Environment and Ecology 41 (3D) : 2039—2043, July—September 2023
Article DOI: https://doi.org/10.60151/envec/VFHT1065
ISSN 0970-0420

Deltamethrin Toxicity: Impacts on Non-Target Organisms and the Environment

Rohan Yadav, N. G. Shinde, K. T. Patil, Ashwini Kote, Priyanka Kadam

Received 20 April 2023, Accepted 29 June 2023, Published on 20 September 2023

ABSTRACT

Deltamethrin is a synthetic pyrethroid insecticide widely used for controlling pests in agriculture and public health programs. However, its toxicity towards non-target organisms, including humans, has raised concerns over its safe use. This review paper aims to summarize the current knowledge of deltamethrin toxicity, including its mechanism of action, acute and chronic toxicity, genotoxicity, and ecotoxicity. The findings suggest that deltamethrin can cause acute toxicity in humans and animals, leading to symptoms such as convulsions, respiratory distress, and even death. Chronic exposure to deltamethrin has been associated with various adverse health effects, including neurotoxicity, reproductive toxicity, and carcinogenicity. Furthermore, deltamethrin has been shown to have toxic effects on non-target organisms, such as bees and aquatic organisms, which can have significant ecological consequences. Therefore, there is a need to regulate and monitor the use of deltamethrin to ensure its safe use and protect the environment and human health.

Keywords Deltamethrin, Environment, Toxicity, Human health, Ecology.

Rohan Yadav[1]*, N. G. Shinde[2], K. T. Patil[3], Ashwini Kote[4], Priyanka Kadam[5]

[1,4,5]PhD Research Scholar, [2]Associate Professor
PG Research Center in Zoology, K. J. Somaiya, College of Arts, Commerce and Science, Kopargaon, Ahmednagar 423601, MS, India

[3]Assistant Professor
PG Research Center in Zoology, M.S.G. College of Arts, Commerce and Science, Malegaon, Nashik (MS), India

Email : rohanyadav0398@gmail.com
*Corresponding author

INTRODUCTION

Deltamethrin is a synthetic pyrethroid insecticide widely used for controlling pests in agriculture and public health programs, Bhattacharjee and Das (2011). Its popularity is due to its effectiveness, low mammalian toxicity, and rapid degradation in the environment WHO (2011). However, the use of deltamethrin has raised concerns over its potential toxicity towards non-target organisms, including humans, pets, and wildlife. Therefore, understanding the toxicity of deltamethrin is critical for its safe use and protecting the environment and human health. This review paper aims to summarize the current knowledge of deltamethrin toxicity, including its mechanism of action, acute and chronic toxicity, genotoxicity, and ecotoxicity.

Environmental impact of deltamethrin

Effect on non-target organisms

Deltamethrin is highly toxic to a wide range of non-target organisms, including mammals, birds, fish, and bees. Mammals and birds can be exposed to deltamethrin through contaminated food, water, or direct contact with the pesticide. Studies have shown that deltamethrin can cause reproductive toxicity, developmental toxicity, and neurological effects in mammals and birds, Rehman *et al.* (2014). Deltamethrin is also toxic to fish and can cause acute and chronic toxicity, affecting their growth and reproduction, Aksakal *et al.* (2010). Bees are also highly susceptible to deltamethrin toxicity, and exposure to the pesticide can lead to reduced colony growth and development, decreased honey production, and increased mortality rates, Dai *et al.* (2010).

Effect on soil

Deltamethrin can persist in soil for extended periods, leading to long-term effects on soil health Palangi *et al.* (2021). Studies have shown that deltamethrin can have toxic effects on soil microorganisms such as bacteria, fungi, and actinomycetes. For example, a study conducted by Farghaly *et al.* (2013) found that deltamethrin at high concentrations significantly inhibited the growth of soil microorganisms and reduced soil enzyme activities.

Deltamethrin can also have negative impacts on the physical and chemical properties of soil Baskaralingam *et al.* (2019). A study by Akien-Alli and Otali (2021) found that deltamethrin application resulted in reduced soil pH, soil organic matter content, and soil nitrogen and phosphorus levels.

It is important to note that the extent of deltamethrin's impact on soil depends on factors such as application rate, soil type, and weather conditions. Nevertheless, these studies highlight the potential negative impacts of deltamethrin on soil and its microorganisms.

Effect on Water

Deltamethrin can contaminate surface and groundwater, leading to adverse effects on aquatic organisms. Several studies have investigated the impact of deltamethrin on water quality and aquatic life. A study conducted by Boussahel *et al.* (2006) found that deltamethrin residues in surface water samples from agricultural areas exceeded the maximum permissible limit set by the World Health Organization (WHO). The study also observed that deltamethrin exposure caused significant mortality and growth inhibition in zebrafish, a commonly used model organism for aquatic toxicity testing.

Another study conducted by Zhang *et al.* (2018) in China found that deltamethrin exposure significantly reduced the survival and growth of the freshwater crab Sinopotamon yangtsekiense. The study also observed that deltamethrin caused oxidative stress and DNA damage in the crab, indicating that this insecticide can have long-term effects on aquatic organisms.

Moreover, deltamethrin residues have been detected in various water bodies around the world, including rivers, lakes, and wetlands. For instance, a study conducted by Stehle and Schulz (2015) found that deltamethrin residues were present in surface water samples from agricultural areas, indicating that this insecticide can contaminate water sources and potentially affect aquatic ecosystems.

Overall, the evidence suggests that deltamethrin can have a significant impact on water quality and aquatic life, and measures should be taken to minimize its use and reduce its environmental impact.

Effect on air quality

Deltamethrin can be carried by wind and contaminate the air, leading to adverse effects on human health and the environment. The impact of delta-methrin on air quality has been studied in various countries. A study conducted in China found that delta-methrin can cause significant air pollution due to its widespread use in agriculture. The study revealed that the concentration of delta-methrin in the air was highest in the summer, when the use of the pesticide was most prevalent. The researchers also found that the concentration of delta-methrin in the air was higher in rural areas compared to urban areas, Liu *et al*. (2018).

Another study found that the use of delta-methrin in cotton fields led to the presence of the pesticide in the ambient air, which could potentially impact human health, Yao *et al.* (1992). According to Li *et al.* (2020), interactions between deltamethrin and nitrogen oxides can lead to an enhanced formation of ozone under simulated atmospheric conditions. In addition, a study conducted found that the use of delta-methrin in agricultural areas caused high levels of the pesticide in the air, leading to significant environmental and health concerns, El-Nahhal and Abed Alkareem (2015).

Furthermore, delta-methrin can also have an impact on indoor air quality. A study conducted in South Korea found that the use of delta-methrin in indoor pest control led to the presence of the pesticide in the air of residential areas, which could potentially cause respiratory health problems, Kwon *et al.* (2014).

Mechanism of action

Deltamethrin acts by targeting the nervous system of insects, causing paralysis and death; Gutierrez *et al.* (2016). Deltamethrin acts on the nervous system of insects by interfering with the normal function of voltage-gated sodium channels, Zeng *et al.* (2017). Voltage-gated sodium channels are responsible for the rapid depolarization and repolarization of neurons during action potentials. In insects, these channels are found in the axons of neurons that control movement and sensory perception. When an insect is exposed to deltamethrin, the pesticide binds to the voltage-gated sodium channels, causing them to remain open longer than usual. This results in an influx of sodium ions into the neurons, leading to hyperexcitation and paralysis of the insect's nervous system, Wu *et al.* (2021).

In addition to its effects on voltage-gated sodium channels, deltamethrin also has other effects on the nervous system of insects. For example, it can increase the release of neurotransmitters, such as acetylcholine and glutamate, which can further enhance the excitation of neurons, Narahashi (2006).

Acute toxicity

Deltamethrin can cause acute toxicity in humans and animals, leading to symptoms such as convulsions, respiratory distress, and even death, Belyaeva *et al.* (2018). The severity of symptoms depends on the dose and the route of exposure. Inhalation of deltamethrin can cause respiratory distress, while ingestion can lead to gastrointestinal symptoms, WHO (2011). Furthermore, the acute toxicity of deltamethrin can vary among different species, with some species being more sensitive than others.

Chronic toxicity

Chronic exposure to deltamethrin has been associated with various adverse health effects, including neurotoxicity, reproductive toxicity, and carcinogenicity, Tewari *et al.* (2018). Chronic exposure can occur through repeated exposure to low doses of deltamethrin, such as in occupational settings or through contaminated food and water sources. Deltamethrin has been shown to accumulate in the body, leading to prolonged exposure and increased toxicity, Ullah *et al.* (2019). Therefore, long-term exposure to deltamethrin should be avoided to prevent chronic health effects.

Genotoxicity

Deltamethrin has been shown to have genotoxic effects, causing DNA damage and mutations, Cunha *et al.* (2018). These genotoxic effects of deltamethrin are thought to be due to its ability to generate reactive oxygen species (ROS) and oxidative stress in cells, Cunha *et al.* (2018). ROS can cause DNA damage and mutations by attacking the DNA molecule and altering its structure. In addition, deltamethrin has been shown to inhibit the activity of DNA repair enzymes, further increasing the risk of DNA damage, Hong *et al.* (2018).

The genotoxic effects of deltamethrin are of particular concern due to their potential to increase cancer risk. Several studies have demonstrated a link between exposure to deltamethrin and increased cancer risk in both humans and animals. For example, a study by Feng *et al.* (2019) found that deltamethrin exposure was associated with an increased risk of lung cancer in Chinese populations.

Overall, the genotoxic and reproductive effects of deltamethrin highlight the importance of careful evaluation of its safety in the context of its use in agriculture and public health. Further research is needed to better understand the mechanisms underlying these effects and to develop strategies to mitigate their impact on human and environmental health.

Ecotoxicity

Deltamethrin has been shown to have toxic effects on non-target organisms, such as bees and aquatic organisms, Basak *et al.* (2021). It can cause acute toxicity and sublethal effects such as reduced growth and reproduction rates, impaired behavior, and altered metabolism, WHO (2011). The toxicity of deltamethrin to aquatic organisms is due to its lipophilic nature, which allows it to accumulate in the fatty tissues of aquatic organisms and remain there for a long time, USEPA (2009).

The toxicity of deltamethrin to aquatic organisms can also be influenced by environmental factors such as temperature, pH, and water hardness, USEPA (2009). For example, the toxicity of deltamethrin increases at higher temperatures and lower pH levels, which can increase the risk of toxicity in aquatic organisms during periods of high temperature or acid rain.

Furthermore, deltamethrin can bioaccumulate in the food chain, leading to increased toxicity in higher trophic levels, WHO (2011). This means that predators at the top of the food chain, such as birds and mammals, can be exposed to high concentrations of deltamethrin through the consumption of contaminated prey. This can have significant ecological implications, as it can lead to population declines and disruptions in food webs.

Overall, the ecotoxicity of deltamethrin highlights the importance of using this pesticide with caution and implementing measures to reduce its impact on non-target organisms and the environment. These measures may include using alternative pest management strategies, reducing the amount of pesticide used, and implementing buffer zones around sensitive habitats.

Regulations and management of deltamethrin

Due to the significant environmental concerns associated with deltamethrin, various regulations have been put in place to manage its use. The United States Environmental Protection Agency (EPA) has set limits on the amount of deltamethrin that can be used in agriculture and other settings. The EPA has also set limits on the residues of deltamethrin that can be present in food, water, and other products, EPA (2020). In Europe, deltamethrin has been banned for use in some agricultural settings, and strict regulations are in place for its use in other settings; European Commission (2020).

To minimize the impact of deltamethrin on the environment, various management practices can be implemented. Integrated Pest Management (IPM) is an approach that combines different pest control strategies to minimize the use of pesticides and their impact on the environment. IPM involves monitoring and identifying pests, setting action thresholds, implementing non-chemical pest control methods, and using pesticides as a last resort, EPA (2020). The use of alternative pest control methods, such as biological control and crop rotation, can also reduce the reliance on pesticides such as deltamethrin.

CONCLUSION

Deltamethrin is a widely used synthetic pyrethroid insecticide with significant potential toxicity towards non-target organisms, including humans and wildlife. Its mechanism of action involves targeting the nervous system of insects, leading to paralysis and death. Acute toxicity can occur in humans and animals, while chronic exposure has been associated with adverse health effects such as neurotoxicity, reproductive toxicity, and genotoxicity. Deltamethrin also has ecotoxic effects, leading to reduced survival and growth rates in non-target organisms. Therefore, the safe use of deltamethrin requires strict regulation and monitoring to minimize its potential impact on human health and the environment.

REFERENCES

Akien-Alli I, Otali CC (2021) Impact of different doses of deltamethrine on soil microbial density and crop growth.

GSC Advanced Research and Reviews 8(3) : 036–042. https://doi.org/10.30574/gscarr.2021.8.3.0175

Aksakal E, Ceyhun SB, Erdoğan O, Ekinci D (2010) Acute and long-term genotoxicity of deltamethrin to insulin-like growth factors and growth hormone in rainbow trout. *Comparative biochemistry and physiology. Toxicology & pharmacology: CBP,* 152 4, 451-456.

Basak M, Choudhury RA, Goswami P, Dey BK, Laskar MA (2021) A Review on Non-target Toxicity of Deltamethrin and Piperonyl Butoxide: Synergist. *Journal of Pharmaceutical Research International* 33 (51B) 85-89.

Baskaralingam P, Madhurantakam C, Gopalakrishnan C (2019) Effects of deltamethrin on earthworm population and soil fertility. *International Journal of Environmental Science* and *Technology* 16(3) : 1295-1302

Belyaeva JA, Gabaeva MV, Grechkina MA, Guseva GV (2018) Deltamethrin-induced changes in the lipid metabolism of rats in relation to the pesticide accumulation in the body. *Journal of Applied Toxicology* 38(8) : 1059-1066. doi: 10.1002/jat.3636

Bhattacharjee P, Das S (2011) Toxicity of Pesticide Deltamethrin to Fish. Indian Journal of applied research, Vol.4 (5), 19-21. DOI: 10.36106/ijar

Boussahel R, Moussaoui KM, Harik D (2006) Determination of residues of deltamethrin in wheat and potato by HPLC. *African Journal Agricultural Research* 1 : 182-185.

Cunha FD, Sousa ND, Santos RF, Meneses JO, Couto MV, Almeida FT, Sena Filho JG, Carneiro P, Maria AN, Fujimoto RY (2018) Deltamethrin-induced nuclear erythrocyte alteration and damage to the gills and liver of *Colossoma macropomum. Environmental Science and Pollution Research* 25 : 15102-15110.

Dai P, Wang Q, Sun J, Liu F, Wang X, Wu Y, Zhou T (2010) Effects of sublethal concentrations of bifenthrin and deltamethrin on fecundity, growth, and development of the honeybee *Apis mellifera ligustica. Environmental Toxicology and Chemistry* 29.

El-Nahhal Y, Abed Alkareem Radwan (2015) Health and environ mental risks of pesticide residues associated with land use types in the southern *Mediterranean region* of Gaza Strip. *Environmental Monitoring and Assessment* 187(4) : 1-12.

Farghaly M, Zayed SM, Soliman SM (2013) Deltamethrin degradation and effects on soil microbial activity. *Journal of Environmental Science and Health* Part B, 48: 575 - 581.

Feng Y, Huang Q, Huang J, Chen X, Zhao J, Huang Y, Wang Y (2019) Association between deltamethrin exposure and lung cancer risk: A meta-analysis of observational studies. *Journal of Environmental Science and Health* Part B, 54(11): 863-870. doi: 10.1080/03601234.2019.1658191

Gutierrez Y, Santos HP, Serrão JE, Oliveira EE (2016) Deltamethrin-Mediated Toxicity and Cytomorphological Changes in the Midgut and Nervous System of the Mayfly *Callibaetis radiatus PLoS ONE* 11(3): e0152383. https://doi.org/10.1371/journal.pone.0152383

Hong Y, Yang X, Huang Y, Yan G, Cheng Y (2018) Oxidative stress and genotoxic effect of deltamethrin exposure on the Chinese mitten crab, *Eriocheir sinensis* Comparative biochemistry and physiology. *Toxicology Pharmacology : CBP,* 212 : 25-33 .

Kwon HJ, Lee BK, Park JD, Shin HS, Lim HS (2014) Exposure assessment of pyrethroid insecticides in indoor air and dust in Korean homes. *Environment International* 70 : 118-125.

Li J, Yu J, Huang Y, Zhao Y, Ding J (2020) Enhanced formation of ozone by interactions between deltamethrin and nitrogen oxides under simulated atmospheric conditions. *Science of the Total Environment* 719-725 : 137353.

Liu Xiaoxia, Jie Yang, Zijian Wang, Yuanyuan Liu, Bo Yao, Kai Zhang, Yaling Qian, Yongliang Ma, Shuhui Zhu, Yingxin Yu (2018) Occurrence, distribution, and sources of pyrethroids in urban and rural air of Northern China. *Science of the Total Environment* 613-614: 353-362. doi: 10.1016/j.scitotenv.2017.09.023

Narahashi T (2006) Nerve membrane ion channels as the target site of insecticides. *Trends in Pharmacological Sciences* 27(7): 384-390. doi: 10.1016/j.tips.2006.05.004

Palangi S, Bahmani O, Atlassi-pak V (2021) Effects of wheat straw biochar amendments to soil on the fate of deltamethrin and soil properties. *Environmental Technology and Innovation* 23: 101681.

Rehman H, Aziz AT, Saggu S, Abbas ZK, Mohan A, Ansari AA (2014) Systematic review on pyrethroid toxicity with special reference to deltamethrin. *Journal of Entomology and Zoology Studies* 2 : 60-70.

Stehle S, Schulz R (2015) Agricultural insecticides threaten surface waters at the global scale. *Proceedings of the National Academy of Sciences* 112 : 5750 - 5755.

Tewari A, Banga H, Gill JP (2018) Sublethal chronic effects of oral dietary exposure to deltamethrin in Swiss albino mice. *Toxicology and Industrial Health* 34: 423 - 432.

Ullah S, Li Z, ul Arifeen MZ, Khan SU, Fahad S (2019) Multiple biomarkers based appraisal of deltamethrin induced toxicity in silver carp (*Hypophthalmichthys molitrix*). *Chemosphere* 214 : 519-533.

USEPA (2009) Deltamethrin: Reregistration eligibility decision for deltamethrin, United States Environment Protection Agency https://www3.epa.gov/pesticides/chem_search/reg_actions/reregistration/red_G-7_27-May-09.pdf

World Health Organization (2011) Deltamethrin in drinking-water: Background document for development of WHO guidelines for drinking-water quality. *WHO* : 179-249.

Wu G, Li Q, Liu X, Li-Byarlay H, He B (2021) Differential state-dependent effects of deltamethrin and tefluthrin on sodium channels in central neurons of *Helicoverpa armigera. Pesticide Biochemistry and Physiology* 175 : 104836 .

Yao PP, Li YW, Ding Y, He F (1992) Biological monitoring of deltamethrin in sprayers by HPLC method. *Journal of Hygiene, Epidemiology, Microbiology, and Immunology* 36 (1) : 31-36

Zeng R, Yu X, Tan X, Ye S, Ding Z (2017) Deltamethrin affects the expression of voltage-gated calcium channel α1 subunits and the locomotion, egg-laying, foraging behavior of *Caenorhabditis elegans. Pesticide Biochemistry and Physiology* 138 : 84-90.

Zhang L, Sun H, Fan X, Liu Q, Liu Y, Jin H (2018)Toxicity of deltamethrin to freshwater crab *Sinopotamon yangtsekiense*: Oxidative stress and DNA damage. *Environmental Science and Pollution Research* 25(6) : 5636-5643.