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Torry Herbicide: An Extensive Examination of Toxicity and its Effects in Freshwater Carps

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Abstract: The impact of tembotrione and atrazine herbicides, commonly used in agriculture, on freshwater carp is concerning. These herbicides have been found to cause acute and chronic toxicity in carp, including mortality, reduced growth, impaired reproduction, and altered metabolic functions. Prolonged exposure to these herbicides in water bodies can amplify their detrimental effects on fish populations. The review emphasizes the need for effective mitigation strategies and regulatory measures to protect aquatic ecosystems and fish species from herbicide contamination, as well as the need for further research on environmentally friendly alternatives. And also highlights the harmful effects of tembotrione and atrazine herbicides on freshwater carp, emphasizing the need for comprehensive risk assessments and management practices to protect aquatic environments and ensure fish population sustainability that also fulfills SDG-14, recommending further research for environmentally friendly alternatives.

Keywords: Torry herbicide, Tembotrione, Atrazine, Carp, Aquatic ecosystem

Introduction

In recent years, applying herbicides to crops is a standard procedure to boost agricultural yields. Consequently, natural streams in agricultural regions become contaminated due to the sporadic heavy use of pesticides(Comoretto et al., 2007; Knauer & Hommen, 2013). Torry is a relatively new triketone herbicide which is a mixed compound of tembotrione and atrazine.Applications of this herbicide are made post-emergence on all types of corn(Solís et al., 2016).Though its primary usage is in maize farming areas, research is still ongoing to see whether it has any potential uses in other fields, including millet, sorghum(Dan et al., 2010), and poppies(Pinke et al., 2014).

Torry herbicide,a combination of tembotrione and atrazine compounds, in whichtembotrioneis the main component, wasintroduced to the market in 2007 and applied as a post-emergence herbicide to manage various grass and broadleaf weed species growing in cornfields(Dumas et al., 2017; Santel, 2009). The newest herbicide in the triketone family, temotrione is made chemically from a naturally occurring phytotoxin and is marketed as "eco-friendly." Yet,these naturally occurring bioactive substances mayharm both non-target species and the environment. Tembotrione has a significant potential for runoff following application, and its usage in locations with porous soils may cause groundwater pollution. It may also pollute surface water through spray drift caused by wind(Barchanska et al., 2017; Tawk et al., 2017).Consequently, this has an impact on the ecological dynamics of species linked with crops at all tropic levels. These species include those that offer ecosystem services like pollination and pest management, such as phytophagous, weed feeders, and predators. Furthermore, exposure has been shown to have physiological and behavioral impacts at the organism level in species that are significant contributors to the ecology of agroecosystems. Changes in temperature, pH, soil composition, or the kind and activity of microorganisms might then have an impact on the stability of herbicides in aqueous and soil compartments(Barchanska et al., 2017; Calvayrac et al., 2013; Velki and Ečimović, 2015). Therefore, there is a risk to human health from herbicides that may readily find their way into plant-based food or the air.Our study is focusedon the effcts of tembotrione components in carp species which is related to humans.Tembotrione is a selective herbicide primarily used in agriculture to control post-emergent broadleaf and grass weeds in cornfields. However, like many herbicides, its use raises concerns about potential impacts on aquatic environments. When tembotrione enters water bodies through runoff or spray drift, it can have several ecological ramifications.

Atrazine which is another component of Torry herbicide, a commonly used herbicide in agriculture, has raised concerns for its detrimental impacts on freshwater ecosystems, particularly on species like carp. Freshwater carp, including common carp (Cyprinus carpio) and grass carp (Ctenopharyngodonidella), are crucial components of aquatic food webs and are extensively distributed worldwide (Ankley et al., 2009). However, they are highly vulnerable to the toxic effects of atrazine contamination due to their physiology and habitat preferences (Blahovaet al 2020).Research has indicated that atrazine exposure can affect freshwater carp in a variety of ways. Carps' endocrine system is interfered with by atrazine, which causes hormone control to be disrupted and negative physiological reactions (Xing et al 2014) (Xing et al 2012). For example, exposure to atrazine has been associated with changes in carp reproductive behavior and the development of their reproductive organs, which may lead to a fall in population size and reduced reproductive success. Furthermore, carp's immune systems may be weakened by atrazine, leaving them more vulnerable to illnesses and environmental stresses (Khalil et al 2017) (Ramesh et al 2009).

Aquatic plants are also essential for preserving the quality of the water and creating habitat for other creatures; their decline due to herbicide exposure can have cascading effects on entire ecosystems (Gabsi et al., 2019).Onesignificant impact of its potential toxicity to aquatic organisms. Studies have shown that tembotrione can be harmful to various aquatic organisms, including algae, aquatic plants, and invertebrates. Algae are particularly susceptible, as tembotrione can inhibit photosynthesis, disrupting the aquatic food chain. In aquatic habitats, tembotrione can linger, exposing local creatures over an extended period,whichmay become more toxic and bioaccumulate in aquatic food chains, potentially reaching quantities that are hazardous to animals at higher trophic levels, such as fish and other vertebrates (Choudri et al., 2019). One of the primary concerns regarding tembotrione's impact on fish is its potential toxicity. Tembotrione can bioaccumulate in fish tissues through the food chain, potentially leading to higher concentrations in predatory fish species. Bioaccumulation of tembotrione and its metabolites in fish tissues raises concerns about the safety of consuming contaminated fish and the potential transfer of these contaminants to higher trophic levels, including humans (Hasanuzzamanet al., 2020). The present review demonstrates that exposure to TorryHerbicide,which contains the main components of tembotrione, maycause acute toxicity in fish, leading to behavioral changes, physiological stress responses, andevenmetabolic, morphological, and mortality. The toxic effects may vary depending on factors such as the concentration of the herbicide, duration of exposure, and the species of fish involved. Chronic exposure to sublethal concentrations of tembotrione can have long-term effects on fish populations. This work aimed to review the literature concerning these issues. The issue needs to be bettered carefully to minimize the adverse effects on fish as well as the target organism in the aquatic environment and also ensure the safe consumption of fish by human beings.

Mode of action

The main ingredients of torry herbicides are tembotrione and atrazine, which are aromatic compounds with a highwater solubility that are used as post-emergence herbicides in maize fields. These herbicides are thought to be very safe because they specifically inhibit the enzyme 4-hydroxyphenylpyruvate dioxygenase, which catalyzes the conversion of 4-hydroxyphenylpyruvate to homogentisate, which depletes carotenoids and interferes with the synthesis of plant pigments and chlorophyll (Ahrens et al., 2013)(Chu et al., 2018).India, as with many other nations, has outlawed atrazine because of its extreme harm to animals and humans. A large body of research has established a strong correlation between atrazine and serious health issues, such as a higher risk of breast cancer in women, a lower sperm count in males, and an increased risk of prostate cancer(Qu et al., 2021) (Giglio et al., 2022). The demise of several other endangered species across the nation, including endangered amphibians, has been connected to atrazine. It is an endocrine disruptor that alters the hormone cycle of amphibians, directly affecting their sexual development. It has been demonstrated that atrazine exposure at as little as 0.1 parts per billion can impact frogs' development of sex traits(Singh et al., 2018) (Pathak et al., 2011). Due to a lack of knowledge on their destiny and behavior in the field as well as the risk they pose to non-target organisms on land and in water, certain active ingredients, including butralin, dinitramine, ethalfluralin, isopropanol, nitralin, nitrofor, oryzalin, and trifluralin, are presently not authorized. Nevertheless, the United States Environmental Protection Agency has approved butralin, ethalfluralin, oryzalin, and trifluralin (EPA 2017).Chemical herbicides like atrazine and metolachlor are used in pre-emergence weed control, preventing weed growth before seeds germinate, a proactive approach used by farmers in corn and soybean cultivation(Merola et al., 2022). Selective herbicides like 2,4-D, dicamba, and clopyralid are used to control specific weed species without affecting desired crops. They are crucial in integrated weed management practices, promoting sustainable and effective weed control (Shaner et al.,2012). Chemical herbicides can significantly contaminate aquatic water sources, posing risks to aquatic organisms and ecosystems when they enter water bodies through runoff or drift. Herbicides like glyphosate, atrazine, and 2,4-D have harmful effects on- aquatic organisms, including reduced photosynthesis, impaired growth, reproduction, and mortality among sensitive species, depending on their chemical composition and concentration (Schipper et al., 2008). Herbicides can cause habitat loss for fish and other aquatic creatures, change the species makeup of the environment, decrease biodiversity, and eventually hurtthe entire food chain (Solomon et al., 2013). Regulatory agencies restrict herbicide use near water bodies and require buffer zones to minimize runoff while developingenvironmentally friendly formulations and application techniques that can help reduceherbicide contamination in aquatic ecosystems (Stehle et al., 2015).

Physiological action

Fin: Exposure to herbicides can potentially impact the fins of Amur carp, either directlythrough contact or indirectly through alterations in their aquatic habitat and food sources.While research specifically addressing the effects of herbicides on Amur carp fins may belimited, insights from studies on other fish species and aquatic organisms can providemvaluable information. It has been demonstrated that several herbicides, such glyphosate andatrazine, can be hazardous to fish, causing alterations in the physiology and histology ofmany organs, including the fins. The structure and functionality of the fins of Amur carp areimpacted by these alterations, which could include tissue injury, inflammation, andcompromised regeneration processes. (Eljasik et al., 2022). Loss of vegetation cover canexpose Amur carp to increased predation risk and reduce their access to suitable spawningand foraging grounds, indirectly impacting the organ and its functionality (Rohr et al., 2010).

Gill: The gills of Amur carp (Cyprinus rubrofuscus) are vital respiratory organs that play acrucial role in gas exchange, allowing the fish to extract oxygen from water and expel carbondioxide. While specific research on the effects of herbicides on Amur carp gills may belimited, insights from studies on other fish species and aquatic organisms can providevaluable information. Direct exposure to herbicides can lead to toxicity in fish gills.(Stevanović et al., 2019). For instance, Amur carp gills may experience increased respiratorystress as a result of herbicide exposure, which could result in hypoxia and metabolicabnormalities (Vali et al., 2022). Amur carp gills may experience increased respiratory stress asa result of herbicide exposure, which could result in hypoxia and metabolic abnormalities(Solomon et al., 2013).

Eye: The eyes of Amur carp (Cyprinus rubrofuscus) are essential sensory organs that play acritical role in navigation, foraging, and predator detection. Fish that are directly exposed toherbicides may develop eye toxicity. Numerous herbicides, such as atrazine and glyphosate,have been demonstrated to have negative effects on fish eyes, including tissue damage,inflammation, and reduced vision. These consequences could show up as modifications to thesize, shape, and pigmentation of the eyes as well as disturbances to the structure and functionof the retina. (Anderson et al., 2021). Herbicides may indirectly affect Amur carp's eyes bychanging the characteristics of the water quality. Fish vision clarity and acuity may beimpacted by herbicide pollution in water bodies because they can alter light penetration,turbidity, and nutrient levels (Socha et al., 2021). Furthermore, early detection of herbicide-induced ocular stress in Amur carp populations can be facilitated by monitoring systems thatcenter on behavioral observations and assessments of ocular health. (Al-Swefee& D. Z.,2014).

Scales: The skin of Amur carp (Cyprinus rubrofuscus) serves as a protective barrier againstexternal threats and plays a crucial role in maintaining osmotic balance, gas exchange, andthermoregulation. While specific research on the effects of herbicides on Amur carp skin maybe limited, insights from studies on other fish species and aquatic organisms can providevaluable information. Fish that are directly exposed to herbicides may develop skin toxicity.Numerous herbicides, including atrazine and glyphosate, have been demonstrated to havenegative effects on fish skin, including inflammation, tissue damage, and changes to thestructure and function of the skin. These consequences could compromise the integrity of theskin barrier and cause secondary infections or poor osmoregulation in Amur carp. They couldalso show up as skin color changes, lesions, ulcers, and increased mucus production (Liu et al2021).

Bioaccumulation and persistence of Tembotrione and Atrazine in soil:

Bioaccumulation and persistence of tembotrione herbicide in the environment have raised concerns about potential ecological impacts. Bioaccumulation refers to the gradual buildup of a substance in living organisms, often through exposure via food or water. Studies have shown that tembotrione can accumulate in aquatic organisms such as fish and invertebrates, posing risks to both aquatic ecosystems and organisms higher up the food chain, including humans (Dumas et al., 2017).Moreover, tembotrione exhibits persistence in soil and water, meaning it can remain active and potent for extended periods after application. This persistence increases the likelihood of environmental exposure and subsequent bioaccumulation in organisms. Research indicates that the degradation of tembotrione in soil and water can vary depending on factors such as temperature, soil composition, and microbial activity(Dong et al., 2023). The bioaccumulation and persistence of tembotrione highlight the importance of considering its environmental fate and potential long-term impacts when evaluating its use in agriculture. Sustainable agricultural practices, including the adoption of integrated pest management strategies and the use of alternative herbicides with lower environmental persistence, may help mitigate the risks associated with tembotrione exposure. Additionally, regulatory measures aimed at monitoring and limiting its use can contribute to minimizing its ecological footprint (Tust et al., 2021). The bioaccumulation of atrazine is primarily observed in aquatic environments, where it can persist for extended periods due to its low water solubility and resistance to degradation. Atrazine enters water bodies through runoff from treated fields and can accumulate in sediments, aquatic plants, and organisms. Aquatic organisms such as fish, amphibians, and invertebrates can absorb atrazine through direct contact with water or ingestion of contaminated food sources. Once absorbed, atrazine can bioaccumulate in the tissues of these organisms over time.Studies reveal that atrazine can cause problems in development and reproduction by interfering with aquatic creatures' endocrine systems. For example, research has demonstrated that atrazine exposure can disrupt frogs' reproductive systems, leading to hermaphroditism and decreased fertility. Atrazine may also upset the hormonal balance of species in impacted environments, as evidenced by its connections to the feminization of male fish and changed hormone levels in aquatic invertebrates (Hayes et al., 2002).

Acute toxicity of Tembotrione and atrazine:

Fish, invertebrates, and algae are among the aquatic species to which tembotrione demonstrates acute toxicity. Fish that come into contact with tembotrione may suffer from negative consequences including decreased swimming activity, changed eating habits, and even death. Commonly utilized as model animals in toxicity studies, invertebrates like Daphnia magna have demonstrated susceptibility to tembotrione exposure, with detrimental effects on survival and reproduction noted at high doses.

Moreover, tembotrione can prevent algae from growing, which might disturb the primary production of aquatic habitats.Terrestrial organisms, particularly non-target organisms and soil-dwelling may also be susceptible to tembotrione toxicity. Studies have demonstrated that tembotrione can inhibit the germination and growth of certain plant species, affecting vegetation dynamics in agricultural and adjacent ecosystems. Soil microbial communities may also be impacted by tembotrione, potentially affecting nutrient cycling and soil health (Dumas et al., 2017).Atrazine, which is also a component of torry,is a widely used herbicide in agriculture, and exhibits acute toxicity to various non-target organisms, posing risks to both aquatic and terrestrial ecosystems. Research has shown that atrazine can adversely affect aquatic organisms such as fish, amphibians, and invertebrates. Fish exposed to atrazine may experience reduced swimming performance, impaired respiratory function, and increased mortality, particularly during early life stages. Amphibians, such as frogs and salamanders, are also vulnerable to atrazine exposure, with studies documenting developmental abnormalities, reduced growth, and disrupted hormone levels. Additionally, aquatic invertebrates, including crustaceans and insects, can suffer from decreased survival and reproduction rates following atrazine exposure (Solomon et al., 2008).

Side Effects of Chronic Exposure to Tembotrione and Atrazine:

Carp fish can suffer negative consequences from long-term exposure to herbicides such as tembotrione and atrazine, which can affect several parts of their physiology and behavior. Atrazine, a common s-triazine herbicide, and tembrotrione, a triketone herbicide, are known to linger in aquatic habitats and pose a serious threat to aquatic species like carp.The potential for these herbicides to cause endocrine system disruption in carp fish is one of the main worries associated with long-term exposure. Fish are among the aquatic species for whom endocrine disruption has been related to both tembotrione and atrazine. These herbicides have the potential to disrupt hormonal pathways, which can result in aberrant gonadal development, poor spawning, and decreased carp population fertility, among other reproductive problems.Aquatic plants may also show decreased photosynthetic activity and stunted development, which might affect the quality of the environment for other creatures (Dong et al., 20024).The potential for these herbicides to cause endocrine system disruption in carp fish is one of the main worries associated with long-term exposure. Fish are among the aquatic species for whom endocrine disruption has been related to both tembotrione and atrazine. These herbicides have the potential to disrupt hormonal pathways, which can result in aberrant gonadal development, poor spawning, and decreased carp population fertility, among other reproductive problems.More importantly, carp fish's brain system may suffer from long-term exposure to atrazine and tembotrione. Research has indicated that these herbicides have the potential to interfere with neurotransmitter systems, resulting in altered behavior, reduced cognitive abilities, and changed carp swimming patterns (Solomon et a., 2013). Carp's capacity to navigate, avoid predators, and feed may be hampered by these neurological impacts, which can eventually affect their chances of surviving and procreating. Prolonged exposure to atrazine and tembotrione can also weaken carp fish's immune systems in addition to their endocrine and neurological impacts. Carp are more prone to infections and illnesses when exposed to these herbicides for an extended period because they can impair immune function. When carp populations are exposed to herbicides, their susceptibility to infections increases, perhaps resulting in decreased overall fitness and greater death rates.Prolonged exposure to atrazine and tembotrione can also weaken carp fish's immune systems in addition to their endocrine and neurological impacts (Weston et al., 2010). Carp are more prone to infections and illnesses when exposed to these herbicides for an extended period because they can impair immune function. When carp populations are exposed to herbicides, their susceptibility to infections increases, perhaps resulting in decreased overall fitness and greater death rates.Long-term exposure to sublethal levels of atrazine can cause reproductive abnormalities, stunted development, and compromised immune system performance in fish. Research has shown that atrazine exposure is linked to developmental defects, changing hormone levels, and population decreases in amphibians, making them particularly vulnerable. Reduced survival and reproductive success in invertebrates, such as insects and crustaceans, can change the dynamics of food webs and ecosystems. Aquatic plants may also show lower photosynthetic activity and slowed development, which can affect theecosystem’s general health and environmental quality(Solomon et al., 2008).

Morphological, physiological, and behavioral alterations:

Fish exposed to tembotrione may experience morphological changes, such as adjustments to their body size, shape, and color. Research has shown that fish exposed to sublethal levels of tembotrione exhibit decreased body size, aberrant fin development, and changed color. These morphological alterations may have an impact on the ability to swim, escape predators, and reproduce successfully, all of which may have an impact on population dynamics and ecological structure.Physiological responses of fish to tembotrione exposure involve disruptions in metabolic processes, enzyme activity, and biochemical pathways. Tembotrione can induce oxidative stress, leading to lipid peroxidation, protein damage, and DNA fragmentation in fish tissues. Additionally, alterations in hormone levels, including those involved in reproduction and stress response, have been observed in fish exposed to tembotrione, potentially impairing reproductive success and population viability.Behavioral alterations in fish following tembotrione exposure encompass changes in locomotor activity, feeding behavior, and social interactions. Fish may exhibit reduced swimming activity, altered feeding preferences, and disrupted schooling behavior in response to sublethal concentrations of tembotrione. These behavioral changes can affect predator-prey dynamics, competitive interactions, and habitat utilization, with implications for individual fitness and population persistence (Choudri et al., 2019).Fish exposed to atrazine may have morphological changes, such as adjustments to their body size, shape, and color. Studies on fish exposed to sublethal levels of atrazine have shown decreased body length, aberrant fin development, and changed color. These morphological alterations may affect the ability to swim, escape predators, and reproduce successfully, all of which may have an influence on population dynamics and ecological structure.Physiological responses of fish to atrazine exposure involve disruptions in metabolic processes, enzyme activity, and biochemical pathways. Atrazine can induce oxidative stress, leading to lipid peroxidation, protein damage, and DNA fragmentation in fish tissues. Additionally, alterations in hormone levels, including those involved in reproduction and stress response, have been observed in fish exposed to atrazine, potentially impairing reproductive success and population viability (Kar et al., 2021).Behavioral alterations in fish following atrazine exposure encompass changes in locomotor activity, feeding behavior, and social interactions. Fish may exhibit reduced swimming activity, altered feeding preferences, and disrupted schooling behavior in response to sublethal concentrations of atrazine. These behavioral changes can affect predator-prey dynamics, competitive interactions, and habitat utilization, with implications for individual fitness and population persistence (Relyea& R. A. 2009).

Conclusive remarks on the multilevel effects

Tembotrione has the ability to change the morphology, physiology, and behavior of non-target species such as fish, amphibians, invertebrates, and plants on an individual basis. These consequences might jeopardize a person's survival, reproductive chances, and general health, which would ultimately have an impact on the dynamics of population and community structure in the impacted ecosystems.At the population level, tembotrione exposure can lead to changes in species abundance, distribution, and genetic diversity. Populations of sensitive species may decline due to reduced recruitment, increased mortality, or impaired reproductive success, potentially altering community composition and trophic interactions. Additionally, the genetic integrity of populations may be compromised by selective pressures imposed by tembotrione exposure, leading to reduced adaptive potential and resilience to environmental stressors.At the ecosystem level, tembotrione can impact biotic and abiotic components of ecosystems, affecting nutrient cycling, primary productivity, and habitat quality. Disruptions in ecosystem processes and functions may have cascading effects on biodiversity, ecosystem services, and human well-being. For example, changes in aquatic plant communities due to tembotrione exposure may affect water quality, sediment stabilization, and habitat provision for aquatic organisms (Pehar et al., 2023).Atrazine may cause changes in the morphology, physiology, and behavior of non-target species such as fish, amphibians, invertebrates, and plants on an individual basis. Within impacted ecosystems, these consequences may jeopardize an individual's survival, reproductive success, and health, which might have an impact on community structure and population dynamics.Exposure to atrazine can alter species distribution, abundance, and genetic diversity at the population level. Reduced recruitment, higher mortality, or poor reproductive success can all contribute to the loss of sensitive species, which might change the structure of communities and trophic relationships. Furthermore, populations' genetic integrity may be compromised by selected pressures resulting from exposure to atrazine, which would lower their capacity for adaptation and resistance to environmental stresses.Abiotic and biotic elements of an ecosystem can be impacted by atrazine, which can affect primary productivity, nutrient cycling, and habitat quality. Ecosystem services, biodiversity, and human well-being may all be impacted in turn by disruptions to ecosystem processes and functions. For example, atrazine exposure can alter aquatic plant communities, which can have an impact on sediment stability, water quality, and the availability of habitat for aquatic creatures (Solomon et al., 2008).

Perspectives for future research:

Future investigations will probably be going to concentrate on figuring out how long-term exposure to atrazine and tembotrione affects fish populations and ecosystems. Studying bioaccumulation, behavioral alterations, acute and chronic toxicity, and effects on aquatic food webs are some possible topics for research. The amounts of herbicides in water bodies may be measured, and their possible effects on fish populations and health can be accessed via monitoring programs.To reduce the negative impacts of tembotrione and atrazine on aquatic habitats, regulatory bodies may set more stringent usage restrictions. This might entail more stringent guidelines for application rates, the need for buffer zones surrounding bodies of water, and environmental monitoring specifications. In sensitive aquatic ecosystems, the use of alternative herbicides with lower profiles of water toxicity may be recommended or even required.Rising public knowledge of herbicides' possible effects on aquatic ecosystems should put more pressure on manufacturers, farmers, and regulators to give environmental stewardship priority. The promotion of optimal management techniques that reduce pesticide runoff and safeguard water quality may be the main goal of education and outreach initiatives.

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