Neonicotinoid insecticides (imidacloprid, thiamethoxam, clothianidin): the silent killers in the environment

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Editor's note: This paper is presented not as a comprehensive review or literature survey, but as an introduction to a very important emerging issue which has yet to be extensively discussed in Australia.

INTRODUCTION

Neonicotinoids are insecticides used extensively in Australia and overseas but ongoing global assessments indicate that they are serious environmental poisons. Neonicotinoids were developed in the 1980s and 1990s and are the most widely used insecticides in the world today. Sales for 2018 are estimated to exceed four billion dollars. In the United States neonicotinoids are applied to more than 150 million acres annually (Carnemark, Jenkins and Walker 2015). They are neuro-active insecticides that are highly toxic to insects. Neonicotinoids are very water soluble and disperse widely through the environment. Birds may be poisoned directly by ingestion of treated seeds or suffer due to reduced numbers of insects.

DISCUSSION

Use and dispersal in plants and the environment

Neonicotinoids are very effective insecticides used in agriculture, by councils, by home gardeners and are even appearing in pet collars. The three neonicotinoids in common use are imidacloprid, thiamethoxam and clothianidin.

In agriculture neonicotinoids are used as granular soil applications and foliar sprays but mainly as seed coating treatments. After planting treated seeds, the neonicotinoid coating dissolves and about five per cent is absorbed by the germinating plant and spreads through all the tissues of the growing plant including the pollen and nectar. This makes the entire plant poisonous and herbivorous insects that eat any part of the plant die (Goulson 2014) The pollen and nectar are toxic to pollinators including honey bees.

The remaining 95 % of the neonicotinoid is lodged in the soil and being very water soluble, it washes into puddles, wetlands and waterways, where it poisons insects and aquatic invertebrates (Sanchez-Bayo, Goka and Hayasaka 2016). These contaminated invertebrates are in turn consumed by fish, frogs and birds. Both surface and ground water are affected.

Neonicotinoids persist in soil for variable periods but soil levels appear to plateau after two to five years. Clothianidin can persist for up to 19 years. The soil dissipation half-life time varies between neonicotinoids and is influenced by soil type (Wood and Goulson 2017).

Dust contamination at planting

Neonicotinoid-containing dust is created around the machinery when planting neonicotinoid-coated seeds. This dust can be dispersed by wind and cover adjacent fields to produce marked toxicity. Murphy (2017) reports on the loss of 500 bee hives in New South Wales in 2013 believed to

be due to neonicotinoid dust from nearby cotton farms.

Lack of proper industrial processing of the seed has been reported with poor adhesion of the neonicotinoid coating resulting in more dust being liberated at planting and so more toxicity. One disaster in Germany in 2008 resulted in neonicotinoid dust killing 11,500 bee colonies (Stokstad 2013).

Insect decline

There has been widespread decline in insects with over 40% of insect species threatened with extinction over the next few decades (Sanchez-Bayo and Wyckhuis 2019). Hallmann *et al.* (2017) recorded a 75% decline in insects over the last 30 years in Germany. This means less butterflies and bees which are key pollinators.

Macfadyen and Hogendoorn (2018) discuss the benefits and risks of neonicotinoid insecticides in relation to Australian agriculture. They suggest that insufficient research has been done in Australia to assess benefits to agriculture versus negative impacts on insect populations. Anecdotal evidence such as fewer insects on motor car windscreens after a long drive (ABC News Science 12 February 2019) indicates that Australia has not been spared the decline in insects. Habitat loss with conversion to intensive agriculture, fertilizers and insecticides, and urban development and pollution have also been implicated, as well as climate change. Attention is focusing on insecticides.

Neonicotinoids are so important in this respect that Dave Goulson and 232 other scientist signatories (Goulson 2018) have called for international restrictions on the use of neonicotinoids because of their massive contribution to the loss of insects. Insects are pests but are critically important to the environment. They pollinate flowers, control other insects, decompose organic matter, aerate and create top-soil. The decrease in insects means less food for insectivorous birds such as swallows, as well as frogs and mammals.

The importance of insects cannot be over-emphasized, as the great entomologist E.O. Wilson stated, 'If insects were to vanish the environment would collapse into chaos' (Goulson 2014).

Insect decline as a threat to birds

A significant decline in bird numbers has been recorded in Australia and overseas. BirdLife Australia (2015) has reported decreases in some of our common birds. In the United Kingdom and France farm birds have declined by 50% in the last three decades (Gabbatiss 2018).

Birds are under pressure for many reasons. Cats and foxes are often blamed, but habitat loss through bush clearing and wetland drainage is important. The cleared land is used for urban expansion and intensive farming. Nature strips and mixed meadows disappear. Spraying with weedicides and insecticides destroy the meadow flowers, weeds and insects, further impacting the birds' food supply.

The impact on birds by the use of neonicotinoids in a farmland setting in the Netherlands was studied by Hallman *et al.* (2014) who showed that 15 species of farmland birds declined faster in areas with higher concentrations of imidacloprid in surface water. They suggested that the decline in birds they observed was due to a shortage of available insect food for the birds and their broods, or consumption of contaminated insects, or a combination of both food shortage and toxicity. The authors also commented that there were areas in the Netherlands with much higher concentrations of neonicotinoids in surface waters than those they studied.

Bird toxicity from poisoned seed

Neonicotinoid poisoning of birds is also reported to be due to seed-eating birds consuming neonicotinoid-treated seeds in lethal and sub-lethal amounts. Seed spilt at planting is available and toxic to foraging birds and animals. A few

neonicotinoid coated seeds can kill a seed-eating bird but proving that birds have been poisoned in the field is difficult as the poisoned birds move away from the poison source before dying. However Millot *et al.* (2017) detail 101 incidents totaling 733 dead birds as well as a mammal as field evidence of poisonings due to imidacloprid-coated seeds.

It is estimated that during agricultural planting about one percent of the neonicotinoid coated seed is spilt. Spillage occurs accidently and along the rows particularly at the headlands where the planters turn around. Wood and Goulson (2017) report that one hectare planted with neonicotinoid-coated seed contained enough accessible seed to deliver a mean lethal dose (LD50) to 100 Grey Partridge, *Perdix perdix*. Gunderson (2017) reports on a study in Minnesota of 38 townships over one spring planting season, where an estimated 15,000 easily visible seed spills occurred. In that report 9 out 10 Grouse livers tested positive for neonicotinoids and 80% of Grouse faecal pellets contained neonicotinoids.

Sublethal poisoning of birds ingesting coated seed was studied by Eng, Stutchbury and Morrisey (2017) from Canada. They demonstrated the adverse effects of small doses of insecticide on birds and showed that imidacloprid-dosed White-crowned Sparrows, *Zonotrichia leucophrys* lost weight, condition and feeding capabilities. Their orientation in relation to migratory needs was impaired with increased risk of mortality or lost breeding opportunity.

Actions taken on neonicotinoids

Neonicotinoids are highly effective insecticides but their adverse effects on honey bees and insects generally has been a major concern and has resulted in restrictions being imposed on the use of these insecticides by a number of countries and states.

In 2018 the European Union (EU) banned the use of neonicotinoids, imidacloprid, thiamethoxam and clothianidin in the open because of their adverse effects on bee health (Butler 2018). This followed an earlier EU ban in 2013.

In North America, the US States of Maryland and Connecticut have limited the use of neonicotinoids (Lemelin 2016). Canada's Ontario introduced new regulations relating to some neonicotinoids in 2018. Health Canada's Pest Management Regulatory Agency in 2019 issued a review restricting the use of neonicotinoid pesticides in relation to bees and other pollinators (Health Canada 2019). The Agency is also studying impacts on aquatic invertebrates.

Following a petition launched by consumer group SumOfUs in 2018 and signed by 30,000 Australians, Woolworths, Coles, Mitre10 and Bunnings undertook to stop selling products containing neonicotinoids.

The Australian Pesticide and Veterinary Medicines Authority (1 August 2019) maintains that on the basis of scientific information available, honey bee populations are not in decline in Australia. The Authority considers that neonicotinoids registered for use in Australia are safe and effective provided products are used according to the label instructions.

SUMMARY

Attention is drawn to the fact that neonicotinoids are proven to be severe environmental poisons in routine use. Many evaluations globally have shown the use of neonicotinoids to be associated with loss of pollinator activity and significant declines in insects. Neonicotinoids adversely affect insectivorous birds and are poisonous to seed-eating birds. The need for action against these environmental poisons has been highlighted by Dave Goulson and 232 other scientist signatories (Goulson 2018) who call for restrictions on the use of neonicotinoids because of their massive contribution to loss of insects and global biodiversity.

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