

AIR POLLUTION ANALYSIS IN THE TERRITORY OF KAUNO KOLEGIJA APIARY

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Abstract. Urban beekeeping has become increasingly important for biodiversity conservation, pollination processes, environmental education, and sustainable food systems. Honey bees are recognised as sensitive bioindicators that reflect environmental pollution levels in urban ecosystems. However, urban environments are characterised by intensive traffic, industrial activity, and elevated concentrations of atmospheric pollutants that may negatively affect bee health, orientation, olfactory sensitivity, and foraging behaviour. Pollutants such as particulate matter, nitrogen oxides, sulfur dioxide, volatile organic compounds, and heavy metals may disrupt floral scent dispersion and impair insects' cognitive functions. Therefore, assessing air quality in urban apiaries has become an important research field.

This article presents an analysis of air pollution in the territory of the Kauno kolegija apiary located at Pramonės Ave. 20 in Kaunas, Lithuania. The study was carried out in 2025 using environmental monitoring data, legally established annual limit values, and GIS-based air pollution dispersion modeling maps. The aim of the study was to evaluate concentrations of major ambient air pollutants in the apiary environment and assess their compliance with Lithuanian and European Union legislation. The pollutants investigated included particulate matter (PM₁₀ and PM_{2.5}), nitrogen dioxide (NO₂), sulfur dioxide (SO₂), carbon monoxide (CO), and volatile organic compounds (VOCs).

The results demonstrated that none of the investigated pollutants exceeded the established annual limit values. The greatest potential concern was related to PM_{2.5}, whose concentration reached 92.9% of the permissible annual limit. PM₁₀ concentrations accounted for 50.85% of the limit value, sulfur dioxide for 60.5%, and nitrogen dioxide for 51.25%. Carbon monoxide and VOC concentrations remained very low, representing only 2.4% and 3% of the annual limits, respectively. Although all measured concentrations complied with current environmental requirements, previous scientific studies indicate that long-term exposure to fine particulate matter and heavy metals may negatively affect bees' orientation, olfactory sensitivity, learning abilities, and overall physiological condition.

The findings suggest that the current air quality in the territory of the Kauno kolegija apiary is suitable for urban beekeeping activities. Nevertheless, given the increasing urbanisation and transport-related pollution, continuous long-term air quality monitoring and further research are recommended.

Keywords: air pollution, apiary, particulate matter, concentration

Introduction

Air pollution remains a major environmental challenge due to its long-term effects on ecosystems and human health. According to available data, the transport sector alone is responsible for approximately 29% of total air pollutant emissions related to climate change (Lyu et al., 2021). Previous studies have demonstrated a relationship between increasing air pollution levels and declines in insect populations (Geetha et al., 2020; Dyer, Seeley, 1991; Negri et al., 2015; de Santana et al., 2018; Mair et al., 2023; Perugini et al., 2011).

The role of honey bees as bioindicators of environmental pollution has been increasingly studied in the scientific literature, particularly regarding the distribution of heavy metals and other chemical pollutants. Van der Steen et al. (2012) found that heavy metal concentrations in adult honey bees varied significantly over time and space. The authors discovered that seasonal variations are linked to bee foraging activity, while metal levels in bees directly reflect local pollution conditions. These results validate honey bees' suitability for tracking both immediate and long-term shifts in environmental contamination.

Lambert et al. (2012) examined bees, honey, and pollen as indicators of environmental lead pollution. The study showed a strong correlation between environmental lead concentrations and their accumulation in bee products, and also highlighted the importance of bee products not only from an ecological but also from a public health perspective. Similar results were reported by Zhou et al. (2018), who, using trace element analysis and lead isotopic composition, identified sources of pollution in European bee populations. Studies also revealed that metals found in bees are often associated with transport, industry, and urbanization (Taha et al., 2017; Khalifa et al., 2020; Al-Alam et al., 2019).

Governments employ a variety of measures to limit vehicle traffic, particularly in heavily urbanised areas, to reduce emissions. Particulate matter, in particular, is recognised as a significant source of air pollution from road transportation (Health Effects Institute, 2010). According to previous studies, investments in public transportation infrastructure can substantially reduce the use of private vehicles and reduce PM_{2.5} and

PM₁₀ emissions by up to 45%. Weather patterns play a significant role in pollutant dispersion, making air quality management more challenging.

The harmful effects of air pollution on human health have been extensively studied; however, its direct effects on insects have received considerably less attention. Pollutants from vehicles and industrial processes have been shown to interfere with floral scents, making it more difficult for insects to locate flowers. This phenomenon may contribute to the decline in bee populations observed in several regions, including California and the Netherlands. Reduced pollination efficiency affects both plants and insects and has broader ecological implications. Fuentes et al. (2008) suggest that rising air pollution levels, particularly during the summer, may play a significant role in these trends.

Studies have shown that floral scent compounds are chemically unstable and readily react with air pollutants, reducing their persistence in the environment. As a result, insects may spend more time searching for food and rely more on visual cues than on olfactory signals (McFrederick et al., 2007).

The object of the study is the apiary located on the grounds of Kauno kolegija.

The study aims to measure air pollution levels in this area and to assess their compliance with legally established limit values.

Research objectives:

1. To assess the concentrations of the main ambient air pollutants (PM₁₀, PM_{2.5}, NO₂, SO₂, CO, and VOCs) in the environment of the apiary located on the territory of Kauno kolegija.
2. To compare the determined pollutant concentrations with the annual limit values established by Lithuanian and European Union legislation.
3. To evaluate the potential long-term effects of ambient air pollutants on bee orientation, cognitive functions, and overall health.
4. To substantiate the need for continuous air quality monitoring in the apiary area to ensure favourable long-term conditions for bee populations.

Research Methodology

To assess air quality in compliance with EU regulations, Lithuania is divided into zones and agglomerations, including the agglomerations of Vilnius and Kaunas cities. Using data from the Dainava Air Quality Monitoring Station, air quality in Kaunas was assessed in 2025 as part of the national environmental monitoring program (Kauno miesto savivaldybės administracija, 2023). The apiary located on the grounds of Kauno kolegija served as the study site for the air pollution assessment (see Figure 1).

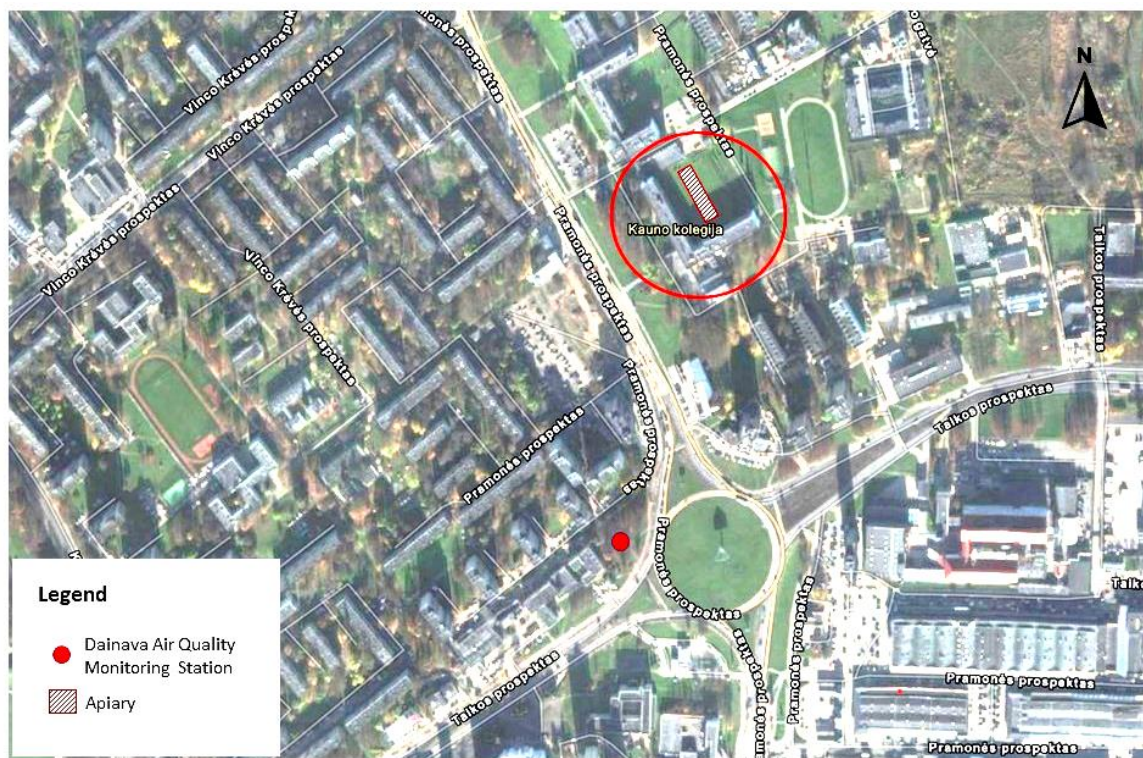


Fig. 1. The location of the apiary (the location of Kauno kolegija is defined by a circle) from the Dainava Air Quality Monitoring Station

The primary pollutants examined in this study included particulate matter (PM₁₀, PM_{2.5}), sulfur dioxide (SO₂), nitrogen dioxide (NO₂), carbon monoxide (CO), and volatile organic compounds (VOCs). In evaluating particulate matter concentrations, average daily values were compared with the annual limit values established by Lithuanian law. ArcGIS modeling software was used for data analysis. The artificial intelligence tool OpenAI ChatGPT was used to prepare this article, which helped clarify the phrases and international terms used. The analysis and conclusions presented in this study are the sole responsibility of the author.

Results and Discussion

According to the study, transportation and industrial activities are the primary causes of air pollution in Kaunas. The following average annual pollutant concentrations were recorded in the area surrounding the apiary in 2025 (see Table 1).

Table 1. Results of the air pollution assessment at the apiary

Name of the pollutant	Average Annual Concentration, Units of Measurement	Established Annual Limit Value, Units of Measurement
Particulate Matter PM ₁₀	20.34 µg/m ³	40 µg/m ³
Particulate Matter PM _{2.5}	9.29 µg/m ³	10 µg/m ³
Carbon monoxide (CO)	0.24 mg/m ³	10 mg/m ³
Nitrogen dioxide (NO ₂)	20.5 µg/m ³	40 µg/m ³
Sulfur dioxide (SO ₂)	12.1 µg/m ³	20 µg/m ³
Volatile organic compounds (VOCs)	0.03 mg/m ³	1.0 mg/m ³

Modeled air pollution dispersion maps for the apiary within the territory of Kauno kolegija are shown in Figure 2.

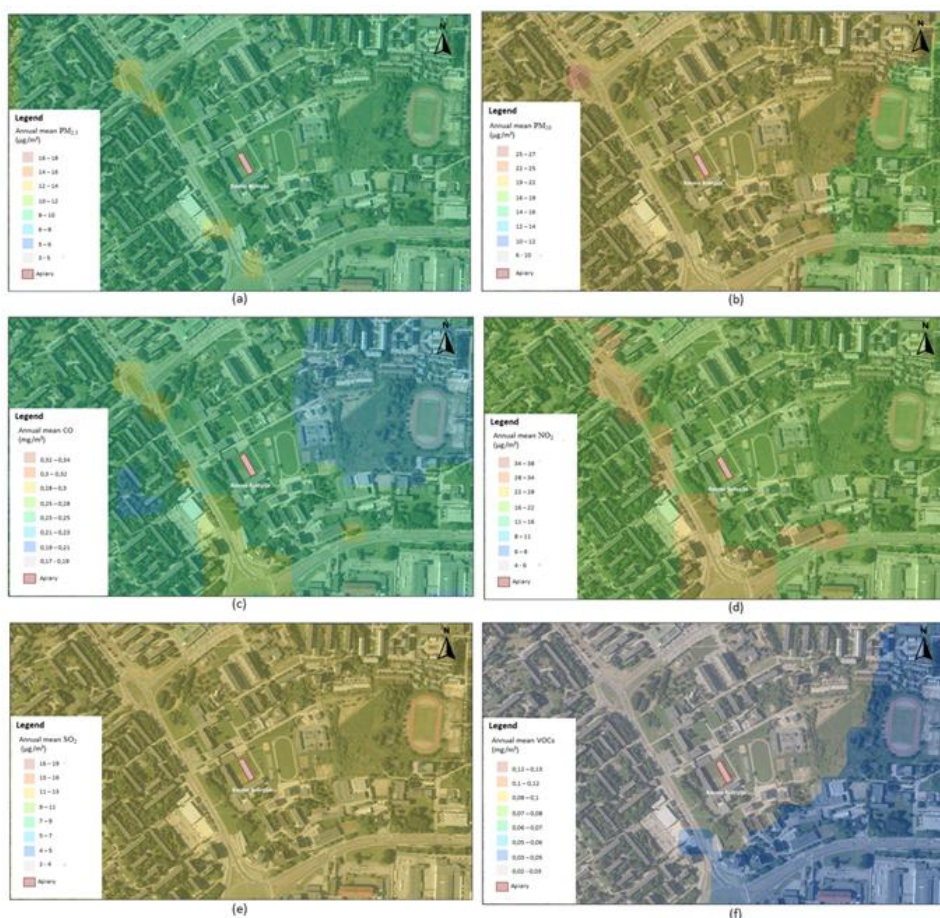


Fig. 2. Dispersion of: (a) Particulate Matter PM_{2.5}, (b) Particulate Matter PM₁₀, (c) Carbon monoxide (CO), (d) Nitrogen dioxide (NO₂), (e) Sulfur dioxide (SO₂), (f) Volatile organic compounds (VOCs)

The average annual concentration of PM₁₀ particulate matter reached 50.85% of the established limit value. This indicates that the PM₁₀ concentration remained within the permissible range. The average PM_{2.5} particulate matter concentration, however, is 92.9% of the limit value, suggesting that the concentration is approaching the limit and may require continued monitoring in the coming years to ensure compliance with standards.

Carbon monoxide (CO) concentrations were particularly low, accounting for only 2.4% of the annual limit value. Nitrogen dioxide (NO₂) concentrations were also below the limit, averaging 51.25% of the limit; however, long-term trends should continue to be monitored.

The average sulfur dioxide (SO₂) concentration was 60.5% of the limit value, indicating compliance with permissible levels. Volatile organic compound (VOC) concentrations were well below the established limit, with an average concentration of only 3% of the limit value.

All pollutant concentrations remained within the established limits. Carbon monoxide and VOC concentrations accounted for only 2.4% and 3% of the allowable limit, respectively, whereas the highest measured concentration was observed for PM_{2.5} particles, reaching 92.9% of the limit value.

Negative Impact of Air Pollution on Insects

Particulate matter is a major concern because it adsorbs toxic substances and provides a surface for the transport of harmful bacteria. These pollutants negatively affect both insect navigation and human health. Previous studies suggest that air pollution can reduce the intensity of floral scents, thereby impairing insects' ability to locate food sources and perform effective pollination.

Recent studies have reported adverse effects of metal pollution on bees' cognitive functions and brain development (Perugini et al., 2011; Gutierrez et al., 2015; Van der Steen et al., 2012). Bees living near pollution sources exhibited reduced olfactory function, according to research conducted in southern France (Monchanin et al., 2024). Additionally, research conducted in India revealed that air pollution decreases bee activity and may shorten their lifespan. Heavy metals and fine particles have been linked to the decline in bee health in urban areas by interfering with their ability to use scent to navigate (Monchanin et al., 2023).

One study specifically investigated how temperature, humidity, carbon monoxide (CO), and ozone (O₃) concentrations influence the flying, guarding, and foraging behaviours of *Hypotrigona gribodoi* bees. While the environmental parameters had a minimal impact on guarding behaviour, the research identified a strong correlation between elevated pollution levels and overall bee activity. This suggests that further analysis is required to fully understand the complex relationship between air pollution and bee behaviour (Combey et al., 2020).

Most studies have focused on specific pollutants or bee species, limiting the generalizability of the findings (Sheng et al., 2023; Escobedo et al., 2020; D'Amato et al., 2016; Kotzagianni et al., 2023). Moreover, assessing the effects of air pollution on bees in their natural habitats is challenging, as it requires complex monitoring methods and spatial modeling. Further comprehensive research is needed to better understand the long-term impacts of air pollution on bee populations, with a focus on the combined effects of multiple pollutants.

According to Ekström et al. (2022), there is currently limited research on the relationship between air pollution and the bees' olfactory abilities. The authors emphasise the importance of long-term studies to assess the complex effects of multiple pollutants as well as more detailed investigations into the combined effects of pesticide use and habitat conditions.

Conclusions

1. The greatest potential concern is associated with fine particulate matter PM_{2.5}, whose average annual concentration reached 92.9% of the permissible limit value. Although the limit was not exceeded, this proximity suggests a possible long-term negative impact on bees' orientation, cognitive functions, and overall health, particularly due to the ability of fine particles to transport heavy metals and other toxic compounds.
2. The analysis of ambient air pollution in the territory of the apiary at Kauno kolegija indicated that in 2025, the concentrations of all major investigated air pollutants did not exceed the annual limit values established by Lithuanian and European Union regulations. These findings suggest that the current air quality in the studied area is generally suitable for the establishment of an apiary and that the direct risk of air pollution to bee health is presently low.
3. The concentrations of other pollutants: carbon monoxide, volatile organic compounds, nitrogen dioxide, and sulfur dioxide were significantly below the established limit values and therefore do not currently

pose a substantial threat to bee activity. However, considering the variability of air pollution and the influence of urban and traffic-related factors, measurements from a single year may not fully reflect long-term trends.

4. In conclusion, although no exceedances of air quality limit values were identified in the apiary area, continuous air quality monitoring and implementation of preventive measures are recommended to ensure favourable long-term conditions for bee populations.

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ORO TARŠOS ANALIZĖ KAUNO KOLEGIJOS BITYNO TERITORIJOJE

Santrauka

Pastaraisiais metais miesto bitininkystė tampa svarbia biologinės įvairovės išsaugojimo, apdulkinimo procesų palaikymo ir aplinkosauginio švietimo dalimi. Bitės laikomos jautriais bioindikatoriais, galinčiais atspindėti urbanizuotų teritorijų aplinkos taršą. Tačiau miestų aplinkoje vyrauja intensyvūs transporto srautai, pramonės veikla ir padidėjusi atmosferos teršalų koncentracija, galinti neigiamai veikti bičių sveikatą, orientaciją, uoslę bei maisto paieškos elgseną. Kietosios dalelės, azoto oksidai, sieros dioksidas, lakieji organiniai junginiai ir sunkieji metalai trikdo kvapų sklaidą bei gali mažinti bičių pažintines funkcijas. Todėl miesto bitynų oro kokybės vertinimas tampa svarbia tyrimų kryptimi.

Straipsnyje pateikiama Kauno kolegijos bityno teritorijos, esančios Pramonės pr. 20 Kaune, oro taršos analizė. Tyrimas atliktas 2025 m., remiantis aplinkos monitoringo duomenimis, teisės aktuose nustatytais ribinėmis vertėmis ir GIS pagrindu sudarytais oro taršos sklaidos modeliais. Tyrimo tikslas – įvertinti pagrindinių oro teršalų koncentracijas bityno teritorijoje bei nustatyti jų atitiktį Lietuvos Respublikos ir Europos Sąjungos teisės aktuose numatytoms metinėms ribinėms vertėms. Analizuotos PM₁₀ ir PM_{2.5} kietųjų dalelių, azoto dioksido (NO₂), sieros dioksido (SO₂), anglies monoksido (CO) ir lakiųjų organinių junginių (VOC) koncentracijos.

Tyrimo rezultatai parodė, kad nė vieno tirto teršalo koncentracija neviršijo nustatytų ribinių verčių. Didžiausia potenciali rizika nustatyta PM_{2.5} dalelėms, kurių koncentracija siekė 92,9 % leistinos ribos. PM₁₀ koncentracija sudarė 50,85 %, sieros dioksido – 60,5 %, azoto dioksido – 51,25 % ribinės vertės. CO ir VOC koncentracijos buvo labai mažos – atitinkamai 2,4 % ir 3 % leistinos normos. Nors nustatyti rodikliai atitiko aplinkosauginius reikalavimus, ankstesni tyrimai rodo, kad ilgalaikis smulkiųjų dalelių ir sunkiųjų metalų poveikis gali bloginti bičių orientaciją, uoslės jautrumą ir bendrą fiziologinę būklę.

Gauti rezultatai leidžia teigti, kad dabartinė oro kokybė Kauno kolegijos bityno teritorijoje yra tinkama miesto bitininkystei. Vis dėlto, didėjant urbanizacijai ir transporto taršai, rekomenduojama tęsti ilgalaikę oro kokybės stebėseną ir tolesnius tyrimus.

Reikšminiai žodžiai: oro tarša, bitynas, kietosios dalelės, koncentracija

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