Assessing Environmental Contamination Through Pollen Analysis of Solitary Cavity-Nesting Resin Bees Around Kolhapur City

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Abstract

This study examines how pollen-nectar mixtures collected by solitary cavity-nesting resin bees can serve as bioindicators of environmental pollution. Researchers utilized paper straw trap nests across various locations, including agricultural (Shirgaon to Kandalgaon road in Gokul Shirgaon, Kolhapur), industrial (MIDC Shiroli, Kolhapur), urban (Dabolkar Corner, Kolhapur City), and a control area (KIT's College of Engineering, Gokul Shirgaon, Kolhapur). The nests, installed in February 2024, contained empty straws and some partially packed with larvae from the control area. These nests were designed to mimic natural habitats, allowing mature bees to build nests and create pollen-nectar mixtures for their offspring. Analysis aimed to detect environmental contaminants in these mixtures. Only one sample from the industrial area (Trap Nest Location 5 at Quality Castings, MIDC Shiroli) was recovered, showing elevated levels of iron, manganese, chromium, and nickel, consistent with industrial emissions. In contrast, the control area produced viable samples with detectable levels of magnesium, zinc, iron, aluminum, and barium. The absence of samples from urban and agricultural areas suggests adverse conditions affecting bee populations. This underscores the sensitivity of resin bees to pollution and highlights their role as bioindicators. The study emphasizes the need for effective environmental management to enhance habitat quality and protect both bees and human health.

Keywords: Bioindicators, Heavy Metal Contamination, Resin Bees

1. Introduction

The relationship between biodiversity and environmental health has become a central issue in environmental science across many fields and legal frameworks. The evaluation of species and population health has gained importance since Burger's seminal observations in 2006, and since then, there has been an increased focus on bioindicators, especially with regard to plants and heavy metals.

The delicate balance of wild bee populations, which is essential for pollination in temperate zones, is significantly threatened by heavy metals, which are well-known for their ongoing harm to ecosystems (Moroń et al., 2012). According to Moroń et al. (2012), there is a double threat to bee populations: they are in danger of losing their ability to pollinate wildflowers and agricultural crops, which is a crucial service. Although heavy metal contamination is widely acknowledged, there is still a crucial knowledge vacuum regarding the precise effects on wild bee populations (Moroń et al., 2012).

Alarming amounts of heavy metals, including arsenic (As), lead (Pb), cadmium (Cd), and chromium (Cr), often surpassing allowable limits, have been found in bee bread and pollen, according to recent investigations (Roman et al., 2016). This emphasises how important bioindicators are for monitoring environmental contamination, especially in isolated locations far from major cities (Skorbiłowicz et al., 2018).

Because of their complex interactions with their surroundings, honey bees are useful bioindicators for a variety of pollutants, including heavy metals (Skorbiłowicz et al., 2018). Research has clarified how urbanisation, industrialization, and vehicle emissions affect bee populations' seasonal fluctuations in metal concentrations (Skorbiłowicz et al., 2018). Furthermore, Taha et al. (2017) found that the concentrations of heavy metals found in honey, pollen, and foraging bees are greatly impacted by the proximity to sources of pollution.

Research on red mason bees has shown that exposure to heavy metals can hinder growth and cause morphological anomalies, such as asymmetry in forewing development (Szentgyörgyi et al., 2017). Furthermore, the growth and survival of species of bees that nest in cavities might be adversely affected by chemicals found in nesting materials (Peterson et al., 2021). Leita et al. (1996) emphasised the significance of honey bees and their products as critical indicators of environmental contamination, highlighting the ubiquitous nature of heavy metal deposition.

Royal jelly, propolis, honey, and other bee-derived products are high in vital nutrients, but they also contain hazardous levels of heavy metals, thus they must undergo stringent quality testing before being consumed (Matuszewska et al., 2021). Honey bees continue to be essential in environmental monitoring programmes because of their capacity to accumulate a broad range of contaminants in their bodies and products (Perugini et al., 2011).

The complex relationships that exist between bee populations and pollution highlight the wider consequences for the health of ecosystems and human well-being. To lessen the negative effects of environmental pollutants on these important pollinators and the ecosystems they sustain, more research and careful observation are required. It is impossible to overestimate the importance of bioindicators like honey bees in preserving ecological integrity as we navigate an increasingly challenging environmental future.

2. Material and Methods

2.1 Study Area

The purpose of this study is to examine the potential use of pollen-nectar mixes gathered by solitary cavity-nesting resin bees as markers of environmental contamination. The study area is near Kolhapur City, Maharashtra, India. It features multiple unique environmental settings, including:

1. To begin with, the control area is located at four different locations within KIT's College of Engineering in Gokul Shirgaon, Kolhapur (16.654357°N 74.261807°E, 16.654451°N 74.261645°E, 16.654501°N 74.261250°E, and 16.654861°N 74.261230°E). This area is thought to be relatively free of human disturbance and to have lower pollution levels than other sites.
2. Second, the agricultural landscape in Gokul Shirgaon, Kolhapur (at two locations: 16.64449°N 74.268693°E and 16.642586°N 74.258754°E) represents areas impacted by agricultural practices like crop cultivation and the use of pesticides, which may have an effect on pollinator health and the quality of floral resources.
3. Third, Kolhapur's MIDC Shiroli (seven locations: The industrial zone is defined by the following lo-

cations: Gnat Foundry Pvt. Ltd. (16.75507°N 74.27848°E), Yashoda Iron Industries (16.75558°N 74.27698°E), Near Raysons Shell Cast (16.75741°N 74.27612°E), Near Siddharth Foundry Pvt. Ltd. (16.756426°N 74.274603°E), Near Quality Castings (16.753211°N 74.274344°E), Near Shriram Foundry Pvt. Ltd. (16.753702°N 74.268542°E), and Datum Industries (16.753678°N 74.267544°E) constitute the industrial zone.

4. Last but not least, the study's urban location is Dabolkar Corner in Kolhapur City (Cosmos Commercial Complex; 16.704968°N 74.243566°E), which highlights the difficulties pollinators encounter in urban settings, such as habitat fragmentation, a decline in floral diversity, and exposure to toxins from the city.

We can evaluate how resin bees react to different environmental stresses by examining the pollen-nectar mixtures they gather at these carefully chosen sites, which range in environmental conditions from relatively clean to heavily influenced by human activity.

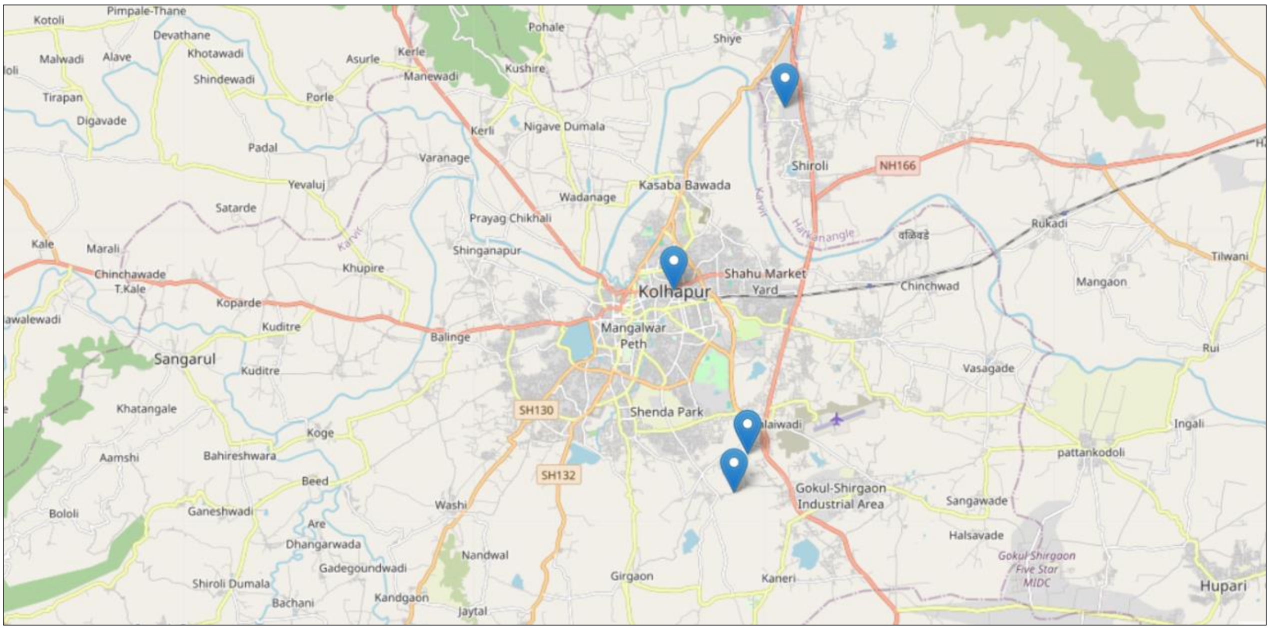

Figure 1 – Distribution of Study Sites around the Kolhapur City

2.2 Trap Nest Installation

2.2.1 Timing

Trap nests were positioned around Kolhapur City in February 2024 in order to coincide with the best time for resin bees to build their nests.

2.2.2 Design

Paper straws that were chosen especially to replicate the natural nesting environments that resin bees prefer were used to carefully construct the trap nests. Each trap nest was made up of a combination of straws that were empty and straws that had resin bee larvae inside of them. It was a calculated decision to include empty straws because the goal was to draw resin bees and encourage them to use them as possible nesting locations. The larvae of resin bees kept in some of the straws were initially taken in May 2023 from the control region. By February 2024, we expected these larvae to reach adulthood and become resin bees. When these resin bees grew to adulthood, they were expected to perform mating behaviours. The empty straws that were included in our trap nests would thereafter be the ideal spots for female resin bees to build their nests. As soon as the resin bees were settled within the paper straws, they would start collecting a combination of pollen and nectar. Their young rely on this pollen-nectar mixture for vital nutrition, which helps them grow inside these made-up nests. Gathering and examining these pollen-nectar combinations was our main objective. Our goal in doing this investigation was to determine whether environmental pollutants were present or not.

2.3 Sampling and Collection

2.3.1 Callenges

Despite the intended sampling approach, several difficulties arose during the collection phase. Resin bee populations in agricultural and urban areas were likely impacted by unfavorable environmental conditions like high air pollution, limited floral resources and insufficient nesting materials. These factors prevented viable pollen-nectar samples from being obtained in those settings, making it challenging to compare environmental pollutants across all chosen locations. However, viable samples were successfully obtained from both the control area and one industrial location, providing key insights despite the overall challenges.

2.3.2 Control and Industrial Samples

Both the control area at KIT's College of Engineering in Gokul Shirgaon, Kolhapur, and one industrial location (Trap Nest Location 5 at Quality Castings in MIDC Shiroli, Kolhapur) produced viable pollen-nectar samples. The control samples demonstrated that resin bees could successfully gather and store pollen-nectar mixes in this region, serving as a reference point for comparing the conditions across different locations. The industrial sample, though limited, also provides valuable data alongside the control samples.

2.3.3 Sampling Strategy

Eight eight-inch-long paper straws were taken from two trap nests at each of the four locations in the designated control area (behind IDEA Lab, behind the main building, opposite the library, and near the biotechnology building) and one straw from the industrial location (Trap Nest Location 5 at Quality Castings in MIDC Shiroli, Kolhapur). These straws were used by female resin bees to construct their nests, which included over 50 chambers from the control area and 7 chambers from the industrial location packed with food provisions—a combination of pollen and nectar—that the females had gathered for their larvae. Using scissors, each chamber was divided and cut separately. For this study, about 57 resin bee larvae were sacrificed. Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) was used to analyse the samples in accordance with ASTM-D 1976-2020 guidelines.

2.3.4 Elemental Analysis

Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES), a technique selected for its sensitivity and accuracy in detecting trace elements, was used to conduct elemental analysis. After being acid-digested to extract elements, samples of pollen-nectar mixes made by resin bees were introduced into the ICP-OES apparatus. Adherence to ASTM-D 1976-2020 guidelines ensured the dependability and consistency of findings, bolstering the research's objective of evaluating the effects of environmental pollution on resin bees throughout various Kolhapur City settings.

3. Results and Discussion

3.1 Results (Control Area)

This section displays the findings from the elemental analysis of pollen-nectar mixtures collected from cavity-nesting resin bees in the control area. The analysis was performed and the milligrammes per kilogramme (mg/kg) of each element were measured using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). Table 1 provides a detailed analysis of the elements present in each of the four samples that were taken from the control region.

Trap Nest 2 had an elevated concentration of aluminium at 1 mg/kg, while Trap Nest 4 had the highest concentration at 2.7 mg/kg. Trap Nest 1 and Trap Nest 3 had the lowest concentrations at 2.3 mg/kg and 1.6 mg/kg, respectively. Arsenic, on the other hand, was present in none of the samples and was found at amounts below the 0.1 mg/kg threshold. Traps 2 and 3 recorded 0.7 mg/kg and 0.6 mg/kg of borate, respectively. Traps 4 and 1 had boron levels ranging from 0.3 mg/kg to 1.9 mg/kg.

The levels of barium in the samples varied a lot; values ranged from 13 mg/kg in Trap Nest 4 to 24 mg/kg in Trap Nest 3. Traps 1 and 2 had values of 22 mg/kg and 23 mg/kg, respectively. In a comparable way, no sample included cobalt or cadmium, both of which had amounts less than 0.1 mg/kg. Trap Nest 4 had a value of less than 0.1 mg/kg of chromium, while Trap Nest 2 and Trap Nest 3 had values below 0.1 mg/kg and Trap Nest 1 had a value of 0.2 mg/kg. Trap Nest 2 and Trap Nest 4 showed values of 0.4 mg/kg of copper, Trap Nest 1 showed values of 0.7 mg/kg, and Trap Nest 3 showed values of 0.6 mg/kg.

Trap Nest 1 recorded the lowest iron content of 1.6 mg/kg, while Trap Nest 4 recorded the highest concentration of 6.8 mg/kg. Trap Nest 2 and Trap Nest 3 recorded the lowest amounts of 2.6 mg/kg and 2.4 mg/kg, respectively. Traps Nest 2 and 3 reported magnesium levels of 22 mg/kg and 24 mg/kg, respectively. Magnesium ranged from 18 mg/kg in Trap Nest 4 to 41 mg/kg in Trap Nest 1. Trap Nest 4's manganese content ranged from less than 0.1 mg/kg to 0.6 mg/kg, while Trap Nests 1 and 2 displayed values of 0.3 mg/kg.

The analysis of metal concentrations in the traps shows that molybdenum, nickel, lead, antimony, selenium, and vanadium were either absent or present in amounts below the 0.1 mg/kg detection limit. This indicates that these metals are virtually non-existent in the area, suggesting minimal contamination from these sources.

However, zinc concentrations varied across the traps. Trap 2 had a zinc level of 2 mg/kg, Trap 4 recorded 1.3 mg/kg, while Traps 1 and 3 showed a range from 1.1 mg/kg to 6.5 mg/kg. This variation points to localized differences in zinc levels, which could be due to specific environmental conditions or sources of zinc in the area.

Overall, while the low levels of other metals indicate a lack of significant contamination, the varying zinc concentrations suggest that further investigation might be needed to understand the sources and distribution of zinc in the environment.

Sr. No.	Element Name	Samples from Four Trap Nests (Control Area) (mg/kg)			
		Near Main Building (TN 1)	Opposite Library (TN 2)	Near Biotech. Building (TN 3)	Behind IDEA Lab (TN 4)
1	Aluminium	1	2	1.6	2.7
2	Arsenic	< 0.1	< 0.1	< 0.1	< 0.1
3	Boron	0.7	0.6	0.3	0.3

4	Barium	23	24	13	21
5	Cadmium	< 0.1	< 0.1	< 0.1	< 0.1
6	Cobalt	< 0.1	< 0.1	< 0.1	< 0.1
7	Chromium	< 0.1	< 0.1	< 0.1	< 0.1
8	Copper	0.4	0.6	0.4	0.5
9	Iron	1.6	2.6	2.4	2.7
10	Magnesium	22	24	20	18
11	Manganese	0.3	0.6	< 0.1	0.3
12	Molybdenum	< 0.1	< 0.1	< 0.1	< 0.1
13	Nickel	< 0.1	< 0.1	< 0.1	0.2
14	Lead	< 0.1	< 0.1	< 0.1	< 0.1
15	Antimony	< 0.1	< 0.1	< 0.1	< 0.1
16	Selenium	< 0.1	< 0.1	< 0.1	< 0.1
17	Vanadium	< 0.1	< 0.1	< 0.1	< 0.1
18	Zinc	1.1	2	1.3	1.7

Table 1 - Gathered sample from four distinct trap nests situated at the Kolhapur Institute of Technology's College of Engineering, Gokul Shirgaon, Kolhapur. Each sample contained around eighteen chemical elements.

3.2 Results (Industrial Area)

This section presents the findings from the elemental analysis of the pollen-nectar mixture collected by a cavity-nesting resin bee at an industrial site (Trap Nest Location 5 in MIDC Shiroli, Kolhapur). The analysis was conducted using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) to find out what chemical elements are present in the sample and to measure the concentration of each element in milligrams per kilogram (mg/kg). Table 2 provides a detailed breakdown of the elements detected in this sample from the industrial area.

The analysis of the industrial area sample from MIDC Shiroli, Kolhapur, reveals various elements indicating environmental conditions and contamination sources. Aluminium was detected at 3.5 mg/kg, showing minimal heavy contamination. Arsenic was below detection limits (< 0.1 mg/kg), indicating low contamination. Boron at 0.8 mg/kg suggests natural or industrial sources. High barium at 18 mg/kg points to industrial processes. Chromium at 1.5 mg/kg indicates moderate industrial pollution, while copper at 0.9 mg/kg suggests metal-related activities. Iron at 34 mg/kg is high, likely from industrial activities. Magnesium at 26 mg/kg is within expected levels, reflecting both natural and industrial sources. Manganese at 3.8 mg/kg is elevated, possibly due to industrial emissions. Molybdenum at 0.6 mg/kg suggests trace presence from specific processes. Nickel at 2.5 mg/kg is higher than background levels, indicating possible contamination. Lead at 0.7 mg/kg reflects moderate levels, and zinc at 5 mg/kg is elevated, likely from galvanization. These findings provide insights into contamination sources and environmental impact in MIDC Shiroli.

Sr. No.	Element Name	Sample from TN Location 5 (Industiral Area)	Unit
1	Aluminium	3.5	mg/kg
2	Arsenic	< 0.1	mg/kg

3	Boron	0.8	mg/kg
4	Barium	18	mg/kg
5	Chromium	1.5	mg/kg
6	Copper	0.9	mg/kg
7	Iron	34	mg/kg
8	Magnesium	26	mg/kg
9	Manganese	3.8	mg/kg
10	Molybdenum	0.6	mg/kg
11	Nickel	2.5	mg/kg
12	Lead	0.7	mg/kg
13	Zinc	5	mg/kg

Table 2 - Gathered sample from Trap Nest Location 5 in MIDC Shiroli, Kolhapur. Sample contained around thirteen chemical elements.

3.3 Discussion

Analysis of elemental compositions revealed key differences between the control and industrial areas. The control area had 18 elements, while the industrial area had 13. Aluminium levels were higher in the industrial area (3.5 mg/kg) compared to the control (1.0-2.7 mg/kg), indicating industrial contributions. Arsenic levels were low and similar across both areas (<0.1 mg/kg), suggesting minimal impact from industrial activities. Boron was more variable in the control area (0.3-1.9 mg/kg) than in the industrial area (0.8 mg/kg), likely from natural sources.

Barium levels were slightly lower in the industrial area (18 mg/kg) compared to the control (21-24 mg/kg), implying broader environmental factors. Chromium was higher in the industrial area (1.5 mg/kg) than in the control (0.2 mg/kg), likely due to casting processes. Copper levels were similar in both areas (0.4-0.9 mg/kg), indicating consistent contamination. Iron was notably higher in the industrial area (34 mg/kg) versus the control (1.6-6.8 mg/kg), reflecting industrial impact. Magnesium was higher in the control (20-41 mg/kg) than in the industrial area (26 mg/kg), suggesting natural soil variation. Manganese was elevated in the industrial area (3.8 mg/kg) compared to the control (0.3-0.6 mg/kg), likely due to steel-making. Nickel was higher in the industrial area (2.5 mg/kg) versus the control (0.1 mg/kg), indicating industrial emissions. Lead and zinc levels were comparable between areas, suggesting a mix of natural and industrial sources.

Elements like cadmium, cobalt, antimony, selenium, and vanadium were found only in the control area, suggesting natural rather than industrial sources. Overall, the data highlight significant industrial impacts, especially for iron, manganese, chromium, and nickel, while elements unique to the control area point to natural contamination sources.

4. Conclusion

This study investigates how solitary cavity-nesting resin bees can serve as indicators of environmental pollution. By using paper straw traps in various environments—agricultural, industrial, urban, and a control area—the research assessed the impact of pollution on resin bees. Findings showed elevated levels of pollutants like iron, manganese, chromium, and nickel at the industrial site, reflecting industrial emissions. The absence of viable samples from urban and agricultural areas points to pollution and resource scarcity as key stressors for resin bees. The control area, showing lower pollutant levels and viable samples, serves as a natural baseline. This highlights the need for clean environments to support resin bees and broader pollinator populations. Integrating resin bees into environmental monitoring is crucial for effective pollution management and maintaining ecological balance.

7. References

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