LETTER

Airborne particulate matter and health effects on bees: A correlation does not indicate causation

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Thimmegowda et al. (1) analyzed the sublethal effects of exposure of the honey bee *Apis dorsata* to high levels of airborne particulate matter (PM) in polluted areas in Bangalore (India). Airborne PM is a mixture of chemicals; its solid components are commonly classified by size, ranging from several micrometers (PM_{10}) to a few nanometers ($PM_{0.1}$). It is well established that the size and composition of PMs determine their adverse health effects in humans (2). Bees are exposed to pollutants, especially airborne particles, during foraging (3–5); thus, studies on the effect of PM on the health of pollinators are important. Existing studies on toxic effects of PM on bees are limited and carried out under controlled conditions (6, 7).

Thimmegowda et al. (1) correlated airborne PM levels in urban sites with the differences in behavior, physiology, and gene expression in bees. Furthermore, field-exposed fruit flies showed similar health outcomes. Although interesting, the study has some major flaws and the conclusions are not convincing.

First, a significant correlation does not necessarily indicate causation. The authors did not investigate other pollutants that are known to induce adverse health effects in insects (8–10); they considered only (solid) PM. Thus, the claim that airborne PM "is the most parsimonious cause" for the observed health effects has not been substantiated.

Second, the authors did not address how the contact between PM and the insect cuticle could affect the health of bees. Moreover, they did not investigate the contact between PM and the internal organs or any live tissue, and there is no evidence of PM ingestion through contaminated honey, pollen, or water. Thus, the conclusion that adverse health effects "could be either from direct or indirect exposure through contaminated food, water" is speculative.

Third, the authors have not provided information on PM toxicity, and they used scanning electron microscope (SEM) coupled with energy dispersive X-ray spectroscopy (EDX) to assess solely metals in PM.

Finally, the elements listed in the manuscript are surprising; the most abundant elements in the earth crust, which are commonly found as mineral particles on the insect body, such as Si (forming silicates) and Ca (forming carbonates), are missing. These elements are abundant in the wind dust, soils, sediments, and building materials; therefore, they can be easily encountered by bees during foraging in most environments. Contrarily, the list comprises several unique elements (Ga, Nb, Pd, Re, Ru, Rh, and Rn), including some rare-earth elements such as Dy, Eu, Ho, Sm, and Yb, which are among the rarest elements on earth. It is unlikely to find these elements on the body of bees, unless there are some peculiar human activities involving such elements, but this has not been verified or discussed. However, the finding of radon, a radioactive noble gas that cannot be detected by SEM-EDX, suggests that the list could be mostly erroneous, possibly due to a poor interpretation of EDX spectra.

Although studies correlating insect health with airborne PM levels are important to understand the effect of pollutants in real-world conditions, the study of Thimmegowda et al. (1) leaves several unanswered questions.

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