The Impact Of Air And Noise Pollution On Honeybee (Apis Mellifera L.) Productivity Across Multiple Habitats

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Abstract. *Honeybees (Apis mellifera L.) play a critical role in pollination, agriculture, and ecological monitoring, yet their productivity is increasingly threatened by environmental pollutants. This study investigates the combined effects of air and noise pollution on honeybee colony performance across habitats in the Kurdistan Region of Iraq. Colonies were assessed for honey production, brood development, and pollen storage, alongside measurements of PM, formaldehyde (HCHO), total volatile organic compounds (TVOCs), and ambient noise levels. The results revealed that higher levels of air and noise pollution were associated with reduced colony productivity, particularly affecting brood development and pollen collection. These findings highlight the importance of managing environmental quality to support sustainable apiculture and suggest that honeybee productivity serves as a sensitive indicator of anthropogenic pollution.*
Keywords *Honeybee productivity, Air pollution, Noise pollution, Apis mellifera, Particulate matter (PM), Volatile organic compounds (VOCs), Environmental stressors.*

1. INTRODUCTION

The Western honeybee (Apis mellifera L.) is commonly raised in the Kurdistan Region of Iraq, where its interactions with plants play an important role in supporting rural livelihoods as well as enhancing agricultural productivity and maintaining ecological balance (Hung et al.,2018). Due to their widespread presence, rapid reproduction, manageable breeding, and distinct behavioral and morphological traits, honeybees are considered highly effective organisms for environmental biomonitoring (Smith et al.,2019). Their sensitivity to ecological changes allows them to serve as reliable indicators of environmental health, reflecting the impacts of various stressors within their surroundings.

In recent decades, environmental pollution has become a major global concern due to its widespread and multifaceted impact on ecosystems. Pollutants originating from industrial activities, transportation, agriculture, and urban development introduce a range of chemical and physical stressors—including heavy metals, pesticides, particulate matter, and noise—into natural systems. These contaminants can alter species behavior, physiology, and survival, particularly in sensitive organisms such as pollinators (Duque & Steffan-Dewenter, 2024).

Among these stressors, air and noise pollution—driven by accelerating urbanization and industrial activity—have become growing concerns (Tkáč et al.,2024). These pollutants can interfere with essential behaviors such as foraging, navigation, and communication within the hive, ultimately compromising colony stability and reducing honey production across various habitats (Di et al.,2025). Crucially, honeybees depend on flowering plants for their nutritional needs, yet air pollution has been shown to hinder their scent-based foraging ability by disrupting the detection of floral odors (Papazian & Blande, 2020). In addition to affecting foraging, exposure to air pollutants can significantly disrupt honeybee communication and navigation. For instance, contaminants weaken the bees' ability to detect alarm pheromones by diminishing their antennae's electroantennography response, which impairs swarm coordination (Saunier et al., 2023, Coallier et al.,2025). Additionally, elevated $PM_{2.5}$ levels common in polluted urban aircan distort skylight polarization, a key navigational cue for foraging bees, leading to longer and less efficient foraging trips (Cho et al.,2021). When combined, these stressors can interact synergistically, further compromising the bees' resilience to environmental challenges (Thimmegowda et al.,2020).

Foraging bees, specifically, transport chemical residues—including pesticides and volatile organic compounds (VOCs)—back to the hive, effectively turning the colony into a living indicator of the surrounding environmental conditions (Chauzat et al.,2011). It is well recognized that honeybee colonies are increasingly exposed to environmental challenges such as intensive agriculture, which often replaces natural habitats and undermines long-term colony survival (Olate-Olave et al.,2021). Research has shown that both biotic and abiotic stressors—ranging from pests and pathogens to pesticides, habitat loss, and climate extremes interact in complex ways to affect honeybee health (Minaud et al.,2024, Amiri et al.,2025). Over the past few decades, the intensification of agricultural practices, the widespread use of agrochemicals, habitat fragmentation, and the introduction of invasive species have contributed to a decline in honeybee resilience. These factors, combined with pollution and shifting climatic conditions, continue to impact the vitality and productivity of Apis mellifera colonies across diverse ecosystems (Minaud et al.,2024).

Despite growing global awareness, there remains a lack of region-specific studies addressing the combined impact of air and noise pollution on honeybee productivity. This study aims to fill that gap by investigating how such environmental stressors influence Apis mellifera colonies across multiple habitat types in the Kurdistan Region of Iraq.

2. MATERIALS AND METHODS

This study was carried out in October 2024 in Duhok Governorate, northern Iraq, across multiple habitat types characterized by varying levels of air and noise pollution. The selected sites included urban areas (Duhok city and Semel), suburban zones (College of Agricultural Engineering Sciences and Marina), agricultural/rural areas (Hawreske village), and natural environments (Ekmalay village). Table (1)

Table 1: Geographical Coordinates and Altitudes of Selected Locations

Location	Latitude	Longitude	Altitude
Ekmalay	36°54'19"N	43°03′04″E	747 m
College	36°51'37"N	42°52'06"E	476 m
Marina	36°55'04"N	42°47′00″E	484 m
Hauriske	36°53'50"N	42°42′47″E	434 m
Semel	36°51'38"N	42°50'03"E	453 m
Duhok	36°51′00″N	42°56′06″E	482 m

At each site, colonies of Apis mellifera were established, with three colonies per apiary housed in standard Langstroth hives. All colonies were of comparable size and strength, maintained in 7-frame hives, and managed under uniform conditions throughout the study to ensure consistency across locations.

Air pollution was measured using portable air quality monitor (LifeBasis Formaldehyde Detector Air Quality Monitor It measures formaldehyde, VOCs, particulate matter (PM1.0, PM2.5, PM10), temperature, and humidity). The monitored pollutants included particulate matter ($PM_{1.0}$, $PM_{2.5}$, and PM_{10}), formaldehyde (HCHO), and total volatile organic compounds (TVOCs). Measurements were conducted between 9:00 a.m. and 3:00 p.m. Coinciding with peak honeybee foraging activity on clear weather days to minimize variability caused by climatic conditions. Each pollutant was recorded over a 30-minute interval, and the average concentration was used for subsequent analysis.

Noise pollution levels were measured using a calibrated handheld sound level meter decibel (dB) (Tadeto S7120 Sound Level Meter). At each site, noise was recorded continuously for a 10-minute period during active foraging hours. The average sound pressure level, expressed in decibels (dB), was calculated for each location. All measurements were conducted once per site under consistent weather conditions and comparable ambient activity levels to ensure data reliability.

Honeybee colony productivity was assessed through three parameters: brood area, stored honey, and stored pollen, using a frame-by-frame inspection method with an inch grid counter.

1. Brood Area: Each brood frame was visually inspected, and the area of sealed brood was estimated using an inch-grid counter placed over the frame. Both sides of each brood frame were measured, and the total brood area per colony was calculated.
2. Honey Storage: The area of capped honey was measured using the same inch-grid method. Capped honey was estimated for each frame side, summed per colony.

3. Pollen Stores: The area of stored pollen (typically visible as multicolored cells) was similarly assessed using the inch counter and recorded per frame.

Measurements were taken at the end of the foraging season (October 2024), Colony strength and queen presence were confirmed prior to data collection.

The data were statistically analyzed by SAS program using Complete Randomized Design (CRD) with three replicates and the means were compared using Duncan's multiple range tests at $P \leq 0.05$.

2. RESULTS AND DISCUSSION

2.1. PRODUCTIVITY PARAMETERS: HONEY, POLLEN, AND BROODS

In honeybee colonies, productivity is typically assessed through key indicators such as honey yield, pollen collection, and brood development. These parameters reflect the overall health, foraging efficiency, and reproductive capacity of the colony (Brodschneider & Crailsheim, 2010). Honey yield serves as a direct measure of nectar foraging and energy storage, while pollen intake is essential for protein nutrition and brood nourishment. Brood count indicates the reproductive output and future population size of the hive. Variations in these metrics across different habitats can reveal the influence of environmental stressors, including air and noise pollution, on colony performance. (Karakas & Gülse Bal, 2019; Szymańska et al.,2022).

Honeybee productivity, as measured by honey yield, pollen collection, and brood size, varied significantly across the six study locations. Hauriske recorded the highest honey production (418.33g) and brood count (156.33), alongside the highest pollen yield (101.67g). In contrast, Ekmalay2 exhibited the lowest values across all three-productivity metrics, with honey at 204.67g, pollen at 10.33g, and broods at 44.

These findings are consistent with previous studies showing that honeybee productivity is strongly influenced by environmental stressors such as pollution, habitat quality, and resource availability (Alburaki et al.,2017; Di Prisco et al.,2013). Based on our field observations, the high productivity recorded at Hauriske can likely be attributed to its favorable environmental conditions. This location was completely isolated from pollution sources, with hives positioned within a cultivated farm surrounded by diverse tree species and a consistent water supply factors that together support healthy brood development, foraging activity, and colony strength. In contrast, Ekmalay2 showed the lowest productivity across all measured parameters, which corresponds with the site characteristics we observed. Although located away from major roads, the site was situated on a steep, exposed slope with limited vegetation and no accessible water sources, likely creating suboptimal foraging conditions and increasing physiological stress on the colonies.

2.2. AIR POLLUTION

Formaldehyde (HCHO) is a widespread air pollutant, often emitted from traffic and industrial activities. Though research on its direct effects on honeybees is limited, HCHO is known to cause respiratory and oxidative stress in insects, which can impair foraging efficiency and overall colony performance (Kim et al.,2019; Rabea et al.,2010). formaldehyde (HCHO) levels varied significantly, with the highest concentration observed in Semel (0.35 ppm), which also showed relatively low productivity. The lowest HCHO levels were found in Ekmalay2 (0.006 ppm), yet this location also had the lowest productivity, suggesting that HCHO alone may not be a direct predictor of bee health, but might interact with other factors (Neumann & Carreck, 2010).

Particulate matter (PM2.5, PM1.0, PM10) from air pollution can accumulate on honeybees' bodies, impairing their flight and foraging abilities. Exposure to PM also induces oxidative stress and weakens immunity, negatively affecting colony health and productivity (Khalid et al.,2024). Particulate matter (PM2.5, PM1.0, PM10) levels varied significantly across the study locations and influenced honeybee productivity. According to the World Health Organization (WHO) 2021 Air Quality Guidelines, the recommended 24-hour mean limits for PM10 and PM2.5 are 45 $\mu g/m^3$ and 15 $\mu g/m^3$, respectively. In our study, Marina exceeded the daily PM2.5 limit (25 $\mu g/m^3$) but still recorded relatively high honey yield (374.33g), suggesting that moderate, short-term exceedances may not immediately impair colony productivity. In contrast, Duhok showed relatively high PM1.0 (26 $\mu g/m^3$) but moderate PM2.5 and PM10 levels, again paired with high honey yield, suggesting that other local factors such as access to forage and water may modulate pollutant impact. However, research has shown that particulate pollution can interfere with bee orientation and foraging behavior by reducing visual range and altering environmental cues (Esaias et al.,1985). Additionally, sustained PM exposure is known to induce oxidative stress and immune suppression in honeybees, which could impact long-term colony viability (Devillers et al.,2002; Calatayud-Vernich et al.,2018).

2.3. VOLATILE ORGANIC COMPOUNDS (VOCS)

volatile Organic Compounds (VOCs) are airborne chemicals that can affect bee health by impacting their nervous system. Marina (0.13 ppm) and Duhok (0.104 ppm) exhibited the highest TVOC levels and the lowest pollen yields—5.67g and 5g, respectively. High TVOC concentrations are known to interfere with bees' olfactory perception, disrupting their ability to detect floral cues and forage efficiently. Prolonged exposure can also impair neurological functions, reducing overall productivity and foraging motivation (Girling et al.,2013; Noël et al.,2022). These results emphasize how air pollution directly impacts bee behavior and colony health. In addition, areas with high TVOC levels often coincide with urban or disturbed environments that may already have fewer floral resources or fragmented green spaces. This combination of fewer flowers and impaired foraging ability results in significantly lower pollen intake, as seen in both Marina and Duhok.

2.4. NOISE POLLUTION

Noise is an unwanted or disturbing sound that interferes with normal activities. Noise pollution disrupts insect communication, mating, and foraging, leading to declines in population and biodiversity (Morley et al.,2014).

The noise levels recorded ranged from 37 dB (Ekmala2) to 75 dB (Semel). Semel, with the highest noise exposure (75 dB), showed the lowest brood count (47), as well as reduced honey (258.67 g) and pollen (5.67) yields, indicating significant negative effects of noise on colony productivity. This supports findings by by Phillips et al. (2021), who reported that noise pollution adversely affects pollinator behavior, reducing foraging efficiency and reproductive success.

Conversely, Hauriske (50 dB) exhibited the highest brood (156.33), honey (418.33 g), and pollen (101.67) yields, demonstrating colony resilience to moderate noise. These results align with broader research linking noise levels above 50-60 dB to disruptions in honeybee communication and foraging behavior (Franks & Farquhar, 2024).

Overall, our results emphasize that high noise pollution (>60 dB) negatively impacts honeybee colony health, particularly brood and pollen collection, and underscore the need for noise mitigation in apiary management.

Table 2: Environmental and Biological Measurements Across Locations

Locations	**Honey**	**Pollen**	**Broods**	**HCHO**	**Pm2.5**	**Pm1.0**	**Pm10**	**TVOCs**	**Noise**
Ekmalay2	204.67c	10.33c	44c	0.006c	16b	10cd	21c	0.013e	37
College	330.33b	67.33b	81bc	0.018b	16b	9d	20c	0.104b	46
Marina	374.33ab	5.67c	93.33b	0.02b	25a	30a	15d	0.13a	54
Hauriske	418.33a	101.67a	156.33a	0.012bc	18b	10cd	24b	0.092c	50
Semel	258.67c	5.67c	47c	0.35a	18b	12c	32a	0.078d	75
Duhok	410a	5c	63bc	0.01bc	16b	26b	16d	0.104b	63

Means followed by a common letter within the same column are not significantly different at the 5% level according to Duncan's Multiple Range Test (DMRT).

CONCLUSION

This study confirms that elevated air and noise pollution significantly reduce honeybee colony productivity.

Higher levels of TVOCs, particulate matter, and noise—especially above 60 dB—were linked to declines in brood size, pollen intake, and honey yield. Additionally, moderate pollution levels showed potential sublethal effects that could impact long-term colony resilience. The results also highlight that access to diverse floral resources can partially mitigate the negative impacts of pollution. These findings emphasize the need for pollution mitigation in apiary management and reinforce the role of honeybees as effective bioindicators of environmental health.Research-wise, there is room for exploitation in this topic of research since not so many things of the Era of National Rise have unfolded. To say the least, in the aspect of politics, Vietnam's foreign policy and diplomacy will have to change to serve the goals in this new era of development.

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