AIR QUALITY IN THE CITY OF HRADEC KRÁLOVÉ

Markéta Holíková, Martina Brenčič, Jaroslav Rožnovský
Czech Hydrometeorological Institute, Brno Branch, Kroftova 43, 616 67 Brno, Czechia

https://doi.org/10.11118/978-80-7701-087-0-0029

Abstract
Hradec Králové is traditionally regarded as a city with a high proportion of greenery, representing an inspiring example of an urban environment. Consequently, both visitors and residents experience diverse urban climates within the city. The Czech Hydrometeorological Institute (CHMI) operates two climatological stations (Nový Hradec Králové and Svobodné Dvory) and one air quality monitoring station (Brněnská) within the municipal area. The urban climate is further studied under the project *"Mitigation of the negative impacts of meteorological extremes (temperature, wind, and precipitation) on public health and the environment in large agglomerations."* Air temperature and humidity measurements are currently conducted at eight locations across the city. In this article, we present the results of an assessment of the urban climate and air quality with regard to the plan to plant additional fruit orchards as part of the urban greenery. We monitor the potential of fruit trees not only as adaptation elements of urban landscapes but also as bioindicators of pollution. As a specific case study, we provide the results of a microanalysis using the SEM/EDX method, identifying the nature of pollutants deposited on the surface of an apple leaf from the Na Potoce orchard.

Key words: urban environment, urban greenery, fruit trees, bioindication

Introduction
Currently, more people inhabit cities and large urban agglomerations than rural areas. This increasing concentration of inhabitants is inherently associated with energy production and environmental pollution. Under urban conditions, natural variability can be altered, which may impact, for instance, the health status of the urban population (Dobrovolný et al., 2012). The urban climate in the Czech Republic is characterized by the formation of urban heat islands, where built-up areas exhibit higher temperatures than the surrounding rural regions. The intensity of this phenomenon is influenced by the building structure, surface types, and the proportion of vegetation (Lehnert et al., 2023).
The city of Hradec Králové is situated in the Elbe Lowland (Polabská nížina) at an altitude of up to 240 m a.s.l., at the confluence of the Elbe and Orlice rivers, without significant topographic relief. From an urban climate perspective, it is crucial that the municipal territory also includes the extensive Hradec Forests (Hradecké lesy) and several ponds and water bodies, which significantly influence temperature and moisture conditions. A major advantage of Hradec Králové is that it ranks among the few cities in the Czech Republic with an extensive area of greenery. This is established by the original master plan from the early 1920s, designed by the architect Josef Gočár (1880–1945). In his concept of urban design, Gočár emphasized the significance and necessity of large-scale greenery. His vision focused on preserving green belts that naturally enter the city along the rivers. He created a ring road system encircling these belts and the entire city center, which has a positive effect on the microclimate and topoclimate of the urban environment.
As new structures are progressively built within the city, the urban environment continues to evolve. Urban surfaces are largely composed of materials that were not present in the original landscape. These materials possess distinct properties, particularly regarding radiation and energy balance. Water is rapidly drained from the city, while new emissions are generated. The issue of the urban environment has become a central subject of research, as the comforts of city life can, in certain situations, transform into negative impacts on the inhabitants (Rožnovský et al., 2023).
The utilization of vegetation for passive biomonitoring represents an effective method for assessing air quality in urban environments. In this context, the leaves and fruits of woody plants function as natural passive samplers that, due to their specific structure and epicuticular waxes, selectively accumulate a wide spectrum of aerosol particles (Prybysz et al., 2020). Unlike monitoring stations that provide real-time data, biological surfaces integrate the history of exposure throughout the entire growing season.
This study presents a methodological demonstration of using apple tree leaves for the detection of anthropogenic aerosols in an urban environment. The objective is to demonstrate the potential of leaf biomass for characterizing the immission situation within a specific microclimate and to identify the influence of traffic and other air pollution sources, even in locations situated outside major traffic hotspots.

Materials and methods

The climatological characteristics of any location within our territory are derived from measurements conducted at the climatological stations (hereinafter referred to as CS) of the CHMI, in accordance with the manual for observers of automated meteorological stations (Lipina et al., 2014). Within the territory of Hradec Králové, these include the Nový Hradec Králové and Svobodné Dvory sites. To characterize the urban climate, a network of specialized meteorological stations was established across various urban settings to evaluate the influence of different surfaces, built-up areas, and both scattered and continuous greenery.

For the study of aerosol particle deposition, an in-situ analysis of the native biomatrix was selected. This procedure involved fixing apple leaves onto aluminum stubs using conductive carbon tape, followed by sputter-coating with a thin layer of gold. The samples were analyzed in high vacuum mode (HV mode). The predicted dehydration of the plant tissue within the microscope chamber was employed as a methodological tool to enhance the microtopography of the leaf surface. This process revealed microstructural irregularities and grooves, resulting in the visual separation of deposited aerosols from the biological substrate. In the original hydrated state of the tissue, these particles would have been less identifiable within the micro-grooves.

Given the heterogeneity of the leaf surface, a combination of morphological and point EDX analysis was utilized. This methodology enables the detailed characterization of specific pollution markers directly within the biomatrix and provides insight into the interaction mechanisms between particulate matter and plant tissue. Point analysis targeted selected representative particles to determine their elemental composition and identify potential sources of anthropogenic contamination within the given microclimate.

Results

Figure 1a illustrates the progression of average monthly maximum air temperatures at CS Hradec Králové – Svobodné Dvory and CS Hradec Králové – Nový Hradec during the 2025 growing season. As observed, the differences in monthly averages for maximum temperatures are minor, however, more pronounced variations are evident in the average monthly minimum air temperatures season (Fig. 1b). of 2025 on the CS.

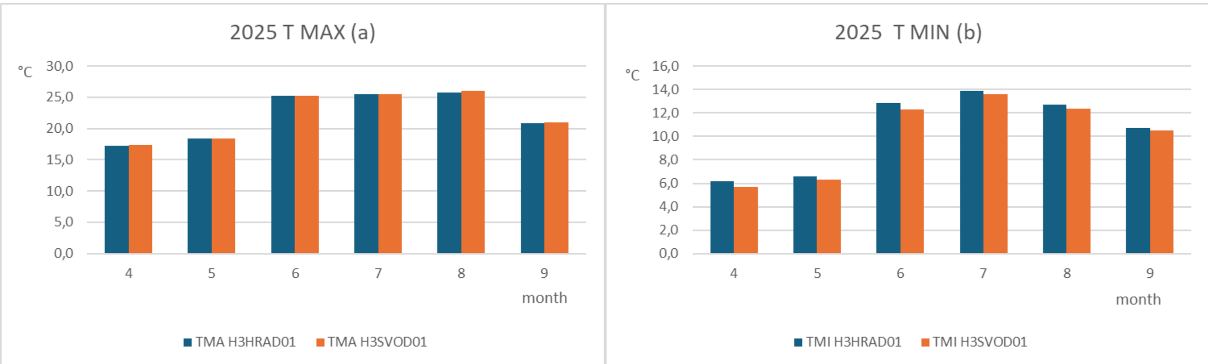

Fig. 1a,b: Average monthly maximum and minimum air temperature (°C) during the 2025 growing season at the climatological stations Hradec Králové – Svobodné Dvory (H3SVOD01) and Hradec Králové – Nový Hradec (H3HRAD01).

Regarding assessing thermal conditions for recreation within the city territory, it is essential to understand the temperature progression in individual urban areas with different surfaces and types of vegetation. To illustrate the differences between various urban locations, Figure 2 shows the maximum air temperature progressions for greenery (Jiráskovy sady), the city center (Velké náměstí), and forest cover (Lesní hřbitov). During the warmest periods, air temperature differences between the evaluated sites can exceed 8°C.

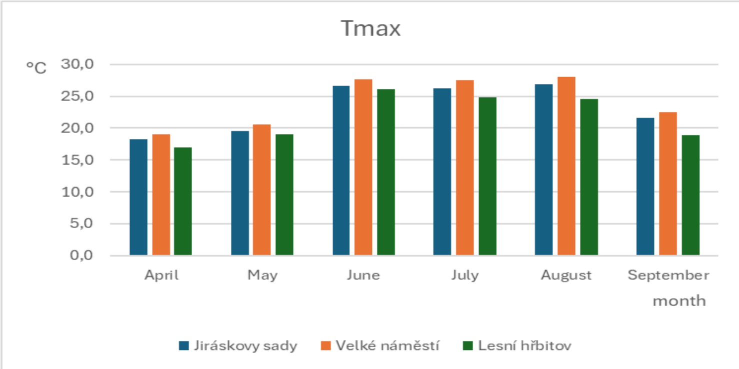

Fig. 2: Maximum air temperatures (°C) during the months of the warm half-year in 2025

This capacity of vegetation to regulate the urban microclimate is closely linked to the physiological and physical properties of the foliage, which also serve as a sink for pollutants within the urban ecosystem. Analysis of the apple leaf microtopography (Fig. 3) revealed a specific structure that fundamentally influences particle deposition. The leaf surface exhibits a finely structured labyrinth of micro-grooves and cuticular folds, forming a natural barrier for the deposited aerosol. This complex network of microstructures, further enhanced by controlled dehydration within the SEM environment, functions as an effective cumulative trap that mechanically fixes aerosol particles within the biomatrix.

This retention effect is likely amplified within the urban heat island microclimate, where stress conditions (high temperatures and low humidity) may lead to further roughening of the cuticle and increased surface micro-roughness. These structural changes in the tissue enhance the potential of leaf biomass to accumulate technogenic dust throughout the growing season, establishing the leaf as a relevant medium for monitoring long-term immission loads in a given locality

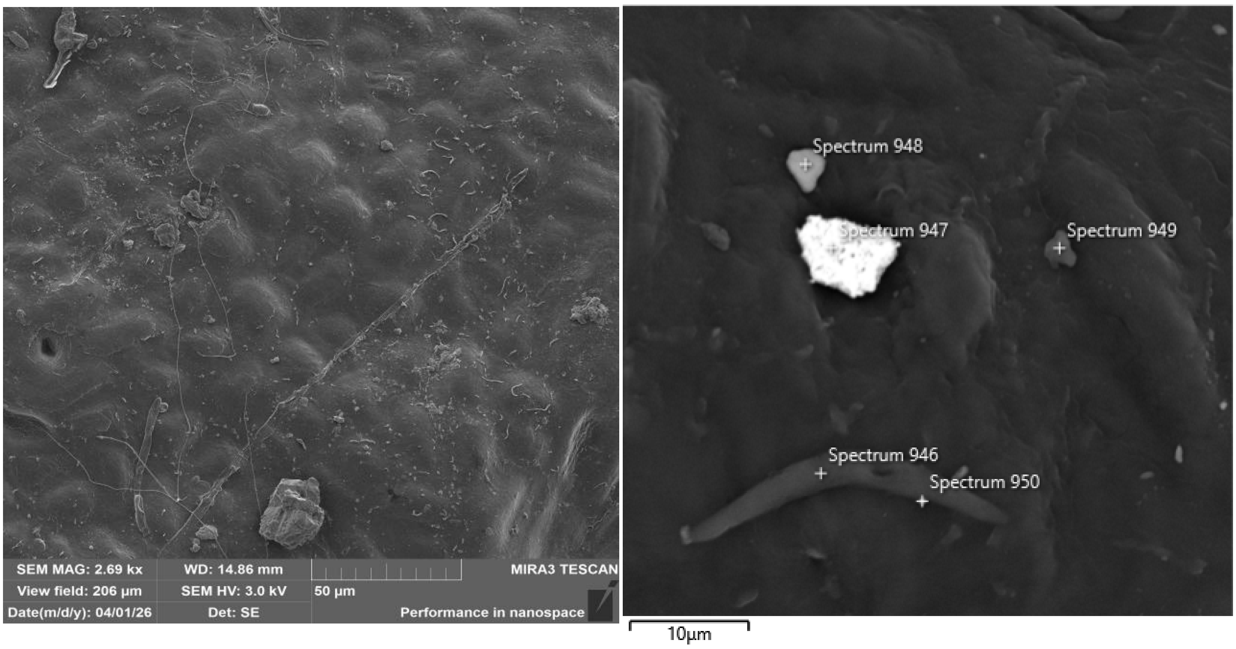

Fig. 3, 4: (Left) Scanning electron micrograph showing the structured cuticular relief with a labyrinth of micro-grooves serving as a natural trap for aerosol deposition. (Right) Backscattered electron (BSE) image highlighting dust particles (bright spots) on the organic leaf substrate due to their high atomic contrast.

The results of the point analyses of selected particles deposited on the apple leaf surface are presented below. The use of a backscattered electron (BSE) detector enabled efficient visual screening of the surface (Fig. 4). Due to high atomic contrast, particles with a higher atomic number (metals) appear as distinctly bright or luminous spots against the gray organic background of the leaf.

Detailed point microanalysis of the deposited particles (Table 1) confirmed the high heterogeneity of the sample and allowed for a distinction between the natural biogenic background and anthropogenic contamination. While spectra 946 and 949 correspond to biogenic structures with a dominant presence of carbon (approx. 76 wt. %) and oxygen (23 wt. %), a significant proportion of iron (32.56 wt. % Fe) was identified at point 947, accompanied by trace elements such as aluminum, silicon, and calcium. A significant share of iron (8.74 wt. %) was also detected at point 950, indicating the widespread presence of finer metallic dust within the investigated microenvironment.

The presence of aluminosilicates at point 948 (Si 3.44 wt. %, Al 3.00 wt. %) indicates the deposition of particles of geogenic origin (soil dust). The image also reveals the presence of organic microstructures (e.g., a fungal hypha in the lower part of Fig. 4). In BSE mode, these structures do not exhibit bright contrast, methodologically confirming their distinct, non-metallic nature—a finding further supported by the detection of potassium (K) as a biomass marker.

Tab. 1: Elemental composition of analyzed spectra (wt. %)

Spectrum Label	C	O	Al	Si	S	K	Ca	Fe
946	76.60	22.32	—	—	—	1.08	—	—
947	32.46	32.89	0.63	0.56	0.46	—	0.45	**32.56**
948	59.20	33.8	3.00	3.44	—	0.19	—	0.38
949	76.36	23.05	—	—	—	0.59	—	—
950	77.37	12.73	—	0.24	—	0.72	0.19	**8.74**

Conclusion

Our analyses of temperature conditions in the city of Hradec Králové confirmed that air temperatures in the urban environment partially differ from climatological station data depending on the surface, built-up area, and vegetation. The highest air temperatures were recorded in the built-up central part of the city, whereas temperatures in Jiráskovy sady and the Forest Cemetery stands were lower, making them more favorable for residents during extreme weather events.

This methodological demonstration confirmed that the apple leaf is a valid tool for the biomonitoring of urban aerosols. The BSE mode allowed for the distinction between the biogenic background and technogenic contamination, represented by sharp-edged particles with a high iron content (32.56 wt. % Fe). Their morphology corresponds to a mechanical origin (brake wear, corrosion), while their presence at the orchard locality Na Potoce suggests a widespread dispersion of emissions even outside major traffic hotspots.

The detection of potassium (K) in organic structures (e.g., fungal hyphae) served as a reliable marker for differentiating biomass from technogenic pollutants. Although metallic particles represent a numerically minority component of the aerosol here, their exact identification is a key indicator of the locality's environmental load. This pilot study thus demonstrates the potential of leaf biomass as a data source for the specific origin of air pollution which standard monitoring networks do not account for.

References

Dobrovolný, P., Řezníčková, L., Brázdil, R., Krahula, L., Zahradníček, P., Hradil, M., Doleželová, M., Šálek, M., Štěpánek, P., Rožnovský, J., Valášek, H., Kirchner, K., & Kolejka, J. (2012). *Klima Brna: Víceúrovňová analýza městského klimatu*. Masarykova univerzita.

Lehnert, M., Geletič, J., & Jurek, M. (2023). Traditional and novel approaches to studying the human thermal environment in urban areas: A critical review of the current state of the art. *Geografie*, 128 (3), 351–377. https://doi.org/10.37040/geografie.2023.012

Lipina, P., Kain, I., & Žídek D. (2014). Návod pro pozorovatele automatizovaných meteorologických stanic (2. upr. vyd.). Český hydrometeorologický ústav.

Przybysz, A., Stępniak, A., Małecka-Przybysz, M., Zhu, C., & Wińska-Krysiak, M. (2020). Particulate matter accumulation on apples and plums: Roads do not represent the greatest threat. *Agronomy*, *10*(11), 1709.

Rožnovský, J., Středštík, J., Litschmann, T., & Holíková, M. (2023). *Role městské vegetace na klima města Hradce Králové a jeho obyvatel formou hygrotermických koeficientů.* Česká bioklimatologická společnost.

Acknowledgement
This contribution was created as part of the project SS07020449, „Mitigation of Negative Impacts of Meteorological Extremes (Temperature, Wind, and Precipitation) on Public Health and the Environment in Large Agglomerations“.

Souhrn
Hradec Králové je tradičně vnímán jako město s vysokým podílem zeleně a v tomto ohledu představuje inspirativní příklad urbánního prostředí. Návštěvníci i obyvatelé města se zde tak pohybují v rozdílném městském klimatu. Český hydrometeorologický ústav (ČHMÚ) zajišťuje na území města měření na dvou klimatologických stanicích (Nový Hradec Králové a Svobodné Dvory) a na jedné stanici kvality ovzduší (Brněnská). Městské klima je studováno v rámci projektu *„Omezení negativních dopadů meteorologických extrémů (teploty, větru a srážek) na veřejné zdraví a životní prostředí ve velkých aglomeracích“*. Na území města probíhá měření teploty a vlhkosti vzduchu na 8 místech. V článku uvádíme výsledky hodnocení městského klimatu a kvality ovzduší s ohledem na záměr vysazovat další ovocné sady v rámci městské zeleně. Sledujeme potenciál ovocných dřevin nejen z hlediska adaptačních prvků městské zeleně, ale také jako bioindikátorů znečištění. Jako konkrétní příklad uvádíme výsledky mikroanalýzy pomocí metody SEM/EDX. Jedná se o identifikaci charakteru znečišťujících látek deponovaných na povrchu listu jabloně (sad Na Potoce).

Contact:
Markéta Holíková
E-mail: marketa.holikova@chmi.cz