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RESEARCH BRIEF

Clean Wisconsin Environmental Health Initiative

Neonicotinoids & Human Health

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SUMMARY – Neonicotinoids are a class of pesticide widely used in Wisconsin to control insects on farm fields, residential lawns and gardens, and for flea and tick prevention in pets. Previously thought to pose no risk to humans, there is increasing evidence that neonicotinoids may have harmful health effects. In this brief, we summarize these concerns and explore environmental exposure risks from drinking water contamination and residues in food.

Most of the human health concerns exist around nervous system effects in children (both fetal and early-childhood exposure) because the rapidly developing nervous system is most vulnerable. To date, most understanding is based on animal models, and more direct human study is needed. Suspected effects on human health include congenital heart defects, reduced cognitive ability, autism spectrum disorder, and reproductive issues. Primary exposure for the general population is from drinking water contamination, food residues, and residential use.

Key takeaways from this brief include:

- Neonicotinoids are estimated to be found in 5% of private drinking water wells statewide
- Detection rates can be over 50% in areas vulnerable to agricultural contamination like the Central Sands region.
    - For example, in Waushara County, over half of the wells in the Wisconsin Department of Agriculture, Trade, and Consumer Protection's study of wells vulnerable to contamination had multiple neonicotinoids detected
- Concentrations of imidacloprid in private wells have been found to exceed health-based levels recommended by the Wisconsin Department of Health.
- Neonicotinoid residues are common in non-organic produce, particularly apples, cherries, pears, strawberries, cauliflower, celery, cilantro, grapes, leafy greens, and potatoes
    - Residues have been found above health-based standards in berries, corn, grapes, green beans, pears, peas, pepper, strawberries and tomatoes
- More research is needed to better understand health effects in humans, particularly in children, and establish appropriate health-based standards that adequately protect the most vulnerable populations
- Individuals can reduce exposure by consuming organic produce and avoiding the use of lawn care or flea and tick prevention products that include neonicotinoids
- Wisconsin should follow the example of 11 U.S. states, Canada, and the EU in passing restrictions on the use of neonicotinoids to protect ecosystems and human health

Definitions

- **Neonicotinoids ("Neonics"):** A type of insecticide that is chemically similar to nicotine. They function by attacking the nervous system of insects and may have negative effects on human health.
- **Human Health Benchmarks:** Non-enforceable drinking water levels that provide information about adverse health effects from drinking water exposure to contaminants (U.S. EPA 2024a).
- **Drinking Water Regulations or Standards:** Legally enforceable standards that apply to public water systems to protect public health (U.S. EPA 2024b).
- **Developmental Neurotoxicity (DNT) Study:** Studies used by the U.S. Environmental Protection Agency and other entities to evaluate the adverse effects of chemicals on the developing nervous system. Typically assess behavioral and neurological effects on rodents during prenatal and postnatal development.
- **Acute Exposure:** Short-term contact through oral, dermal, or inhalation route with a substance. Includes periods up to 1 day (U.S. EPA 2011a).
- **Chronic Exposure:** Repeated exposure by oral, dermal, or inhalation route for more than 10% of the life span in humans (U.S. EPA 2011b).
- **Maximum Residue Limit/Tolerances:** Maximum acceptable levels of pesticides and veterinary drugs in food and agricultural products set by U.S. Environmental Protection Agency and monitored by the U.S. Department of Agriculture Pesticide Data Program (USDA Food Safety Inspection Service 2025).
- **Biomonitoring:** Collection and analysis of human specimens such as blood, saliva, or urine to detect chemical contaminants (Kyle 2011).
- **Pre-natal Toxicity:** Negative effects of a substance on the developing fetus during pregnancy (Lamb 2018).
- **Post-natal Toxicity:** Negative effects of a substance on development during early life stages (Lamb 2018).

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Introduction

Neonicotinoids, commonly referred to as “neonics”, are a class of insecticide that has become pervasive in modern agriculture. Chemically similar to nicotine, neonicotinoids attack the nervous system of an insect, causing paralysis and eventually death (Gupta et al. 2019). They are the most widely used pesticide in the world for their effectiveness in controlling a variety of pests such as aphids, whiteflies, and other sap-feeding insects (Clean Wisconsin 2025).

Neonics are “systemic”, meaning the pesticide is absorbed by the plant and moves throughout its tissues to the leaves, stem, roots, and flowers. They can be applied as seed coatings or directly to plants and soil.

There are five neonicotinoids approved for use in the United States: acetamiprid, clothianidin, dinotefuran, imidacloprid, and thiamethoxam. While thiacloprid was initially approved for use in 2003, the registration was voluntarily withdrawn by the manufacturer in 2016 and is no longer available for use (U.S. EPA 2003, U.S. EPA 2014).

Initially, neonicotinoids were celebrated for their properties of requiring only one application per season and perceived low toxicity to mammals. However, newer research shows neonicotinoids have spread beyond agricultural fields, where they have damaged ecosystems. Neonicotinoids are harmful to bee populations: chronic exposure impairs a colony’s ability to regulate temperature, build nests, and disrupts behaviors like foraging and navigation (Crall et al. 2018). They have been shown to cause behavioral and DNA damage in freshwater fish (Jeninga et al. 2023). In addition, birds that feed on crop seeds and insects are exposed to neonicotinoid application. From 2008-2014, neonicotinoids contributed to a 12% annual decline in grassland bird populations (Li 2020). Studies have observed reduced food consumption, impaired migratory behaviors, and thyroid damage in birds after neonicotinoid exposure (Eng et al. 2017; Pandey 2015).

In the United States, 4 million pounds of neonicotinoids are applied annually (Cimino et al. 2016). Over 90% of corn acreage is treated with neonicotinoids and over 50% of soybean farmers report using neonicotinoid treatments (Perry 2020, Hurley 2016). In Wisconsin, there are more than 500 registered products containing neonicotinoid active ingredients (Senger et al. 2019).[1]

Estimates of uses in Wisconsin by type of neonicotinoid and by crop are shown in Figures 1 and 2. It is hard to identify current trends because the United States Geological Survey (USGS) stopped including seed treatment in their estimates in 2015. However, prior to this change there was a generally increasing trend in their usage in the state between 1990 and 2014. As shown in the figures, most agricultural use is in seed treatment. However, only between 1 and 10% of the neonic in the seed coating is taken up by the plant (Tooker et al. 2017). This means that over 90% of the neonic remains in the soil, where it can be transported to drinking water supplies, streams, rivers and lakes.

[1]Neonicotinoid products registered in Wisconsin (Type, Number): Imidacloprid, 356; Clothianidin, 38; Thiamethoxam, 60; Acetamiprid, 30; Dinotefuran, 50; Thiacloprid, 0.

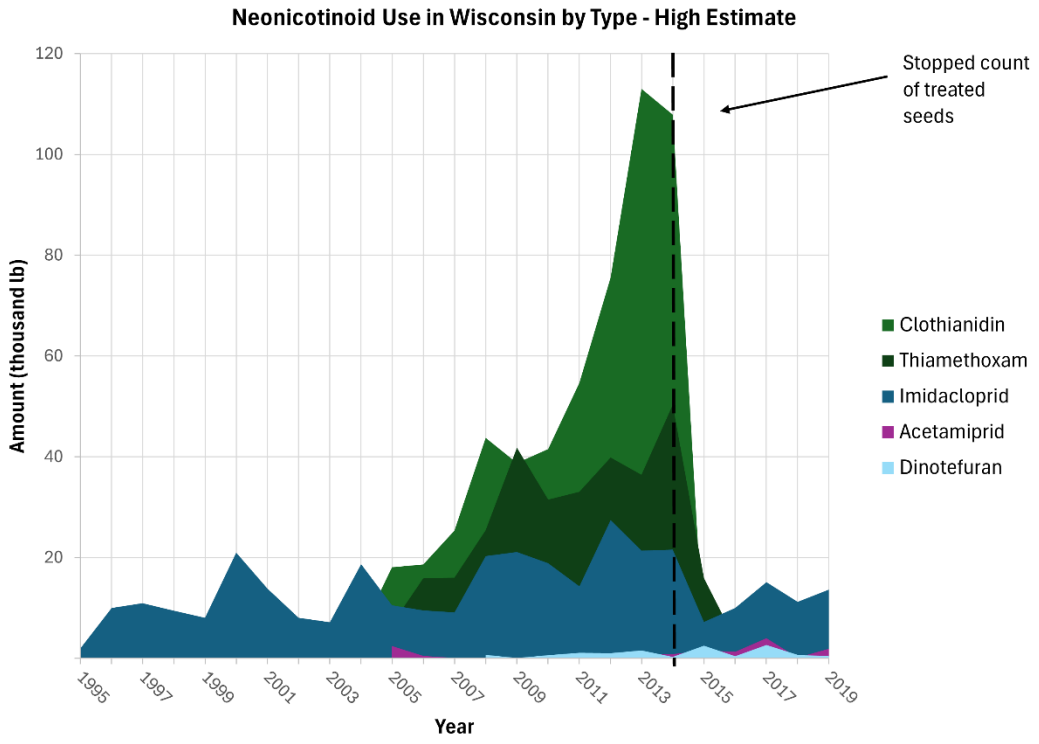

Figure 1. High estimate of neonicotinoid use in Wisconsin from 1995-2019 from USGS Pesticide National Synthesis Project (Wieben 2021). Note that after 2014, estimates stopped including seed treatments. Low estimates showed similar trends.

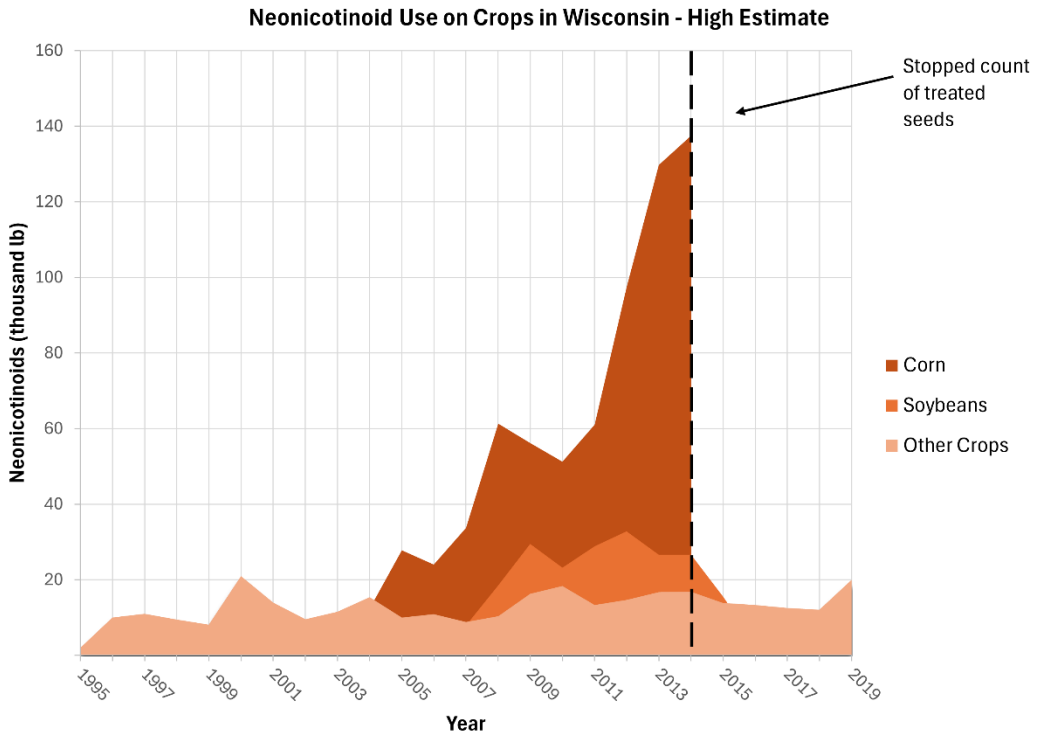

Figure 2. High estimate of neonicotinoid use on major crops in Wisconsin from 1995-2019 from USGS Pesticide National Synthesis Project (Wieben 2021). Note that after 2014, estimates stopped including seed treatment. Low estimates showed similar trends.

Human Health Impacts

The widespread use of neonicotinoids has raised questions about potential human health risks. However, the extent of human health effects is currently understudied and further direct human study is necessary to understand the breadth of impacts and establish safe limits for human exposure.

Direct exposures to neonicotinoids from spraying can lead to headaches, dizziness, lethargy, eye/throat irritation, and seizures (Sass 2024b). Exposure to imidacloprid has been significantly associated with a congenital heart defect that can block blood flow and cause holes in the heart chamber (Carmichael et al. 2014, Mayo Clinic Staff 2023). One study indicated slight associations between household imidacloprid use and autism spectrum disorder (Keil et al. 2014). Other studies found prenatal and childhood exposures to neonicotinoids were associated with reduced cognitive abilities (Gunier et al. 2017, Wang et al. 2019). Human studies have also reported negative reproductive effects like reduced testosterone and poor sperm quality (Mendy 2022, Hafez et al. 2016).

Given the lack of direct human study, current human health benchmarks are based on animal studies, which have demonstrated negative health outcomes (WI DHS 2022a, U.S. EPA 2017a, U.S. EPA 2017b).

The EPA regularly evaluates the safety of agricultural products through developmental neurotoxicity (DNT) studies of rodents. These studies determine the potential impact on fetal and early infant development of the brain and nervous system. They are required to be conducted by pesticide manufacturers but often contain insufficient information or are waived by the EPA (Sass 2024a).

DNT studies show impaired brain growth, decreased motor activity, and disrupted nervous system receptors responsible for memory, cognition, and behavior (Sass 2024a, Cimino et al. 2016). Other animal studies indicate links to genetic mutation, decreased immune function, reduced growth rates, and reproductive issues including reduced pregnancy rates and higher rates of embryo death and stillbirth in mammals (Thompson et al. 2020).

Finally, it should be noted that when the EPA extrapolates from animal studies, it uses an uncertainty factor to account for differences between species. However, this factor does not account for increased risks associated with fetal or early life exposure (Sass 2024a). The Food Quality Protection Act of 1996 recommends an additional "child protective factor" to limit these risks, but only 12% of chronic exposure limits on pesticides incorporate this factor (Naidenko 2020).

Exposure Risks

Neonicotinoids have been detected in soil, groundwater, streams, drinking water, and as residue on food products, creating multiple exposure routes (Schaafsma et al. 2015, Senger et al. 2019, Hladik 2015, Sultana et al. 2018, Craddock et al. 2019).

In the United States, neonicotinoids were found in 50% of urine samples in people three years and older. Children aged 3-5 had higher concentrations than any other group, presenting concerns about populations most vulnerable to negative health effects (Ospina et al. 2019). Another study found that 95% of pregnant women across multiple states had neonicotinoids detected in their bodies, and detection rates increased throughout the four-year study (Buckley et al. 2022).

Drinking Water

Approximately 30% of Wisconsinites use private well water as their primary source of drinking water.[2] Private wells are not subject to the same regulations as public water systems, which must maintain certain water quality standards and complete regular testing (U.S. EPA 2024c). Only an estimated 10% of private well owners test their water regularly for contaminants (WI DHS Division of Public Health 2018).

[2] Estimates from the United States Geological Survey, the Wisconsin Department of Health Services, the Wisconsin Department of Natural Resources, and University of Wisconsin Extension range from 25-40%

The Wisconsin Department of Agriculture, Trade, and Consumer Protection (DATCP) conducts periodic groundwater monitoring surveys of private drinking water wells throughout the state. The most recent survey estimates 5.3% of all private drinking water wells in Wisconsin contain neonicotinoids. Estimates suggest one quarter to one third of Wisconsin residents use private wells. Between 2016 and 2023, statewide detection rates for neonicotinoids increased from 0.2% to 5.3%, largely due to a decrease in lab detection limits (Romano et al. 2024).

DATCP also regularly surveys wells that are particularly vulnerable to agricultural pollution (e.g., WI DATCP 2020). Wells are selected for testing based on their proximity to agriculture, geologic conditions, or prior data indicating high pesticide levels. Across all targeted samples between 2019 and 2023, 20% of drinking wells had at least one neonicotinoid detected, and 9% had multiple neonics detected (Table 1 and Fig. 4). Clothianidin was the most frequently detected neonicotinoid, and there were no detections of acetamiprid or thiacloprid.

Neonicotinoid detection rates were highest in the Central Sands region[3], with Juneau and Waushara County having detections in more than half of all wells tested (Figure 4). In Waushara County, over half of wells had multiple neonics detected.

Table 1. Detection rates of neonics in private wells in DATCP targeting sampling of private wells vulnerable to agricultural pollution. Laboratory analysis detection levels for neonics had a meaningful reduction beginning in 2019. Thus, detection rates between the two time periods should not be directly compared and data has been split.

Neonicotinoid	Percent of Wells with Detections, 2015-2018 (Max Concentration, µg/L)	Percent of Wells with Detections, 2019-2023 (Max Concentration, µg/L)
Acetamiprid	0	0
Clothianidin	5.6 (2.04)	18.5 (2.22)
Dinotefuran	0.1 (N/A)	0.1(N/A)
Imidacloprid	4.8 (2.19)	8.2 (2.14)
Thiacloprid	0	0
Thiamethoxam	4.3 (2.78)	7.5 (4.09)
Any Neonicotinoid	7.3	19.6
Multiple Neonicotinoids	1.7	8.6

[3] The Central Sands region in central Wisconsin is characterized by sandy soils that allow relatively easy transport of contaminants and shallow groundwater aquifers, making the area particularly vulnerable to drinking water contamination.

In 2022, 10% of targeted groundwater samples exceeded the imidacloprid health-based standard recommended by Wisconsin Department of Health Services of 0.2 μg/L (WI DATCP 2024). Standards for other neonicotinoids are outlined in Table 2.

Table 2. Health-based standards from the WI DHS and U.S. EPA drinking water benchmarks for neonicotinoids, along with the health endpoints the standards are intended to protect against.

Neonicotinoid	Wisconsin DHS Recommended Health-Based Standard (µg/L)*	Wisconsin DHS Cited Health Impacts in Animal Studies*	EPA Chronic Human Health Benchmarks (µg/L)**	EPA Cited Health Impacts in Animal Studies**
Imidacloprid	0.2	Nervous system, thyroid, reproductive, glucose regulation effects	500	Nervous system effects
Clothianidin	1000	Liver, blood, kidney effects	580	Nervous system, liver and kidney, blood cell system effects
Thiamethoxam	120	Skeletal abnormalities, liver, blood, reproductive effects	71	Nervous system, liver and kidney, reproductive, blood cell system effects
Acetamiprid	Not evaluated	N/A	420	Nervous system, liver function, decreased body weight
Dinotefuran	Not evaluated	N/A	6000	Nervous system, kidney function, decreased body weight
Thiacloprid	Not evaluated	N/A	0.004	Likely carcinogenic, liver, thyroid effects

*WI DHS WI DHS 2022a ** U.S. EPA 2017b, U.S. EPA 2019a, U.S. EPA 2019b, U.S. EPA 2017a, U.S. EPA 2019c, U.S. EPA 2012

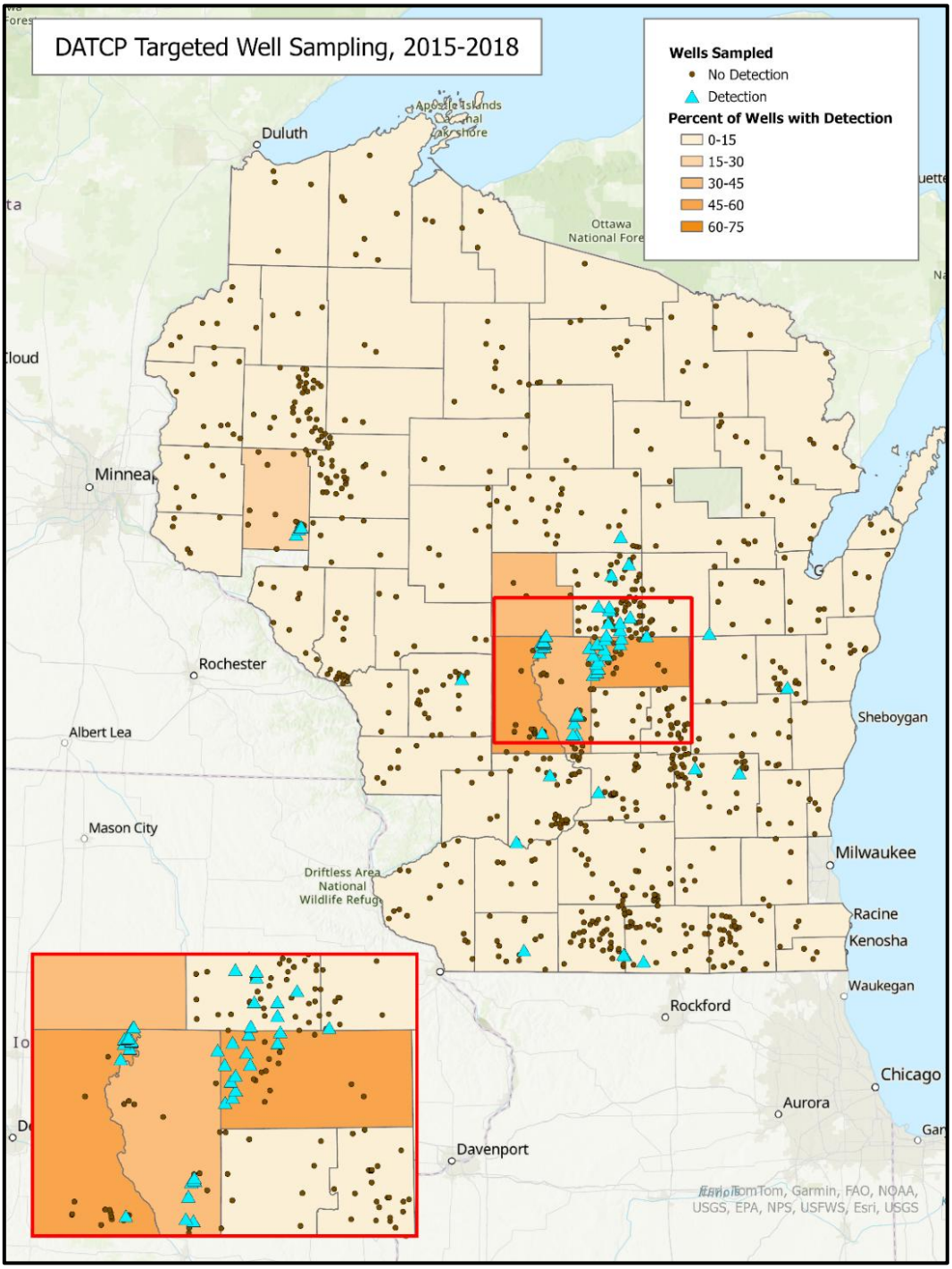

Figure 3. Private wells tested for neonics in the WI Department of Agriculture, Trade, and Consumer Protection (DATCP) targeted well sampling between 2015 and 2018. The targeted sampling includes wells that are vulnerable to agricultural pollution due to their geologic condition, proximity to agriculture, or prior data. Shown in the inset is a more detailed view of a high concentration of wells tested in the Central Sands region.

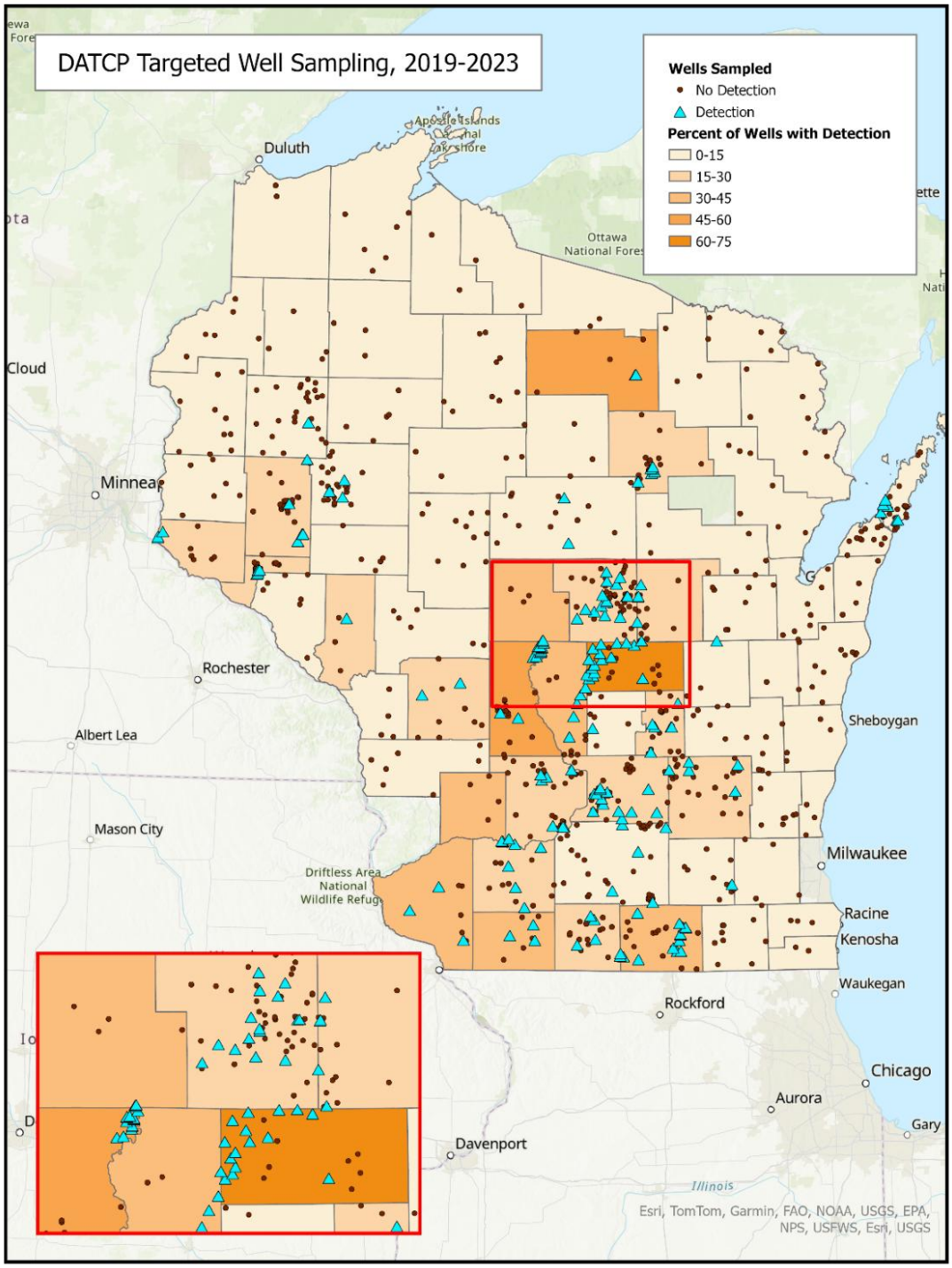

Figure 4. Private wells tested for neonics in DATCP's targeted well sampling between 2019 and 2023. Shown in the inset is a more detailed view of a high concentration of wells tested in the Central Sands region. Note that starting in 2019, laboratory analyses could detect neonics at much lower levels. This leads to increased detection rates compared to earlier sampling years.

Food Residues

Total daily dietary intake of neonicotinoids in the United States is estimated at 10.1 µg/day, below tolerance levels suggested by the World Health Organization (WHO) (Thompson et al. 2020). The WHO established an acceptable daily intake of 10-200 g per kg of body weight for a lifetime without appreciable health risk. Another analysis also found that estimated total daily intake in the United States was below health-based safety levels (Chang et al. 2018). However, given the prevalence of neonicotinoid residues in food, these analyses suggest that future research collect more and better-quality residue data, improve daily intake estimates, and further investigate toxicological thresholds of neonics in humans.

From 1999-2015, the United States Department of Agriculture Pesticide Data Program tested thousands of samples from US food markets for neonicotinoid residue, including fruits, vegetables, meat, dairy, and baby food[4]. Apples, cherries, pears, strawberries, cauliflower, celery, cilantro, grapes, collard greens, kale, lettuce, potatoes and spinach all had at least 20% of samples with neonicotinoid residue. When detected, average residue levels were well below EPA tolerance levels (around 5% of the EPA tolerance level), but maximum residue levels exceeded EPA tolerance levels in berries, corn, grapes, green beans, pears, peas, pepper, strawberries and tomatoes (Craddock et al. 2019). Of all neonicotinoid types, imidacloprid was most frequently detected, found in 12% of all samples.

Average detection among all organic commodities was less than 1%. No samples of infant formulas contained neonicotinoid residue. However, baby foods including apple sauce, peaches, and pears had acetamiprid detected in 51%, 36%, and 25% of samples, respectively. None of these exceeded health-based safety levels (Craddock et al. 2019).

Another global survey found that 75% of honey samples contained neonicotinoids (Thompson et al. 2020).

Household Use

The focus of this brief is the human health effects of environmental contamination by neonicotinoids, which largely comes from their agricultural use. However, we also note that they are used for residential lawn and garden care, household pest control (e.g., bed bugs, roaches, and ants) and for veterinary applications (against fleas, ticks, etc. on pets and cattle)[5]. For example, of the 360 products with Imidacloprid registered in Wisconsin, half are for household use (WI DATCP 2022b).

This residential use provides another exposure route for the general population. Indeed, between 2018-2022, flea and tick collars for pets containing neonicotinoids caused 1,700 pet deaths and 1,000 human poisonings in the United States (Sass 2024b). In the EPA's human health assessment of neonicotinoids, residential exposures were estimated to be a larger source of exposure to most[6] neonicotinoids than dietary intake (food residues and drinking water contamination) for the general population. However, dietary intake can exceed residential exposure in cases of above-average drinking water contamination (U.S. EPA 2017b, U.S. EPA 2019a, U.S. EPA 2019b, U.S. EPA 2017a, U.S. EPA 2019c, U.S. EPA 2012).

[4] Methods include washing of all fruits and vegetables before chopping, mixing, or blending the sample into a homogenous mixture. Sampling is intended to test for systemic presence of neonicotinoids (USDA AMS 2024).
[5] For list of common household products containing neonicotinoids, see: Fact Sheet: Help the Honey Bees! (Center for Food Safety 2013).
[6] Acetamprid being the exception.

Disproportionate Impacts

Historically, environmental pollution has disproportionately impacted Black, Indigenous, People of Color (BIPOC) and low-income communities. In 2021, there were 31 pesticide manufacturing facilities in the US listed by the EPA as in "significant violation" of environmental laws like the Clean Water Act and Clean Air Act. Of residents within one mile of these facilities, 44% had incomes less than two times the federal poverty level. Additionally, over half of the facilities had higher BIPOC population within one mile when compared to state demographic averages (Donley et al. 2019).

Pesticide exposures are particularly concerning for people who work, live, and play near locations where pesticides are applied through spraying. Farm workers in California had urinary pesticide levels up to 395 times the national average. Today, 83% of farmworkers identify as Hispanic or Latinx (Donley et al. 2019). In a study sampling 171 pregnant women in five states, neonicotinoids were found in 95% of the participants, with higher levels in Hispanic women compared to non-Hispanic women (Buckley et al. 2022). One study found pesticides in 85% of household dust samples where farm workers lived and in 88% of urine samples of children living in those homes (Simcox et al. 1995). Finally, as an illustration of how pesticides are used as a quick fix to chronic problems in underserved communities, a study of subsidized housing in New York reports that 33% of residents reported applying pesticides in their homes at least once per week (Donley et al. 2019).

Existing Policy

As of 2024, eleven states[7] in the U.S. have passed restrictions on residential and non-commercial uses of neonicotinoids (Gulino 2024). In 2023, New York became the first state to ban neonicotinoid-treated seeds for commercial use on corn, soybean, and wheat production. Vermont also passed a similar ban, intending to phase out treated seeds entirely by 2029. These laws typically cite pollinator declines and concerns for human health (Kushen 2024).

In 2023, Senate Bill 360 was brought to the Wisconsin legislature, which would ban the use of neonicotinoids on land owned by WI DNR. It failed to pass in April 2024 (S.B. 360 2023). WI DNR also periodically updates groundwater quality standards with input from WI DHS. In 2019, DHS proposed the neonicotinoid standards in their Cycle 10 recommendations, listed in Table 2. They were not approved (WI DNR 2022).

Outside of the United States, Europe implemented a partial, temporary ban on outdoor neonicotinoid use in 2013 for clothianidin, imidacloprid, and thiamethoxam. This partial ban was originally put in place to protect pollinators and was eventually made permanent in 2018, expanding to all outdoor uses (Directorate-General 2023). Canada also has a variety of restrictions in place. Ontario and Quebec introduced a system known as "verification of need" for use of neonicotinoid coating on field crop seed, such as corn and soybean seeds. This system requires manufacturers and farmers to hold a certificate to sell and use neonicotinoids. Due to this system, neonicotinoid use in Quebec went from 100% (corn) and 50% (soybeans) to less than 0.5% and 0%, respectively (Raichel 2024). Quebec also plans to expand its program to all insecticides in 2025 (City of Quebec 2024).

In response to these bans, farmers and agricultural workers may be concerned about their crops and related economic impacts. However, there has been extensive research showing there are no overall economic benefits to farmers when using neonicotinoids for seed coating, particularly for major field crops (Grout et al. 2020). Multiple analyses of soybean farms indicated that neonics provide negligible improvements in crop yield (Mourtzinis et al. 2019, Labrie et al. 2020).

[7] California, Colorado, Connecticut, Maine, Maryland, Massachusetts, New Jersey, New York, Rhode Island, Vermont, and Washington

Recommendations

Further research on human health impacts is necessary (Sass 2024a, Naidenko 2020). Research should focus on chronic rather than acute exposures, drinking water and food sampling, biomonitoring, and pre- and postnatal toxicity (Cimino et al. 2016, Naidenko 2020). Some studies suggest a need for new risk assessment methods to further protect human health (Naidenko 2020, Donley et al. 2019). The EPA should make DNT studies a core requirement for registration of every pesticide. Deficiencies in DNT studies for neonicotinoids are cause for concern. For example, the EPA flagged failures to submit data for mid and/or low- dose animals as a "study deficiency," then set the effect levels at the high dose (Sass 2024a).

Individuals can reduce their exposure to neonicotinoids by consuming organic products. To qualify as organic, a crop must be produced on a farm that has not used synthetic pesticides, herbicides, or fertilizers for 3 years before harvest. To identify organic foods, consumers should look for the USDA Organic food label. "100% Organic" indicates a product only includes organic ingredients and processing aids. Just "Organic" indicates that at least 95% of the product is organically produced (Forman et al. 2012).

The Environmental Working Group (EWG) regularly publishes the "Shopper's Guide to Pesticides in Produce," which analyses pesticide residue data from the USDA on thousands of fruit and vegetable samples. In this guide, EWG identifies the "Dirty Dozen" - 12 non-organic products with the most pesticide detections. In 2024, 95% of samples in the Dirty Dozen contained pesticides. They also publish the "Clean Fifteen" - 15 non-organic products with low or no pesticide residues (EWG Science Team 2024).

Policy recommendations include:

- Prioritize funding for research on the health impacts of neonicotinoids.
- To protect pollinators and people, WI DNR should add neonicotinoids to its groundwater quality standards.
- Increase public education about neonicotinoids, particularly for communities at higher risk of exposure.
- Propose state legislation in Wisconsin similar to Canada's "verification of need" system for use of neonicotinoids on field crops.
- Develop and implement policies that promote education about the presence of neonicotinoids in non-agricultural products to drive informed consumer choices.
- Encourage public awareness campaigns about farmers' growing recognition that neonicotinoid use has few benefits.
- Advocate for increases in organic production.

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Additional Resources

Clean Wisconsin: Neonicotinoids and their impact | Wisconsin Neonic Forum - Clean Wisconsin

Environmental Working Group: Shopper's Guide to Pesticides in Produce

Natural Resources Defense Council: Human Health Risks from Neonic Pesticides

U.S. Department of Agriculture: Pesticide Data Program

U.S. Department of Health and Human Services: Neonicotinoid Pesticides & Adverse Health Outcomes

U.S. Environmental Protection Agency: EPA Actions to Protect Pollinators

University of Iowa Environmental Health Science Research Center: Neonicotinoids: Implications for Public Health

WI Department of Agriculture, Trade, and Consumer Protection: Surface and Groundwater Monitoring | Groundwater Standards for Pesticides

Xerces Society: Understanding Neonicotinoids