Neonicotinoid Insecticides

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Contributor: Yu Li

Neonicotinoid insecticides (neonics) are a novel class of insecticides that act selectively on the nicotinic acetylcholine receptors (nAChRs) in the central nervous system of insects [1].

Keywords: neonicotinoid insecticides ; food chain ; exposure level ; human health impact ; environmental risk assessment

1. Introduction

Since the introduction of the first neonic, named imidacloprid, by the Bayer Corporation in the 1980s, seven major neonics have reached markets worldwide: imidacloprid, thiacloprid, clothianidin, thiamethoxam, acetamiprid, nitenpyram, and dinotefuran [2]. Representing the fourth kind of insecticide, neonics are gradually replacing several conventional insecticides currently in the market, such as the chlorinated hydrocarbons, organophosphorus insecticides, carbamates, and synthetic pyrethroids; owing to their advantages, such as low dosage requirements, rapid effects, and high activity, the neonics have become widely used insecticides throughout the world [3].

Neonics are commonly used for foliage spraying in field systems and for soil and seed treatment during crop planting to protect seedlings from early-season root and leaf pests [4]. Neonics have been registered in 120 countries and are used for over 140 crops, such as rice, wheat, corn, cotton, peanut, and soybean. In addition, neonics exert good control of sucking pests in the atmosphere, e.g., aphids and leaf-hoppers, and pests in the soil, such as grubs, termites, and nematodes [5]. Neonics belong to the group of neuro-active insecticides, which are capable of inducing toxicity by controlling insect behavior and by excessively exciting or paralyzing the insects by blocking the transmission of cholinergic signals [6]. nAChRs, which are the main target of the neonics, are used widely in the control of crop diseases and insect pests. In 2008, Barbara et al. studied radioligand binding of nAChR, and observed that neonics interacted mainly with [3H]-α-bungarotoxin and [3H]-imidacloprid in the nAChR. Meanwhile, the precise binding site interactions, providing implications for understanding the ligand-binding interactions between the nAChRs in insects and neonics, were identified using membranes from the whole body as well as from specific tissues of insects [7]. In 2015, Simon-Delso et al. demonstrated that imidacloprid, the forerunner of neonicotioid insecticides, is a partial agonist of insect nAChRs, while clothianidin and acetamiprid appear to be full agonists using the patch clamp method [8]. In 2018, Taillebois et al. reported a discussion on the number of binding sites between nAChR and neonics, stating that the binding sites of neonics were from radioligand binding on the native tissues. In addition, the authors compared the binding properties of the most commonly used neonics in several insect species, and reported that the neonic–nAChR binding sites were linked to the biological samples used and the insect species under consideration [9].

2. Assessment of the Human Health Impact and Environmental Risk of Neonics

In the last 20 years, the number of people exposed to neonics in daily life has been increasing steadily, and long-term exposure to neonics is expected to have an adverse effect on the human body [10]. Therefore, there should be awareness regarding the increased human exposure to neonics and the associated potential health impacts.

Recent studies have demonstrated that exposure to neonics, such as imidacloprid, exerts adverse effects on human health. In 2014, Wei et al. investigated whether exposure to neonics during early pregnancy would cause anencephaly, spina bifida, and cleft lip and palate in pregnant women. The subjects belonged to San Joaquin Valley, California, and included 73 anencephalic children, 123 children with spina bifida, and 394 those with cleft lip and palate. The results of the correlation analysis conducted in that study revealed that the use of agricultural pesticides such as imidacloprid close to the residences of pregnant women during pregnancy was positively correlated with the probability of occurrence of fetal teratogenic mutation [11]. In the same year, Keil et al. used the Bayesian logic model to evaluate the relationship between autism spectrum disorders and the use of imidacloprid. The analysis dataset contained complete information regarding 262 normal development controls and 407 autistic children. Sensitivity window analysis conducted in that study revealed that, in comparison to normal development controls, the autistic children exhibited higher levels of imidacloprid exposure during pregnancy. Therefore, a certain correlation existed between imidacloprid exposure and autism spectrum disorders

[12]. Furthermore, Koureas et al. investigated the oxidative damage to DNA in different populations in Greece, and studied its correlation with pesticides and other potential risk factors; the study included 80 insecticide sprayers, 85 rural residents, and 121 residents of the city of La SAR. It was observed that the frequency of neonics was associated with the 80 pesticide sprayers in terms of the oxidative damage to whole blood DNA [13]. In 2015, Marfo et al. studied 35 symptomatic patients with unknown causes and 50 asymptomatic patients, and proposed that a correlation existed between the concentration of neonics in the urine and the increased prevalence of neurological symptoms, including amnesia, finger tremor, headache, etc. [14]. In 2017, Seltenrich et al. indicated that long-term exposure to neonics would result in adverse development or neurological outcomes, including tetralogy of Fallot, congenital anencephaly, autism spectrum disorder, memory loss, and finger tremor [15]. In 2018, Mesnage et al. reported that neonics could cause adverse reproductive, developmental, and physiological effects, including decreased sperm production and function, reduced pregnancy rate, increased fetal mortality, still-birth rate, and preterm birth rate, as well as weight loss and lipid accumulation in the offspring [16].

Although it has been recognized that exposure of neonics exerts adverse effects on human health, there nonetheless exist certain limitations in the current research related to this field, and it is difficult to provide a comprehensive speculative conclusion. Therefore, for the neonics already developed and registered, further investigation is required to predict their impact on human health theoretically. In addition, future research and development related to neonics should focus on reducing their accumulation and transmission in agricultural products in order to reduce their exposure to humans via food intake.

3. Conclusions

Neonics are used widely throughout the world, and the ecological problems caused by the application of neonics have attracted great attention globally. QuEChERS (Quick, Easy, Cheap, Efficient, Rugged and Safe), LC-MS/MS, and other detection methods have revealed the presence of a large number of neonics in the water, soil, atmosphere, and food chain, which is expected to have an adverse impact on the environment. The existing evidence provided by the epidemiological studies, both in vivo and in vitro, revealed that neonics have the potential to cause serious damage to non-target animals and humans within the ecosystem. Although these results have established a solid foundation for future studies to be conducted in relation to neonics, the research and development of green pesticides, the blocking of pollutant transmission, and the remediation of contaminated soil continue to be in the initial stages. In addition, even though the levels of pesticide residues in most foods are relatively low, the joint toxic effects produced as a result of the simultaneous presence of a number of residues of a variety of pesticides are not clearly understood so far. Therefore, it is important that the understanding of the transmission pathways of neonics in the food chain is deepened in order to fundamentally achieve reasonable prediction and control of the source, process, and end behavior of these insecticides in the future. Furthermore, effective remediation of contaminated soil and the problem of joint toxicity caused by the simultaneous presence of the residues of a variety of pesticides also deserve attention.

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