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Response to Tennekes (2018) "The Resilience of the Beehive" *Journal of Toxicology and Environmental Health B* 20: 316–386

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ABSTRACT

This paper is a response to a letter from Dr. H Tennekes ("The Resilience of the Beehive" Journal of Toxicology and Environmental Health B 20: 316–386). Here we emphasize that our quantitative weight of evidence analyses were focused on the level of the honeybee colony. These colony-level responses include redundancy and resiliency as well as a number of possible sublethal effects of pesticides on the colony. We also note that the literature has shown that binding of neonicotinoid insecticides to the nicotinic acetylcholine receptor is reversible. The comments in this letter do not provide reasons to change our conclusions, that, as currently used in good agricultural practices as seed-treatments, imidacloprid, clothianidin, and thiamethoxam do not present significant risks to honeybees at the level of the colony.

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QWoE method; clothianidin; imidacloprid; thiamethoxam; risk assessment

Dr. Tennekes appears to have conflated toxicological responses in individual worker honeybees with responses at the level of the colony. As we clearly stated in our quantitative weight of evidence (QWoE) analysis (Solomon and Stephenson 2017a), we were focused on effects at the level of the colony (and only on honeybees). It is well known that colonial insects, such as ants (Sendova-Franks and Franks 1994) and honeybees (Blacquière et al. 2012), benefit from the resiliency and redundancy of function that is a consequence of the structure of the colony, its component casts, and a constant addition of new individuals. In addition, as outlined in the conceptual model for exposure (Figure 2 in Solomon and Stephenson 2017a), exposure of bees in the colony are very different from exposures in lower-tier toxicity tests in individual worker honeybees. Thus, for honeybees, there is no easy linear extrapolation from effects on isolated worker bees in a laboratory test to potential effects at the level of the colony. This is the very reason that the USEPA has recommended Tier-2 and Tier-3 testing of honeybee colonies to provide data for risk assessment of insecticides that have not passed the triggers of simple Tier-1 laboratory toxicity testing (USEPA 2014, 2016). Unfortunately, detailed guidelines for performing these higher-tier studies are not available at this time; however, many of the more recent studies that are included in our QWoE analysis would be good models for development of such guidelines.

Dr. Tennekes devotes much of his comment to revisiting the accumulation of the toxic effects of neonicotinoids in insects (Tennekes 2010; Tennekes and Sánchez-Bayo 2013). Based on toxicodynamics and toxicokinetics, the application of the Druckrey–Küpfmüller equation to the mechanism of toxic action of neonicotinoids in honeybees is inappropriate. As is widely understood, this equation was developed to explain responses of mammals to carcinogens where there is irreversible binding of the toxicant to the receptor, and the resulting downstream effects (mutations) can be irreversible. As has been pointed out (Maus and Nauen 2011), this is not the case for the neonicotinoids, where binding to the target, the nicotinic acetylcholine receptor (nAChR), is reversible. Unlike the endogenous neurotransmitter, acetylcholine, which is rapidly inactivated by the enzyme acetylcholinesterase, the neonicotinoid insecticides are not inactivated at the synapse. However, they

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are inactivated by metabolism and excretion in insects, including the honeybee (Suchail et al. 2004). The half-life of imidacloprid (IMI) in honeybees orally exposed to LD50 doses was short (5 h), and the half-life of IMI and all metabolites was of the order of 25 h. As a result, they do not accumulate over time. None of this evidence supports the use of the Druckrey–Küpfmüller equation for neonicotinoids.

Dr Tennekes is correct in his statement that honeybees have demonstrated impressive resilience at the level of the colony ("beehive"), and this is only measurable in higher-tier toxicity tests and the level of the colony. In our QWoE, several of the higher-tier studies conducted with IMI, clothianidin, and thiamethoxam (Solomon and Stephenson 2017b; Stephenson and Solomon 2017a; Stephenson and Solomon 2017b) reported small (but statistically significant) effects on mortality or behavior of workers; however, these did not result in consistent or significant effects on other measurement endpoints at the level of the colony. The colony condition assessments used to evaluate the higher-tier studies focused on sustainability and survival of the colony and included multiple measurement endpoints, such as mortality (adults, workers, drones, pupae, larvae, queen); colony strength (hive weights, number of workers, total number of adult bees, overwintering performance, rates of food consumption, etc.); colony development (queen development, brood development, numbers of eggs, larvae, capped cells, pupae, honey, nectar, and pollen stores); foraging intensity and activity; flight dynamics (intensity and activity); behavior (trembling, agitation, immobilization, incoordination, hyper- or hypo-responsiveness, etc.); and productivity of the hive (hive weights, honey production, etc.). Although *in vivo* immune responses were not included in the colony-level assessments, colony health (infestation with *Varroa* mite, viruses, or disease) was. The fact that these measurements included several related to susceptibility to diseases and parasitism indicates that immune responses were not compromised in colonies exposed to neonicotinoids. Links between colony collapse disorder and increased loads of pathogens are not proof of insecticides as causal agents; there are many other more plausible explanations, such as those related to husbandry, weather, nutrition, or susceptibility to novel parasites and diseases.

Our QWoE was focused on honeybees where there were sufficient data from higher-tier studies to conduct a weight of evidence analysis. Currently, there are insufficient higher-tier studies on other bees and pollinators to carry out a weight of evidence analysis. We hope that the scientific community will use our summaries of unpublished studies to develop testing methods for these other species. In this regard, one of the sponsoring companies for our analysis has recently made its regulatory studies accessible to the public (https://cropscience-transparency.bayer.com/). These reports provide detailed descriptions of methods and will increase transparency and contribute to improved scientific methods in this important area of environmental toxicology and risk assessment. The comments from Dr. Tennekes do not provide reasons to change the conclusions of our QWoE—that, as currently used in good agricultural practices as seed-treatments, IMI, clothianidin, and thiamethoxam do not present significant risks to honeybees at the level of the colony.

References

Blacquière, T., G. Smagghe, C. A. M. Van Gestel, and V. Mommaerts. 2012. Neonicotinoids in bees: A review on concentrations, side-effects and risk assessment. *Ecotoxicology* 21:973–92.

Maus, C., and R. Nauen. 2011. Response to the publication: Tennekes, H.A. (2010): The significance of the Druckrey–Küpfmüller equation for risk assessment—The toxicity of neonicotinoid insecticides to arthropods is reinforced by exposure time. *Toxicology* 280:176–77.

Sendova-Franks, A. B., and N. R. Franks. 1994. Social resilience in individual worker ants and its role in division of labour. *Proceedings of the Royal Society B: Biological Sciences* 256:305–09.

Solomon, K. R., and G. L. Stephenson. 2017a. Quantitative weight of evidence assessment of higher tier studies on the toxicity and risks of neonicotinoid insecticides in honeybees 1: Methods. *Journal of Toxicology and Environmental Health, Part B* 20:316–29.

Solomon, K. R., and G. L. Stephenson. 2017b. Quantitative weight of evidence assessment of higher tier studies on the toxicity and risks of neonicotinoid insecticides in honeybees 3: Clothianidin. *Journal of Toxicology and Environmental Health, Part B* 20:346–64.

Stephenson, G. L., and K. R. Solomon. 2017a. Quantitative weight of evidence assessment of higher tier studies on the toxicity and risks of neonicotinoid insecticides in honeybees 2: Imidacloprid. *Journal of Toxicology and Environmental Health, Part B* 20:330–45.

Stephenson, G. L., and K. R. Solomon. 2017b. Quantitative weight of evidence assessment of higher tier studies on the toxicity and risks of neonicotinoid insecticides in honeybees 4: Thiamethoxam. *Journal of Toxicology and Environmental Health, Part B* 20:365–82.

Suchail, S., G. De Sousa, R. Rahmani, and L. P. Belzunces. 2004. *In vivo* distribution and metabolisation of ^{14}C-imidacloprid in different compartments of *Apis mellifera* L. *Pest Management Science* 60:1056–62.

Tennekes, H. A. 2010. The significance of the Druckrey–Küpfmüller equation for risk assessment - The toxicity of neonicotinoid insecticides to arthropods is reinforced by exposure time. *Toxicology* 276:1–4.

Tennekes, H. A., and F. Sánchez-Bayo. 2013. The molecular basis of simple relationships between exposure concentration and toxic effects with time. *Toxicology* 309:39–51.

USEPA. 2014. Guidance for Assessing Pesticide Risks to Bees. Washington, DC: Office of Chemical Safety and Pollution Prevention, Office of Pesticide Programs. United States Environmental Protection Agency. Report Accessed https://www.epa.gov/sites/production/files/2014-06/documents/pollinator_risk_assessment_guidance_06_19_14.pdf.

USEPA. 2016. Guidance on Exposure and Effects Testing for Assessing Risks to Bees Washington, DC: Office of Chemical Safety and Pollution Prevention, Office of Pesticide Programs. United States Environmental Protection Agency. Report Accessed https://www.epa.gov/sites/production/files/2016-07/documents/guidance-exposure-effects-testing-assessing-risks-bees.pdf.