International Journal of Ecotoxicology and Ecobiology
2023; 8(1): 9-12
http://www.sciencepublishinggroup.com/j/ijee
doi: 10.11648/j.ijee.20230801.12
ISSN: 2575-1727 (Print); ISSN: 2575-1735 (Online)

Toxicological Effects of Thiamethoxam on Non-Target Aquatic Organisms

Mohammad Mosleh Uddin[1, 4, *], Shayla Sultana Mely[2], Al Faruk[1, 3]

[1]Department of Fisheries Management, Bangladesh Agriculture University, Mymensingh, Bangladesh

[2]Bangladesh Fisheries Research Institute, Mymensingh, Bangladesh

[3]Murjanah Fish Establishment, Dammam, Saudi Arabia

[4]Department of Fisheries, Ministry of Fisheries and Livestock, Chittagong, Bangladesh

Email address:

mohammadmoslehuddin342@gmail.com (Mohammad Mosleh Uddin)

[*]Corresponding author

To cite this article:

Mohammad Mosleh Uddin, Shayla Sultana Mely, Al Faruk. Toxicological Effects of Thiamethoxam on Non-Target Aquatic Organisms. *International Journal of Ecotoxicology and Ecobiology*. Vol. 8, No. 1, 2023, pp. 9-12. doi: 10.11648/j.ijee.20230801.12

Received: April 2, 2023; **Accepted**: May 19, 2023; **Published**: June 6, 2023

Abstract: Thiamethoxam (THM), a neonicotinoid insecticide, has garnered significant attention due to its prevalence in agriculture and potential toxicity to aquatic organisms. This study aims to summarize the toxicological effects of THM on non-target aquatic organisms. Insecticide THM enters aquatic ecosystems through various routes, including runoff from treated fields, drifting from sprayed areas, and leaching into groundwater. The impact of THM on various species of fish, crustaceans, and aquatic insects has been extensively studied, yielding disparate results regarding its toxicity. The toxicity of THM is contingent upon various factors, including the species and developmental stage of the organism and the conditions of exposure. Despite this variability, several studies have indicated that certain species of fish and crustaceans are highly susceptible to the toxic effects of THM. In addition to the acute toxicity of THM, its chronic effects have also been a source of concern. Chronic exposure to low levels of insecticide has been demonstrated to result in many deleterious effects, including growth inhibition, altered behavior, and decreased reproductive success. Given the potential toxicity of THM to aquatic organisms, it is imperative to undertake a comprehensive risk assessment to minimize its release into the aquatic environment. Further research is needed to better understand the full extent of the toxicological effects of THM on non-target aquatic organisms and to develop effective mitigation strategies.

Keywords: Environmental Contamination, Neonicotinoid, Ecotoxicology, Non-Target Species

1. Introduction

Thiamethoxam (THM) is a synthetic neonicotinoid insecticide with the chemical formula C8H10ClN5O3S [1]. It is a white crystalline powder with a molecular weight of 251.7 g/mol [1] and has low solubility in water (0.22 g/L at 25°C) and moderate solubility in organic solvents like methanol, ethanol, and acetone [2]. The melting point of THM is 165-168°C, and its boiling point is 417°C [2]. In terms of physical properties, THM is a highly stable compound with a shelf life of several years when stored under proper conditions [3]. It has low volatility and a low potential for atmospheric transport, making it relatively immobile in the environment [3]. The insecticidal activity of THM is due to its ability to bind to nicotinic acetylcholine receptors in the insect nervous system, leading to paralysis and death [4]. It is a systemic insecticide that is taken up by plants and distributed throughout the plant tissue, providing long-lasting protection against pests [4]. THM has been shown to have significant impacts on beneficial insects such as honeybees and bumblebees, with studies indicating reductions in their foraging behavior, learning abilities, and overall colony performance [5, 6]. Additionally, THM has been linked to declines in bird populations, particularly in areas where treated crops are grown [7]. Its persistence in soil and water environments also raises concerns about its potential to contaminate non-target ecosystems and harm aquatic species [8]. Overall, THM has well-defined chemical and physical properties that contribute to its effectiveness as an insecticide but also raise concerns about its potential environmental impacts and its effects on non-target species such as pollinators [9].

THM can have negative impacts on aquatic ecosystems as it can persist and persist in the environment, even in small amounts. In aquatic ecosystems, THM can have toxic effects on aquatic invertebrates and fish, as well as affect the food chain and disrupt the overall balance of the ecosystem. Studies have shown that THM can enter aquatic ecosystems through runoff from agricultural fields or through leaching into groundwater. It can then persist in water for long periods, leading to the exposure of aquatic organisms to low levels of the insecticide over an extended period [10]. THM can also accumulate in aquatic food webs, leading to biomagnification and potentially harmful effects on top predators [9]. In addition, THM can adversely affect the reproduction and survival of aquatic invertebrates, leading to declines in populations of important species such as crustaceans and mollusks [9]. These declines can have far-reaching impacts on the food chain and the overall functioning of the aquatic ecosystem. Overall, THM can pose a significant risk to aquatic ecosystems, and it is important to consider its potential impacts when evaluating the use of this insecticide.

Summarizing information about the toxicity of THM to aquatic organisms is crucial for understanding the potential impacts on these non-target species and the aquatic ecosystem as a whole. Aquatic organisms such as crustaceans, mollusks, and fish are particularly susceptible to the toxic effects of THM, which can lead to declines in populations and disruptions in the food chain. Additionally, THM can persist in water for long periods, leading to continuous exposure of aquatic organisms to low levels of the insecticide. This prolonged exposure can have far-reaching impacts on the aquatic ecosystem, potentially affecting not only individual species but also the overall balance of the ecosystem. The aim of this study is to summarize the toxicological effects of THM on non-target aquatic organisms to ensure the health and sustainability of ecosystems and to make informed decisions about its use in agriculture and other industries.

2. Toxic Effects of THM on Aquatic Organisms

2.1. Fish

THM is a neonicotinoid insecticide that is widely used in agriculture and horticulture to control various insect pests. However, the toxic effects of THM on aquatic organisms, such as fish, have become a matter of concern due to its potential to contaminate surface water and groundwater. In this context, experimental studies have been conducted to evaluate the toxic effects of THM on fish using various methods and endpoint measurements. In one study [11], the acute toxicity of THM was evaluated using zebrafish (*Danio rerio*) as a model organism. The fish were exposed to various concentrations of THM in water for 96 hours, and the mortality rate was recorded. The results showed that the 96-hour median lethal concentration (LC50) of THM was 37.5 μg/L. This indicates that at this concentration, half of the exposed fish died within 96 hours. Another study [12] investigated the sublethal effects of THM exposure on the behavior, growth, and survival of common carp (*Cyprinus carpio*). The fish were exposed to environmentally relevant concentrations of THM for 21 days, and various endpoints were measured, such as swimming behavior, body length, and survival rate. The results showed that exposure to THM caused significant changes in the swimming behavior of the fish, with a decrease in the average swimming speed and increased distance from the bottom of the tank. Additionally, exposure to THM reduced the growth rate of the fish and decreased their survival rate. More recent studies have further investigated the toxic effects of THM on fish. One study found that THM exposure altered the expression of genes involved in oxidative stress, immune defense, and energy metabolism in goldfish (*Carassius auratus*) [13]. Another study reported that THM exposure induced oxidative stress and caused damage to the gills, liver, and spleen of catfish (*Clarias gariepinus*) [14]. Additionally, a study by Liu et al. (2021) found that THM exposure reduced the growth rate, disrupted the gut microbiota, and impaired the antioxidant defense system in juvenile grass carp (*Ctenopharyngodon idella*) [15]. In conclusion, the experimental studies described above provide evidence for the toxic effects of THM on fish [14]. The results indicate that exposure to this insecticide can cause significant changes in behavior, growth, physiology, gene expression, and antioxidant defense system, which can have adverse impacts on aquatic ecosystems. Further research is needed to fully understand the mechanisms underlying these effects and to determine the long-term consequences of THM exposure on fish populations and the ecosystem as a whole. It is important to note that LC50 values can vary depending on various factors, such as the size and age of the fish, the temperature of the water, and the duration of exposure to the pesticide. These values should be used as a general reference and not as a definitive measure of toxicity, as the actual toxic effects of THM may vary in different environments and circumstances. The toxicity of a chemical varies with the species tested. The toxicity of THM in various fish species has been determined and reported (Table 1).

Table 1. *An overview of the toxicity of THM on various stages of different fish species. [16-19].*

Species	Life stage	Threshold effects i.e. LC50 (mg/L)
Banded gourami (*Trichogaster fasciata*)	Larvae	0.27 (96 h)
Rainbow trout (*Oncorhynchus mykiss*)	Adult	>125 (96 h)
Bluegill sunfish (*Lepomis macrochirus*)	Adult	>114 (96 h)

Species	Life stage	Threshold effects i.e. LC50 (mg/L)
Common carp (*Cyprinus carpio*)	Adult	>120 (96 h)
Rainbow trout (*Oncorhynchus mykiss*)	Larvae	386 (96 h)
Rare minnow (*Gobiocypris rarus*)	Eggs	351.9 (96 h)

*Here, LC50= Lethal Concentration 50%

2.2. Crustaceans

THM is a widely used neonicotinoid insecticide that is applied to crops and soil to control insect pests. However, its widespread use has raised concerns about its potential toxic effects on non-target organisms, including zooplankton. Zooplankton is an important component of aquatic ecosystems, serving as a food source for many aquatic species and playing a crucial role in the carbon and nutrient cycles [20]. To assess the toxic effects of THM on zooplankton, laboratory studies have been conducted to determine the lethal concentration (LC50) values of THM in various zooplankton species. The LC50 value is the concentration of a toxic substance that is lethal to 50% of the organisms in a test population [21]. In one study, the LC50 value of THM for the zooplankton species *Daphnia magna* was found to be 43.2 ng/L after 48 hours of exposure [22]. Another study determined the LC50 value for the rotifer species *Brachionus calyciflorus* to be 33.9 ng/L after 72 hours of exposure [23]. A third study reported an LC50 value of 35.7 ng/L for the cladoceran species *Ceriodaphnia dubia* after 48 hours of exposure [24]. These results indicate that THM can have a significant toxic effect on zooplankton, even at relatively low concentrations. The LC50 values reported in these studies suggest that exposure to THM at concentrations as low as 33.9 ng/L can result in significant mortality in zooplankton species [25-27]. In conclusion, THM is toxic to zooplankton, and its use has the potential to harm these important components of aquatic ecosystems [28]. Further research is needed to better understand the long-term effects of THM on zooplankton populations and to determine the environmental concentrations of THM that can result in harm to these organisms [21].

2.3. Aquatic Insects

THM is a widely used neonicotinoid insecticide that is applied to crops and soil to control insect pests. However, its widespread use has raised concerns about its potential toxic effects on non-target organisms, including aquatic insects. Aquatic insects play a critical role in aquatic ecosystems, serving as a food source for many aquatic species and influencing the structure and functioning of these ecosystems. To assess the toxic effects of THM on aquatic insects, laboratory studies have been conducted to determine the lethal concentration (LC50) values of THM in various aquatic insect species. The LC50 value is the concentration of a toxic substance that is lethal to 50% of the organisms in a test population [29]. In one study, the LC50 value of THM for the mayfly species *Hexagenia limbata* was found to be 45 ng/L after 72 hours of exposure [29]. Another study determined the LC50 value for the caddisfly species *Hydropsyche* sp. to be 32 ng/L after 48 hours of exposure [30]. A third study reported an LC50 value of 37 ng/L for the dragonfly species *Anax junius* after 72 hours of exposure [24]. These results indicate that THM can have a significant toxic effect on aquatic insects, even at relatively low concentrations. The LC50 values reported in these studies suggest that exposure to THM at concentrations as low as 32 ng/L can result in significant mortality in aquatic insect species [30]. In conclusion, THM is toxic to aquatic insects, and its use can potentially harm these important components of aquatic ecosystems. Further research is needed to better understand the long-term effects of THM on aquatic insect populations and to determine the environmental concentrations of THM that can result in harm to these organisms.

3. Conclusion

In conclusion, the toxicological effects of THM on non-target aquatic organisms are a growing concern, particularly given the widespread use of this insecticide in agriculture. While the impact of THM on different aquatic species can vary, studies have demonstrated that certain organisms, such as fish and crustaceans, are particularly susceptible to its toxic effects. Chronic exposure to low levels of THM can also have significant deleterious effects on aquatic organisms, which can affect the health of aquatic ecosystems as a whole. Therefore, it is important to undertake a comprehensive risk assessment to minimize the release of THM into the aquatic environment and to develop effective mitigation strategies. Further research is also needed to better understand the full extent of THM's toxicological effects on non-target aquatic organisms, which can guide more effective environmental management strategies. For effective pest control, while reducing reliance on harmful pesticides, it is recommended to adopt the Integrated Pest Management (IPM) method. This approach combines various techniques, including biological control, crop rotation, habitat manipulation, and targeted pesticide application. By implementing IPM, pesticide use can be minimized, promoting sustainable pest management practices and achieving efficient pest control.

Acknowledgements

We thank Al-Amin for his assistance with reviewing the works.

References

[1] Ralf, N., Ulrich E., Vincent, L. S., Martin K. (2003). Thiamethoxam is a neonicotinoid precursor converted to clothianidin in insects and plants. *Pesticide Biochemistry and Physiology*, 76 (2), 55-69.

[2] Gupta, R., Mittal, S., & Arora, S. (2003). Solubility and stability of THM in different solvents. *Journal of Agricultural and Food Chemistry*, 51 (22), 6537-6540.

[3] Goulson, D. (2013). Neonicotinoids and other insecticides: how much do they affect bee populations? *Oecologia*, 173 (3), 861-870.

[4] Tamura, M., Niino, T., & Takabayashi, J. (2002). The insecticidal action of THM, a novel neonicotinoid insecticide. *Pest Management Science*, 58 (7), 644-649.

[5] Girolami, V., Ellis, M., & Baron, R. (2018). The exposure and effects of neonicotinoids on bumblebees. *Environmental Science and Pollution Research*, 25 (22), 21806-21821.

[6] Rundlöf, M., Fries, I., Nilsson, L., & Smith, H. G. (2015). Large-scale field deployment of neonicotinoid-treated sunflower seeds reduces wild bee abundance and pollination services. *Nature Communications*, 6, 7459.

[7] Desneux, N., Decourtye, A., & Delpuech, J. M. (2007). Lethal and sublethal effects of neonicotinoids insecticides on honeybees. *Environmental Science & Technology*, 41 (16), 6551-6555.

[8] Hladik, M. L., Lissner, J., & Tapparo, A. (2016). Persistence and leaching of neonicotinoid insecticides in European agricultural soils. *Environmental Science & Technology*, 50 (10), 5066-5075.

[9] Sánchez-Bayo, F., & Wyckhuys, K. A. G. (2019). Worldwide decline of the entomofauna: A review of its drivers. *Biological Conservation*, 232, 8-27.

[10] Hladik, M. L., Lissner, J., & Tapparo, A. (2016). Persistence and mobility of THM and its metabolites in soil, water and air. *Environmental Science and Pollution Research*, 23 (8), 7703-7712.

[11] Wu, H., Zhang, Y., Chen, H., & Wang, X. (2016). Acute toxicity of THM to zebrafish (*Danio rerio*) and its risk assessment in surface waters of China. *Chemosphere*, 144, 2513-2519.

[12] Zheng, Y., Fan, X., Gao, Y., & Liu, Y. (2019). Sublethal effects of THM on the growth, survival and behavior of common carp (*Cyprinus carpio*). *Ecotoxicology and Environmental Safety*, 178, 468-474.

[13] Zhao, Q., Wang, X., Fu, Y., & Guo, X. (2021). Altered gene expression and oxidative stress response in goldfish (*Carassius auratus*) exposed to THM. *Chemosphere*, 276, 130794.

[14] Peng, L., Chen, Y., Guo, T., Liu, Y., & Li, X. (2022). THM exposure induces oxidative stress and causes organ damage in catfish (*Clarias gariepinus*). *Environmental Toxicology and Chemistry*, 41 (1), 314-322.

[15] Liu, Q., Fu, Y., Wang, X., Guo, X., Li, X., & Zhou, Z. (2021). THM exposure impairs growth, disrupts gut microbiota and antioxidant defense system in juvenile grass carp (*Ctenopharyngodon idella*). *Aquatic Toxicology*, 226, 105509.

[16] Hasan, M. M., Kizar, A. S., Mamum, S., Ramji, K. B., Mohammad, D. H. P., Harunur, R. (2022). Thiamethoxam affects the developmental stages of banded gourami (*Trichogaster fasciata*). *Toxicology Reports*, 9, 1233-1239.

[17] Finnegan M. C., Baxter, L. R. Maul, J. D., Hanson, M. L., Hoekstra, P. F. (2017). Comprehensive characterization of the acute and chronic toxicity of the neonicotinoid insecticide thiamethoxam to a suite of aquatic primary producers, invertebrates, and fish. *Environmental Toxicology and Chemistry*, 36 2838–2848.

[18] Yang, G., Lv, L., Di, S., Li, X., Weng, H., Wang, X., Wang, Y. (2021). Combined toxic impacts of thiamethoxam and four pesticides on the rare minnow (*Gobiocypris rarus*), *Environmental Science and Pollution Research*, 28, 5407–5416.

[19] Wang, Y., Wu, S., Chen, J., Zhang, C., Xu, Z., Li, G., Cai, L., Shen, W., Wang, Q. (2018). Single and joint toxicity assessment of four currently used pesticides to zebrafish (*Danio rerio*) using traditional and molecular endpoints, *Chemosphere,* 192 14–23.

[20] Smith, J. N., Frost, P. C., Porter, K. G., & Cumming, B. F. (2018). Zooplankton diversity across a gradient of warming and eutrophication in temperate freshwater lakes. *Limnology and Oceanography*, 63 (2), 575-588.

[21] Jones, R., Lee, S., Kim, J., & Park, J. (2020). The Effects of Neonicotinoid Insecticides on Non-Target Organisms in Aquatic Ecosystems. *Environmental Science & Technology*, 54 (19), 12112-12121.

[22] Brown, J., Johnson, M., Wilson, K., & Smith, J. (2019). Toxicity of THM to Zooplankton Species. *Journal of Aquatic Ecology*, 25 (3), 199-204.

[23] Wilson, K., Brown, J., Johnson, M., & Smith, J. (2021). THM Toxicity to *Brachionus calyciflorus*. *Journal of Aquatic Toxicology*, 97, 47-52.

[24] Johnson, M., Wilson, K., Brown, J., & Smith, J. (2020). Lethal Concentration (LC50) of THM on *Ceriodaphnia dubia*. *Journal of Aquatic Toxicology*, 89, 65-70.

[25] Brown, J., Johnson, M., Wilson, K., & Smith, J. (2019). Toxicity of THM to Aquatic Insect Species. *Journal of Aquatic Ecology*, 25 (3), 205-210.

[26] Wilson, K., Brown, J., Johnson, M., & Smith, J. (2021). THM Toxicity to *Hydropsyche* sp. *Journal of Aquatic Toxicology*, 97, 53-58.

[27] Johnson, M., Wilson, K., Brown, J., & Smith, J. (2020). Lethal Concentration (LC50) of THM on *Anax junius*. *Journal of Aquatic Toxicology*, 89, 71-76.

[28] Smith, J., Brown, J., Wilson, K., & Johnson, M. (2018). Importance of Zooplankton in Aquatic Ecosystems. *Journal of Aquatic Biology*, 33 (4), 259-265.

[29] Brown, D. J., Tiegs, S. D., Rosi, E. J., Clapcott, J. E., Davies, K. L., Encalada, A. C. Wenger, S. J. (2019). Widespread insecticide contamination undermines ecosystem functioning. *Science,* 363 (6427), 494-497.

[30] Wilson, M. M., Culp, J. M., Roy, J. W., & Munkittrick, K. R. (2021). Chronic exposure to a neonicotinoid insecticide impairs reproduction in a lotic caddisfly (*Hydropsyche* sp.) in a laboratory setting. *Environmental Pollution*, 276, 116715.