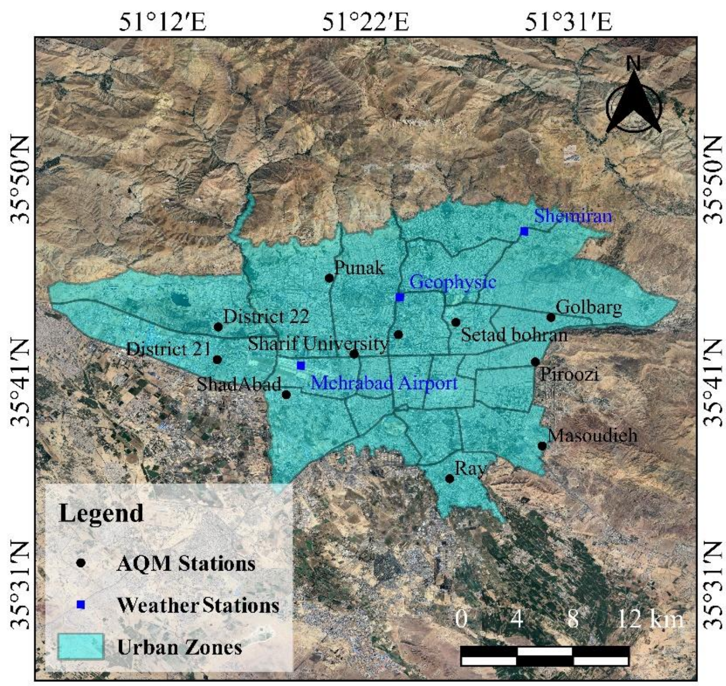


Fig. 1b. Distribution of AQMSs.

The dominant pollutant in Tehran

According to the latest report by the Tehran Air Quality Control Company (AQCC), the air quality in the capital throughout 2023 was as follows:

> The city experienced only 10 clean days (2.7% of the year), while 236 days (64.7%) were classified as "acceptable." However, there were 107 days (29.3%) of air pollution deemed "unhealthy for sensitive groups" and 12 days (3.3%) with air quality labeled as "unhealthy for all groups."

Regarding major air pollutants, the number of days exceeding the permissible limits was:

- **98 days with elevated levels of $PM_{2.5}$**
- 26 days with excessive ozone (O_3)
- 17 days with high concentrations of PM_{10}
- 5 days with levels of nitrogen dioxide (NO_2) exceeding the standard
- In contrast, sulfur dioxide (SO_2) and carbon monoxide (CO) remained within permissible limits throughout the year, with no recorded violations.

Furthermore, the annual mean concentration of $PM_{2.5}$ was recorded at 30.6 $\mu g/m^3$, exceeding Iran's national air quality standard (12 $\mu g/m^3$) by a factor of 2.5 and surpassing the World Health Organization's (WHO) recommended threshold by a factor of 5. This indicates a persistently high level of fine particulate pollution, posing significant public health concerns.

These statistics indicate that in the metropolitan city of Tehran, the pollutant **$PM_{2.5}$** is in an undesirable condition based on daily and annual standards, and with the highest number of days exceeding the permissible limit, it **is the city's dominant pollutant.**

Components of $PM_{2.5}$

$PM_{2.5}$ is a complex mixture of fine particles suspended in the air that measure 2.5 microns or less in diameter. These particles consist of both organic and inorganic compounds, which vary in composition depending on the sources of emission, atmospheric conditions, and geographical location. The major components of $PM_{2.5}$ can be categorized as follows:

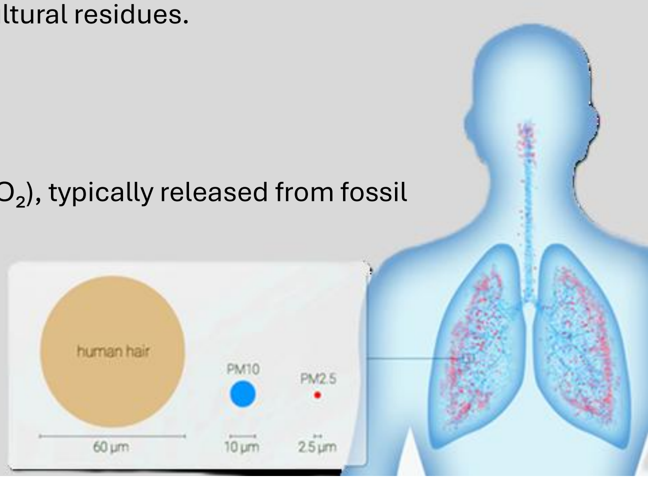
1. Organic and Carbon Compounds:

Elemental Carbon (EC): Also known as black carbon, this compound is formed during the incomplete combustion of carbon-based materials like fossil fuels, wood, and charcoal. It is a primary component of soot and contributes to both air pollution and climate change by absorbing sunlight.

Organic Carbon (OC): Organic carbon includes a variety of carbon-based compounds, primarily formed from incomplete combustion or from natural processes such as plant decay. Some of these compounds, such as polycyclic aromatic hydrocarbons (PAHs), are toxic and carcinogenic. Sources of organic carbon include vehicle exhaust, industrial processes, and biomass burning, which involves the burning of organic materials like wood or agricultural residues.

2. Inorganic (Mineral) Compounds:

Sulfates (SO_4^{2-}): Sulfates are formed when sulfur dioxide (SO_2), typically released from fossil fuel combustion in power plants, vehicles, and industrial processes, reacts with water vapor and other compounds in the atmosphere. These particles play a significant role in the formation of acid rain and contribute to regional air pollution.



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Nitrates (NO_3^-): Nitrates are produced when nitrogen oxides (NO_x), which are primarily emitted from vehicle engines, industrial activities, and power plants, react with other substances in the atmosphere. Nitrates contribute to the formation of secondary fine particles and are linked to respiratory problems and cardiovascular diseases.

Ammonium (NH_4^+): Ammonium compounds are primarily produced by agricultural activities, such as the use of fertilizers and animal waste. When ammonia (NH_3) reacts with sulfuric and nitric acid in the atmosphere, ammonium salts are formed. These compounds combine with sulfates and nitrates, contributing to the formation of fine particulate matter.

Heavy Metals: Heavy metals such as lead (Pb), cadmium (Cd), nickel (Ni), chromium (Cr), and copper (Cu) are toxic and can have serious health impacts. These metals enter the atmosphere through industrial emissions, fuel combustion, and the wear of vehicle tires and brakes. They can accumulate in the body and cause neurological and cardiovascular damage, among other health problems.

Mineral Dust Particles: These particles include natural materials like silica (SiO_2), aluminum oxide (Al_2O_3), and iron oxide (Fe_2O_3). They originate from construction activities, mining, road dust, and desertification or dust storms. Although these particles are naturally occurring, human activities can increase their concentrations in the air.

The composition of $PM_{2.5}$ in Tehran

The study by Arhami et al. (2018) was the first research in Tehran to investigate the composition and sources of $PM_{2.5}$ and carbonaceous aerosols, analyzing their seasonal trends. In this study, fine PM samples were collected over the course of one year, and their chemical constituents, including organic markers, metals, and ions, were analyzed. The results showed that carbonaceous compounds (organic carbon and elemental carbon) make up, on average, 29% of the $PM_{2.5}$ mass. Vehicles were identified as the primary source of organic carbon (OC), accounting for 72% of the measured OC. Furthermore, mobile sources were the largest contributor to total $PM_{2.5}$ production (40%), followed by dust (24%) and sulfate (11%).

The contribution of $PM_{2.5}$ chemical components throughout the year in this study is given in **Fig. 2**:

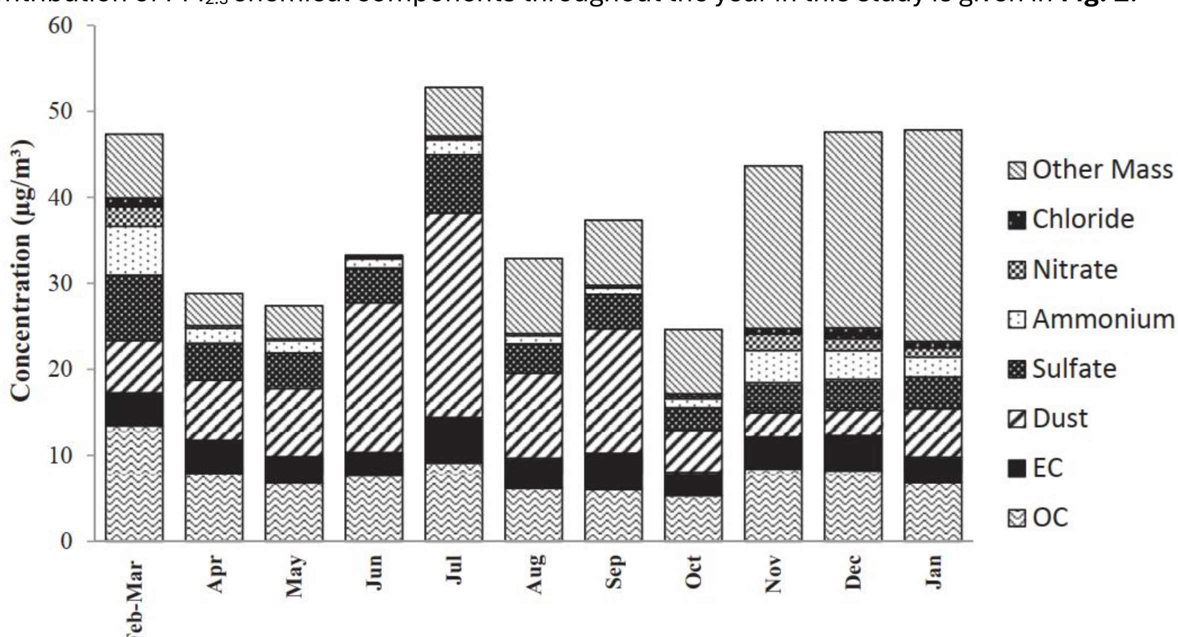

Fig. 2. Annual contribution of chemical components to $PM_{2.5}$ in Tehran. (Arhami et al. (2018))

Health effects and costs associated with $PM_{2.5}$ pollutant in Tehran

The study by Bayat et al. (2019) utilized the Concentration-Response Function (CRF) from the Global Exposure Mortality Model (GEMM) to estimate that 7,146 adult deaths (aged ≥25 years) in Tehran in 2017 were directly attributable to $PM_{2.5}$ exposure (95% CI: 6,596–7,513). The primary causes of mortality related to this pollutant included ischemic heart disease (3,437 deaths; 95% CI: 3,315–3,516), stroke (886 deaths; 95% CI: 693–1,002), lower respiratory infections (531 deaths; 95% CI: 414–589), chronic obstructive pulmonary disease (364 deaths; 95% CI: 271–420), and lung cancer (274 deaths; 95% CI: 236–298). Furthermore, the estimated economic loss resulting from premature deaths linked to $PM_{2.5}$ exposure was approximately USD 3 billion (95% CI: 2.67–3.04 billion) in 2017 (Bayat et al. (2019)).

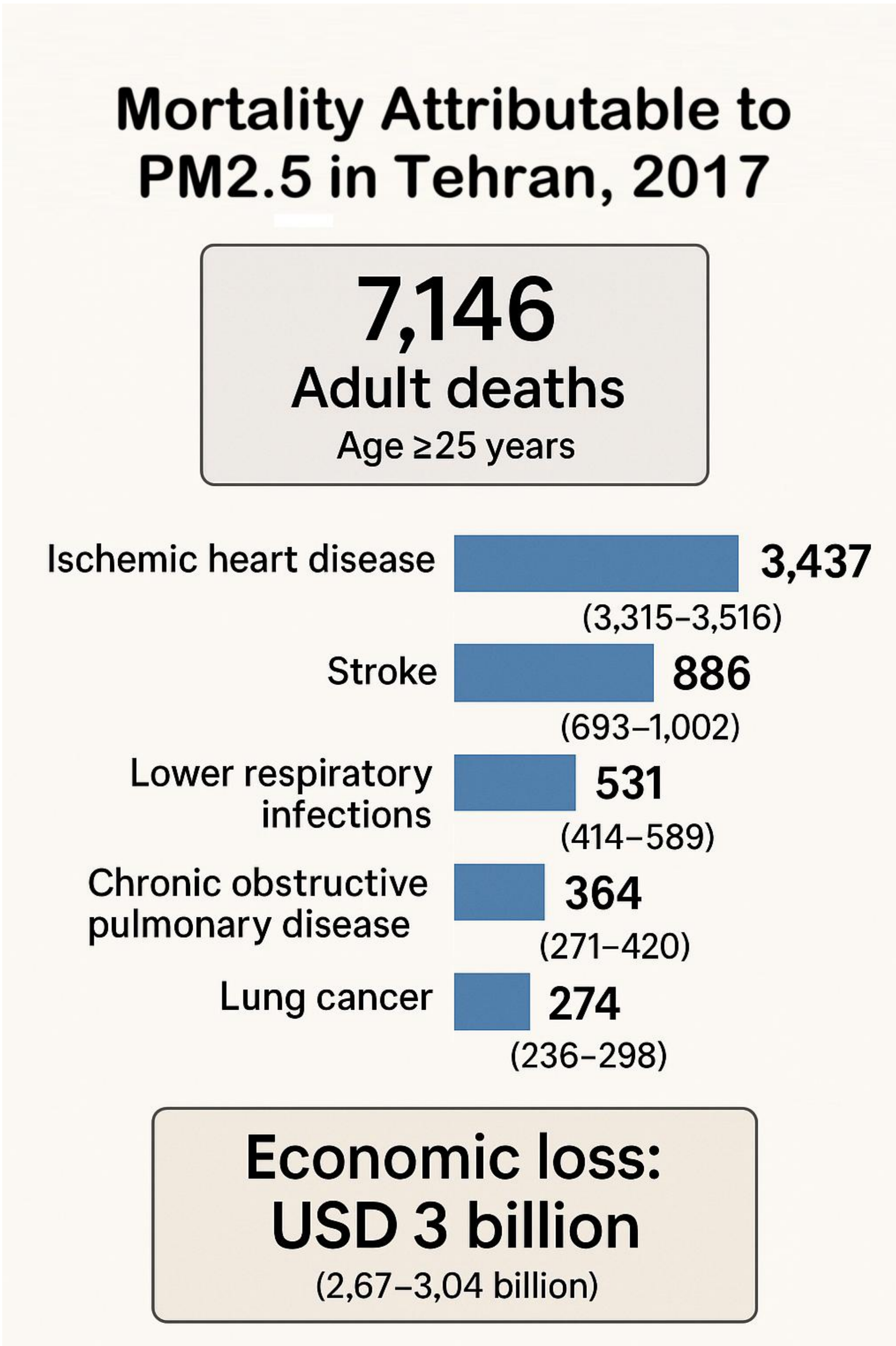

Fig. 3. Health effects and costs associated with $PM_{2.5}$ pollutant in Tehran.

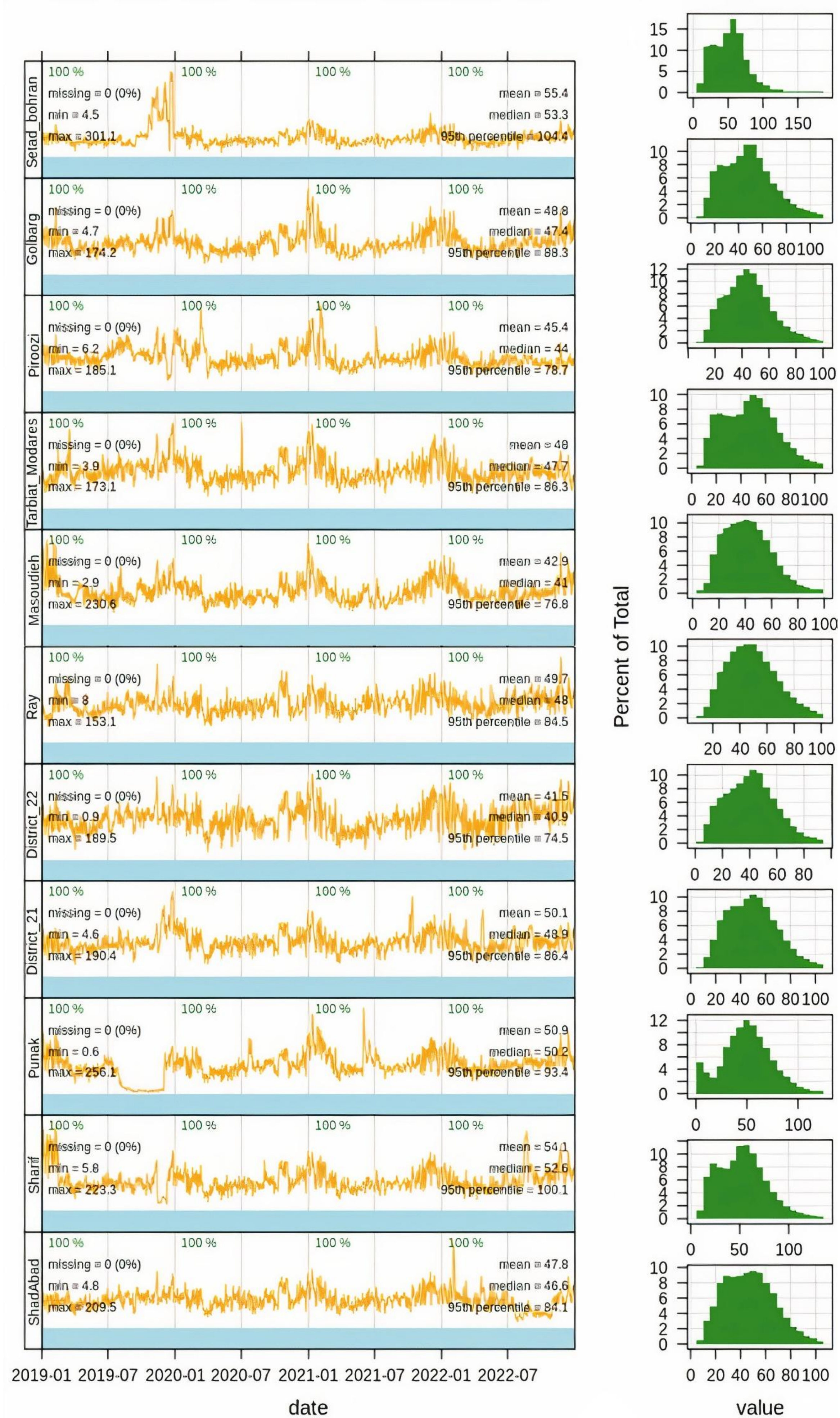

Fig. 4. The hourly concentration of NO_2 and the statistical indices

Hourly concentration of pollutants in each AQMS

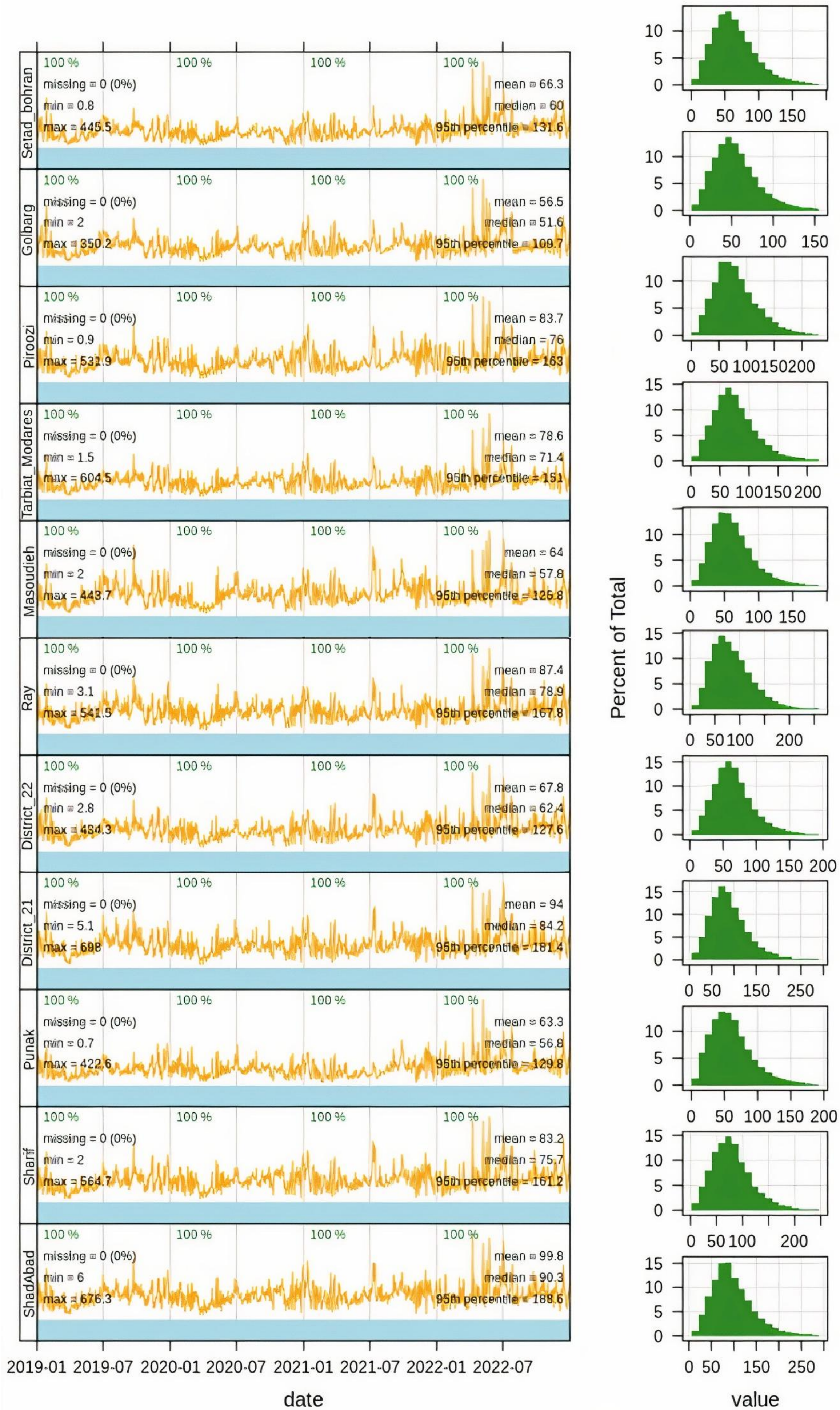

Fig. 5. The hourly concentration of PM_{10} and the statistical indices

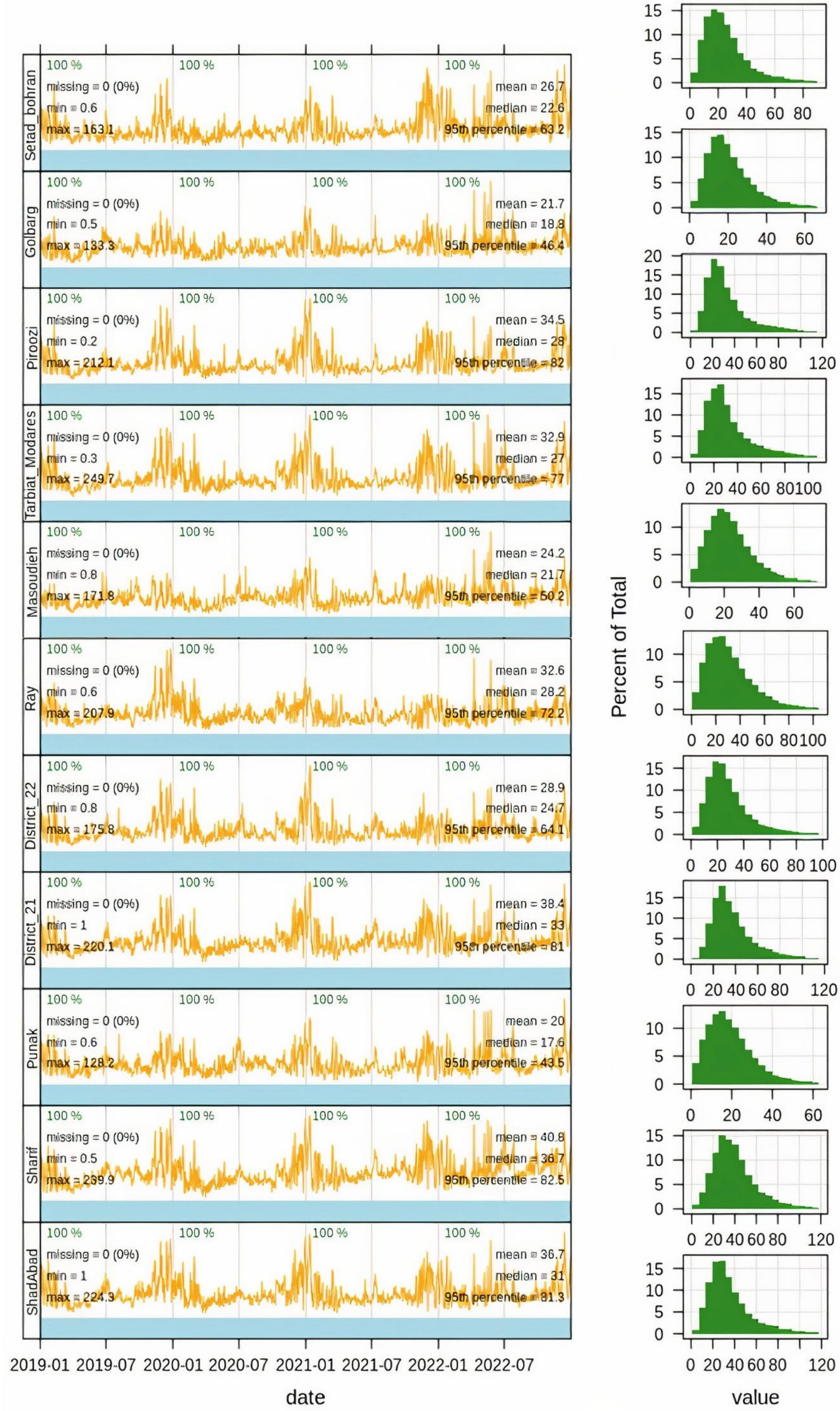

Fig. 6. The hourly concentration of $PM_{2.5}$ and the statistical indices

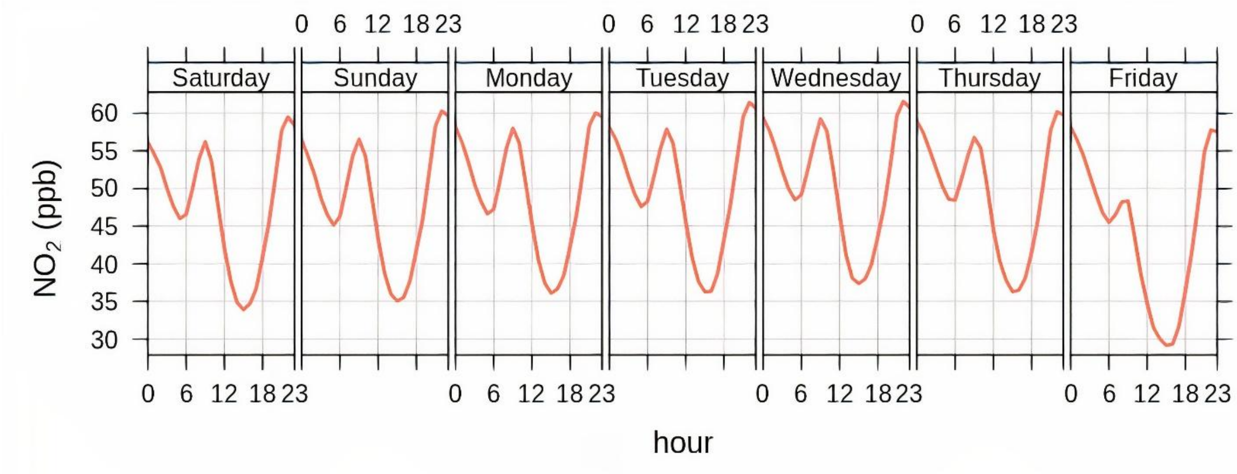

Fig. 7. Average temporal dynamics of NO_2 on different days and times of the week.

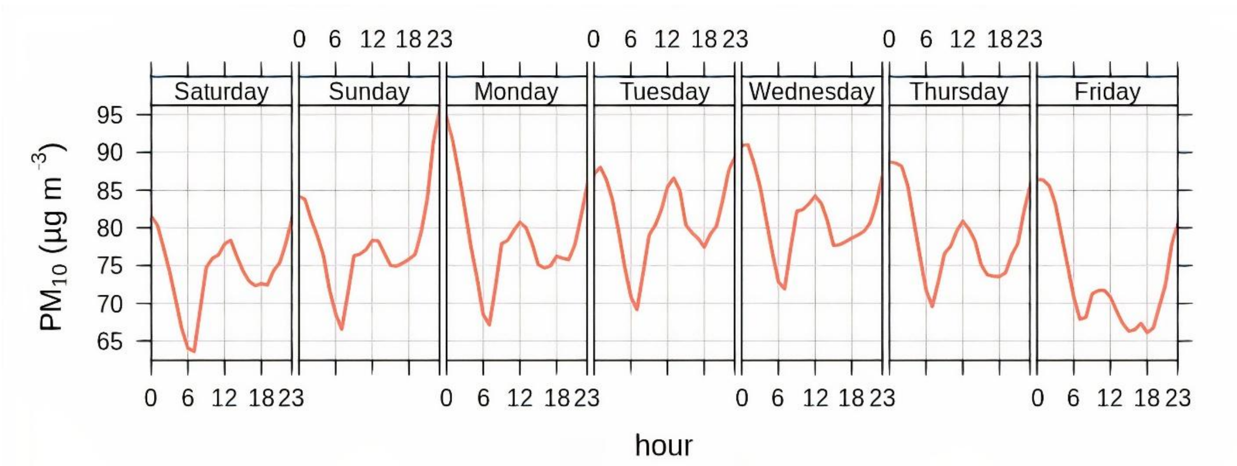

Fig. 8. Average temporal dynamics of PM_{10} on different days and times of the week.

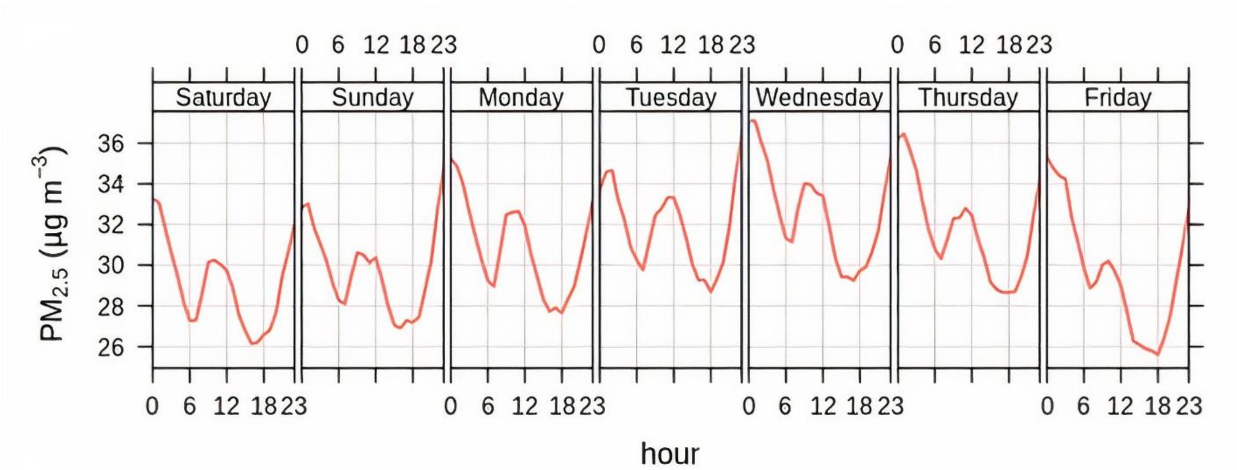

Fig. 9. Average temporal dynamics of $PM_{2.5}$ on different days and times of the week.

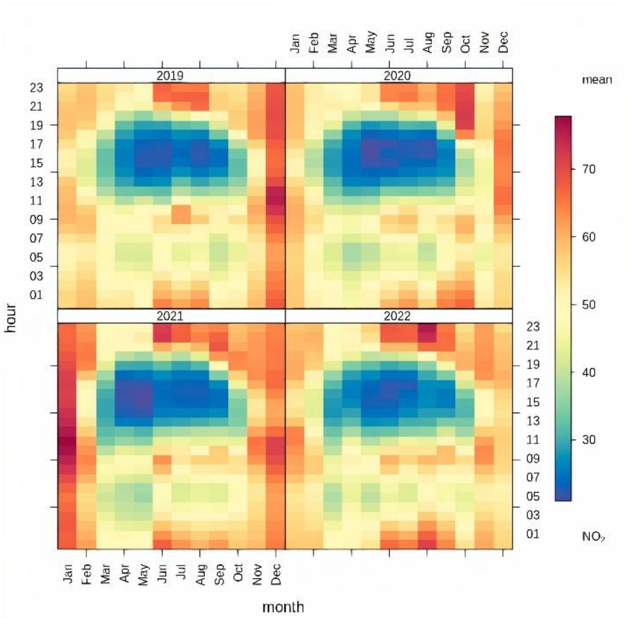

Fig. 10. Monthly, daily, and hourly average concentration of NO_2

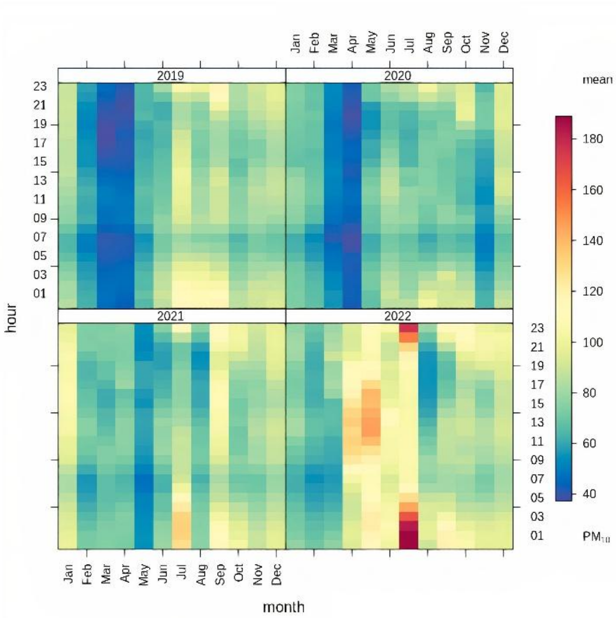

Fig. 11. Monthly, daily, and hourly average concentration of PM_{10}

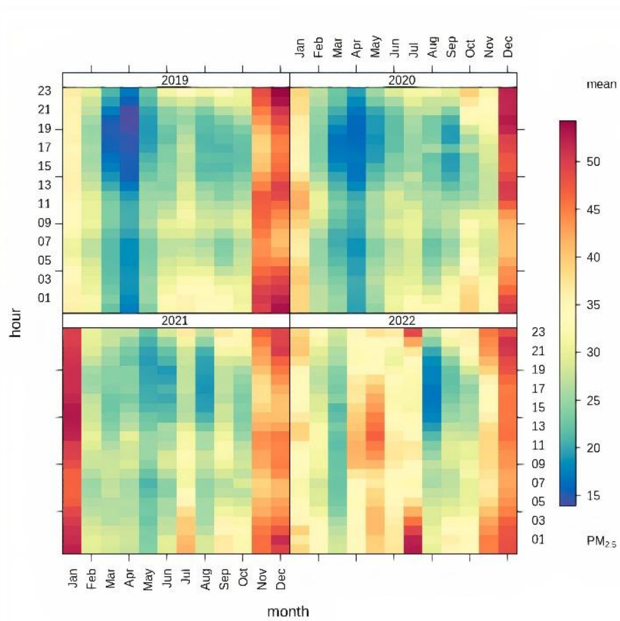

Fig. 12. Monthly, daily, and hourly average concentration of $PM_{2.5}$

References

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Emadodin, I., Taravat, A., & Rajaei, M. (2016). Effects of urban sprawl on local climate: A case study, north central Iran. *Urban Climate*, *17*, 230–247.