PROTECTING AQUATIC ECOSYSTEMS

Insecticide Seed Treatments Threaten Midwestern Waterways

Most of the corn and soybean seeds planted across roughly 148 million acres of the Midwest are treated with insecticides. These insecticides can move into waterways and threaten populations of sensitive aquatic insects, like mayflies, which are critical food sources for other wildlife.

The Midwest is characterized by iconic waters, from the Great Lakes to the powerful Mississippi River. Equally iconic are the region's rolling fields of corn and soybean. Unfortunately, a dramatic rise in planting seeds treated with insecticides means that these fields threaten the health of Midwestern waterways. This report explores the water quality consequences of planting millions of acres of insecticide-treated seed across the Midwest.

What is at Stake in the Midwest?

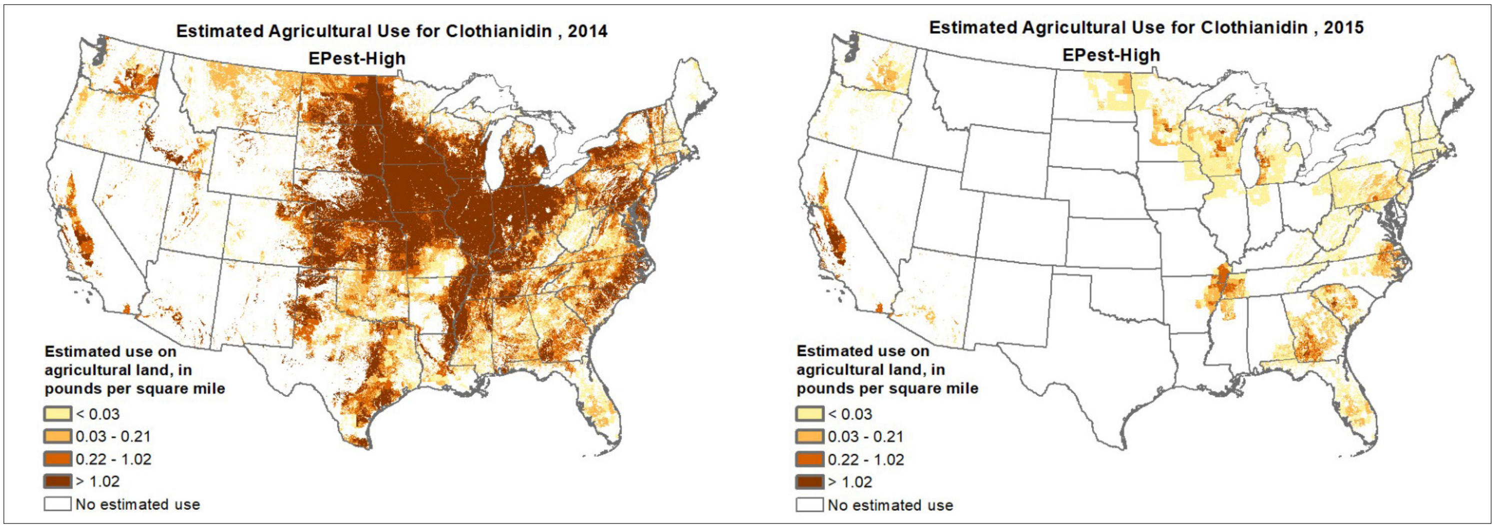
Midwestern waterways are alive with beneficial invertebrates that provide valuable ecological services. These essential species are threatened by a wide variety of contaminants, especially systemic insecticides that move readily into waterways. Not only can insecticides kill insects outright, but they can also cause damaging effects that leave them more vulnerable to other stressors and harm populations over time.

When aquatic insects decline, the effects can be far-reaching and ripple up the food chain: fish and birds rely on healthy populations of aquatic insects for their food (Hallman et al. 2014, Suter & Cormier 2014, Yamamuro et al. 2019, Stepanian et al. 2020). Midwestern aquatic insects are critical for migratory birds whose spring journeys north rely on stopovers across the region (Schepker et al. 2020). Declines in sensitive aquatic insects are already being observed—recent mayfly emergence studies have shown 50–80% population declines in parts of the Midwest (Stepanian et al. 2020). Mayflies are especially sensitive to pesticides, with studies showing effects on swimming behavior, feeding inhibition, immobility, and more at very low concentrations of neonicotinoids (Morrissey et al. 2015, Bartlett et al. 2018). While the observed mayfly declines are likely influenced by multiple factors, reducing exposure to pesticides can limit stress on sensitive populations.

How Common are Insecticide Seed Treatments in the Midwest?

Treating seeds with pesticides before they are planted is a growing trend in row-crop agriculture. Fungicides have been applied to seeds for many years, but insecticide seed treatments have become ubiquitous only over the past decade. Many insecticide seed treatments are pesticides in the neonicotinoid class, the most commonly used insecticides worldwide. Neonicotinoids (also known as neonics) are applied to many landscapes, from agricultural fields to home gardens. Their

Figure 1. Pesticide Use Estimates Demonstrate the Extent of Neonicotinoid Seed Treatment



Seed treatments are estimated to account for most of the clothianidin and thiamethoxam applied to fields in the Midwest, illustrated by the drastic difference in clothianidin use estimates from 2014 to 2015, when seed treatment estimates were removed from the data. The 2014 map shows estimated use including seed treatments, and the apparent decline in the 2015 map reflects their removal due to uncertainties with data collection. However, planting neonicotinoid treated seed remains a standard practice across the Midwest and has likely only increased since data collection stopped in 2014.

Maps: Courtesy of the U.S. Geological Survey (USGS n.d.)

properties make them, and similar insecticides, especially concerning.

Neonics are systemic, binding to water, which allows them to move throughout plants and to be applied as a seed treatment intended to be taken up by the growing crop. But because they move readily with water, neonics often end up in waterways. Most of the neonics applied to seeds are actually not absorbed by the growing plants, leaving 80–98% of the pesticides in the soil, where they can then move into surface or groundwater (Alford & Krupke 2017).

In Midwestern agriculture, neonics are most commonly used as seed treatments for crops including corn, soybean, alfalfa, wheat, and some vegetables. Neonics are applied to nearly all of the corn seed and the majority of soybean seed planted across roughly 148 million acres in the Midwest, an area about the size of Minnesota and the Dakotas combined (Douglas & Tooker 2015, Hitaj et al. 2020, USDA 2021).

Despite widespread use, there is little reliable data on planting of pesticide-treated seed because treated seed is exempted from federal pesticide regulations by the Environmental Protection Agency (EPA). This means that state and federal agencies do not have access to information about where and how much treated seed is planted on the landscape, the way they do for other pesticide applications. The U.S. Geological Survey (USGS) estimates annual agricultural use for hundreds of pesticides, but stopped including treated seed use after 2014.

Still, researchers estimate that almost all of the neonic use in corn and soybean production are seed treatments, which is supported by the USGS pesticide use estimate data from before and after treated seed was removed from the estimates (Figure 1, Douglas & Tooker 2015). ***Neonicotinoid use patterns for corn and soybean suggest that the majority of neonic detections in watersheds dominated by these two crops can be attributed primarily to seed treatments*** (USGS n.d., Hladik et al. 2014, Douglas & Tooker 2015)**.**

Disposal of Treated Seed: Another Contamination Pathway

Seed companies often have leftover seed that cannot be planted, and the impacts of disposing this excess treated seed are only now coming to light. Lack of oversight of disposal meant that for years, a single ethanol plant in Nebraska received the vast majority of excess treated seed in North America. Unfortunately, processing treated seed into ethanol resulted in pesticide-laden byproducts. These toxic byproducts were spread on fields in the area, contaminating water and soil, and impacting wildlife and the community. Sampling in a pond five miles downstream of the plant identified clothianidin at 50.3 million ng/L and thiamethoxam at 60.6 million ng/L—well above levels that devastate aquatic invertebrates (NDEE 2021). As of summer 2021, the plant has been shut down and the state is overseeing its cleanup. Still, a larger question remains—how will pesticide-treated seed be disposed of in the future? Regulators must address this issue and develop rules to guide the disposal of treated seed.

Table 1. USGS Neonicotinoid Surface Water Samples in the Midwest

Neonicotinoid*	Samples	Non-Detect	Detect	Percent Detect	Range (ng/L)	Median (ng/L)
Clothianidin	222	85	137	62%	0.9 – 333	9.5
Imidacloprid	5,689	3,376	2,313	41%	1.1 – 2,150	22.6
Thiamethoxam	222	138	84	38%†	0.9 – 185	5.45

Table Notes:

* The range and median values reflect samples where the neonic was detected. Imidacloprid has been sampled since 1999, but clothianidin and thiamethoxam have only been analyzed since 2012. Data Source: USGS surface water samples for clothianidin, imidacloprid, and thiamethoxam from 1999 to 2020 across 12 Midwestern states. Courtesy of the U.S. Geological Survey (NWQMC n.d.).

† Thiamethoxam breaks down into clothianidin, which may partially explain the lower incidence of thiamethoxam, even though both pesticides are common seed treatments.

How Do Neonicotinoids Impact Midwestern Waters?

How Common are Neonicotinoids in Midwestern Waters?

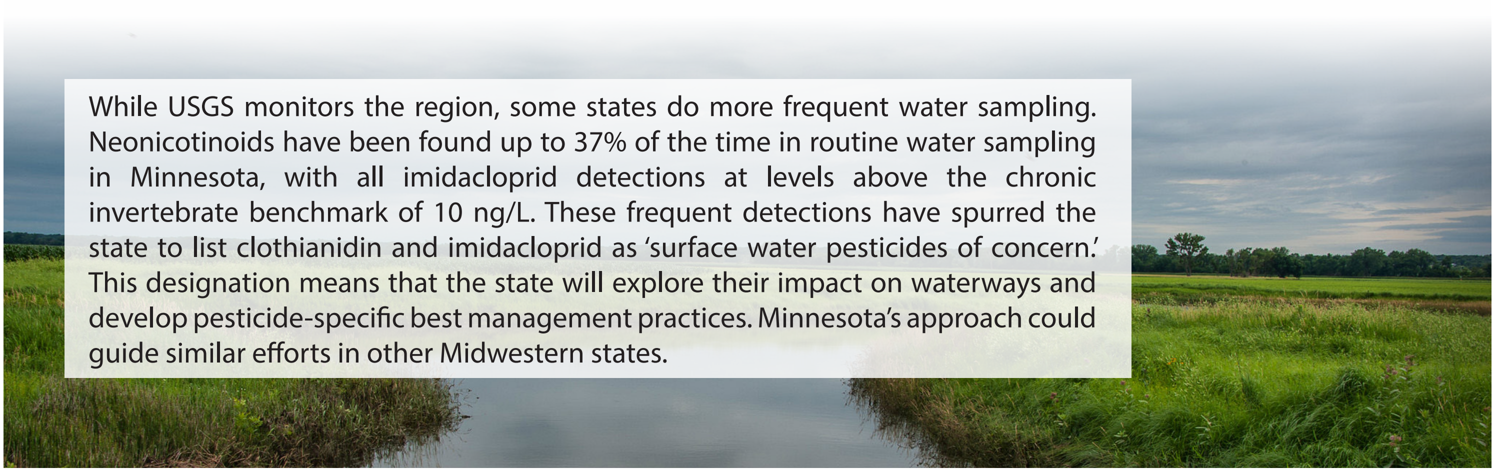
Neonicotinoids are present in Midwestern waterways throughout the year, often at levels that pose risk to aquatic species (Hladik et al. 2018, Schepker et al. 2020). Targeted research has found neonics in wetlands, puddles, and ditches in and near fields planted with treated seed (Schaafsma et al. 2015, Schepker et al. 2020). Broader studies across the Midwest have also noted elevated pulses of neonics in waterways during crop planting, attributed to seed treatments (Hladik et al. 2014, Berens et al. 2021).

Xerces reviewed USGS surface water samples to understand how often neonics are found throughout the Midwest and how they may be impacting species (Table 1, NWQMC n.d.). Imidacloprid has been sampled since 1999, so it has the largest sample size, while clothianidin and thiamethoxam have only been sampled since 2012. Imidacloprid was detected in 41% of samples. Clothianidin was the most commonly detected, found in 62% of water samples, and thiamethoxam was the least frequently detected, found 38% of samples. The less frequent detections of thiamethoxam could be due to the fact that it breaks down into clothianidin in the environment.

How Do Neonicotinoids Affect Aquatic Ecosystems?

Many aquatic insects that support healthy Midwestern waterways and wildlife are extremely sensitive to neonics (Morrissey et al. 2015, Sanchez-Bayo et al. 2016, Nowell et al. 2017, Raby et al. 2018a, b). When they are found, neonics are often drivers of invertebrate toxicity in Midwestern waters (Shoda, Stone & Nowell 2016, Nowell et al. 2017, Covert et al. 2020). Exposure to neonics can be lethal or cause sublethal effects including reduced growth, feeding and reproduction, immobility, and delayed emergence (Morrissey et al. 2015, Miles et al. 2017, Bartlett et al. 2018, Cavallaro et al. 2018). These sublethal impacts can harm populations over time and make individuals more sensitive to other stressors like water temperature. Neonic contamination can also alter food webs, shifting predator-prey interactions and harming predators who consume contaminated prey (Miles et al. 2017, Tooker & Pearsons 2021).

In order to quantify potential risk to aquatic communities, the EPA sets aquatic life benchmarks (ALB). These benchmarks reflect concentrations below which pesticides are not expected to represent a risk of concern for aquatic life (Table 2). When water samples routinely exceed benchmarks, it signals to regulators that contamination may need to be further examined and addressed.



While USGS monitors the region, some states do more frequent water sampling. Neonicotinoids have been found up to 37% of the time in routine water sampling in Minnesota, with all imidacloprid detections at levels above the chronic invertebrate benchmark of 10 ng/L. These frequent detections have spurred the state to list clothianidin and imidacloprid as 'surface water pesticides of concern.' This designation means that the state will explore their impact on waterways and develop pesticide-specific best management practices. Minnesota's approach could guide similar efforts in other Midwestern states.

Table 2. EPA Freshwater Invertebrate Aquatic Life Benchmarks (ALB)

Neonicotinoid	Freshwater Invertebrate Acute ALB (ng/L)	Freshwater Invertebrate Chronic ALB (ng/L)
Clothianidin	11,000	50
Imidacloprid*	385	10
Thiamethoxam	17,500	740

Table Notes:

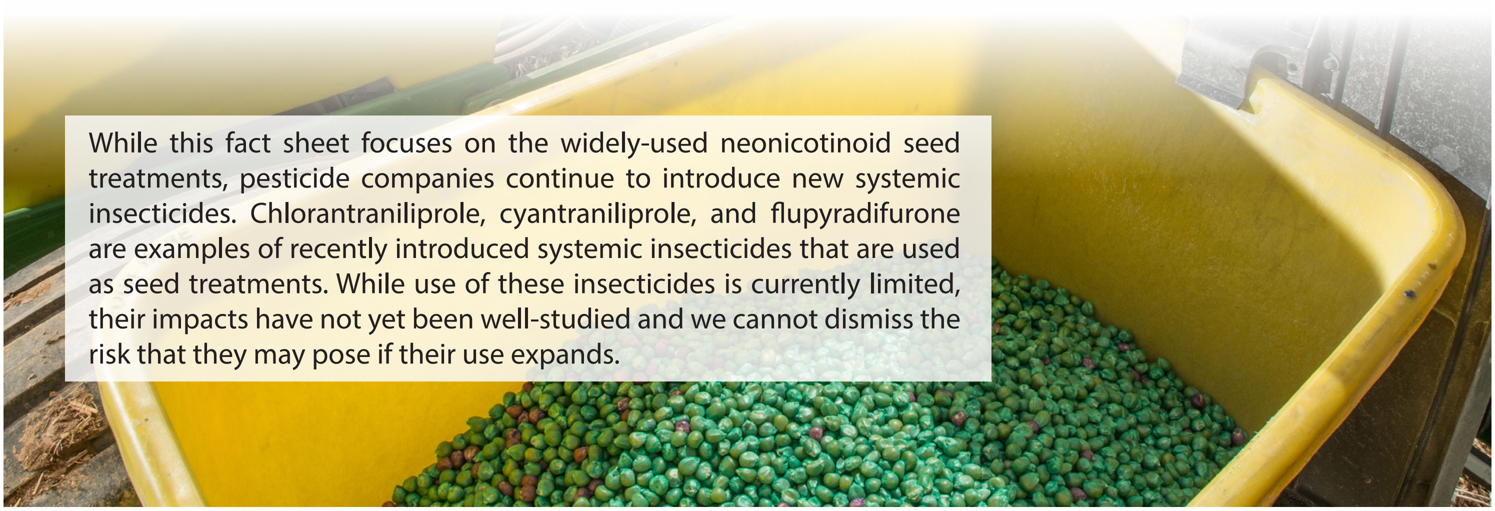
* EPA's recently revised benchmarks for imidacloprid are substantially lower than for clothianidin and thiamethoxam, despite research showing they are all similarly toxic to aquatic insects.

The benchmarks for imidacloprid were revised to significantly lower levels in 2017—the chronic ALB dropped from 1,050 ng/L to 10 ng/L (Table 2). This change was driven by data showing that many aquatic insects are much more sensitive to neonics than the standard species used to set benchmarks (Morrissey et al. 2015). Xerces compared Midwestern imidacloprid detections to its revised chronic freshwater invertebrate ALB and found that 81% of imidacloprid samples exceeded it, signaling significant risk to ecosystems. Despite research suggesting that clothianidin and thiamethoxam have similar levels of toxicity as imidacloprid, their ALBs have not yet been revised (Cavallaro et al. 2017, Raby et al. 2018a, b, EPA 2020). These benchmarks need to be updated in order to better reflect how these pesticides affect aquatic species.

While benchmarks can be useful tools for evaluating water sampling data, the true risk to aquatic communities is greater than individual ALB exceedances. Research in wetlands surrounded by crops showed lower aquatic invertebrate biomass associated with neonic concentrations well below EPA chronic benchmarks (Schepker et al. 2020). This suggests that the ALBs, even the revised ALB for imidacloprid, may not be protective of sensitive species. Benchmarks also underestimate risk by failing to account for cumulative effects. Given their similar modes of action, researchers have suggested that regulators should consider the total concentration of neonics in a sample, rather than each individual concentration (Morrissey et al. 2015). Despite these shortcomings, the frequent exceedance of neonic benchmarks suggests ongoing stress on invertebrates in Midwestern freshwater ecosystems.

Rethinking Use of Insecticide Seed Treatments

With so many acres planted with treated seed, one might assume that these neonic seed treatments are providing a major benefit to farmers. In many cases, this does not appear to be true. Research in corn and soybeans found that neonic seed treatments did not provide an economic benefit (EPA 2014, Purdue Extension 2015, Alford & Krupke 2017). Instead, they are often considered a form of insurance against sporadic pests, but one that comes at a heavy cost for both farmers and ecosystems. Seed companies rarely offer their most popular varieties without insecticides, leaving farmers who want to access the latest seed traits (such as improved drought tolerance or yield) with little choice to avoid insecticide seed treatments whether they anticipate pest pressure or not. However, there are many viable alternative practices that can replace the use of neonic seed treatments (Tooker et al. 2017, Veres et al. 2020). These practices can be as simple and cost-effective as delaying the date of planting or rotating crops to break a pest's lifecycle. If seed companies offer farmers more choices of seeds without insecticides, farmers can make informed pest management decisions based on demonstrated pest pressure, benefiting their bottom line and Midwestern waterways.



While this fact sheet focuses on the widely-used neonicotinoid seed treatments, pesticide companies continue to introduce new systemic insecticides. Chlorantraniliprole, cyantraniliprole, and flupyradifurone are examples of recently introduced systemic insecticides that are used as seed treatments. While use of these insecticides is currently limited, their impacts have not yet been well-studied and we cannot dismiss the risk that they may pose if their use expands.

What Can We Do To Protect Midwestern Waters?

Across the Midwest, the ubiquitous planting of seed treated with insecticides threatens waterways. Water sampling shows elevated neonicotinoid levels associated with seed planting, and concentrations throughout the year are often high enough to pose a chronic risk to foundational aquatic species. The breadth of contamination from insecticide seed treatments warrants action on all levels: state and federal regulators, the seed industry, farmers, and community members can all be part of the solution.

Government agencies can incentivize farmers to be more selective about if and when they use insecticide seed treatments and fund applied research into alternative pest management strategies. They can also strengthen water quality standards and impose mitigation measures to ensure waterways are protected from harmful contamination. ***Seed dealers*** can offer more seed varieties without insecticides, allowing farmers to access improvements in crop breeding without having to plant treated seeds where there is no demonstrated pest pressure. ***Farmers*** can take advantage of existing research on alternative pest management and increase demand by requesting seed without insecticides. ***Concerned community members*** can advocate for legislation that supports farmers' ability to make sustainable pest management decisions on their lands, ultimately benefiting the waterways we all share. With all hands on deck, we can reduce the threat that systemic insecticides pose to waterways across the Midwest and around the country.

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