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ENVIRONMENTAL NEURODEVELOPMENTAL RISK

IN THE AGRICULTURAL MIDWEST

Prenatal exposure through infancy, toddlerhood, and the preschool years

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EVERNORTH FOUNDATION · TOXICITY AWARENESS · RESEARCH & ANALYSIS

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Central conclusion

From conception to age five, the developing brain is both more susceptible to its surroundings and more profoundly influenced by them, and the agricultural Midwest presents a concentrated combination of exposures: pesticide application, agricultural air pollution, seasonal smoke, contaminated household dust, waterborne chemicals, and lead in older housing. Human studies link these exposures to autism likelihood, developmental delay, lower cognitive and adaptive performance, ADHD-related traits, sleep disturbance, aggression, and greater autism symptom burden. [1-36]

This report follows the evidence across the developmental timeline from pregnancy through age five, and then connects those findings to documented Midwestern exposure pathways in air, water, soil, household dust, and child-care environments. This resource is intended for individuals, families, educators, advocates, and organizations seeking a complete understanding of how environmental contaminants influence early neurodevelopment and wellness.

Throughout this review, terms such as “associated with,” “correlated with,” and “can contribute to” preserve the language of the human studies while presenting their findings affirmatively and in context.

> **FROM VICTORIA**
>
> *I spent years researching and analyzing the physical impacts environmental contaminants can have on human wellness. Of late, I have immersed myself in their neurodevelopmental effects as well, and a plethora of understanding welled as I delved into this field. Their impacts span many compartments, and this is my first comprehensive inquiry into one of them: neurodevelopment.*

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1. Executive synthesis

The most persuasive evidence is cumulative. The Midwest is one of the nation's most agriculturally intensive regions, and exposure can occur through several routes at once: pesticide drift, rainfall and atmospheric transport, treated soil, tracked-in residues, carpet dust, drinking water, seasonal burning, agricultural ammonia that forms PM2.5, and older housing or contaminated soil containing lead. [1-5, 20-29]

For the developing brain, timing matters. EPA describes fetal development and early childhood as windows of susceptibility because children have distinct behaviors, higher intake relative to body mass, and developing metabolic, renal, immune, respiratory, and

neurological systems. The same dose can have different consequences depending on when exposure occurs. [1-2]

For autistic children, added environmental strain may be expressed through the functions already most vulnerable: sleep, communication, social engagement, attention, inhibition, sensory regulation, adaptive behavior, emotional recovery, and pain communication. Studies in children who already have autism have associated particulate exposure with poorer adaptive and cognitive functioning, more severe autism and ADHD symptoms over time, and greater stereotypic-behavior burden. [17-20]

Evidence at a glance

Exposure or window	Human / regional finding	Why it matters in early childhood	Evidence
Prenatal organophosphates	At 24 months, age three, age five, and age seven, higher prenatal exposure was associated with poorer mental, motor, attention, pervasive-developmental, and cognitive outcomes. [6-8, 36]	Establishes effects across the years when language, motor control, attention, and adaptive systems are emerging.	High
Postnatal Organophosphates	A child's own chlorpyrifos biomarker was associated with lower motor and social-development scores at age three. [11]	Shows that vulnerability continues after birth and is not limited to gestation.	Direct
Pyrethroids **Ages 2-4**	Studies reported externalizing or affective behavior at age two, ADHD-related traits ages two to four, and substantially higher ADHD-like scores at age four. [12-15]	Overlaps meltdowns, impulsivity, poor inhibition, emotional volatility, and difficulty sustaining engagement.	Direct

Exposure or window	Human / regional finding	Why it matters in early childhood	Evidence
Preschool **Daily exposure**	125 Northern California preschoolers wore silicone wristbands; multiple insecticides were commonly detected, exposure rose near fields and in higher-use counties, and ordinary handwashing/cleaning did not consistently predict lower exposure. [5]	Shows exposure traveling with children across home and child care and persisting beyond ordinary hygiene routines.	High pathway
Midwest household dust	Iowa studies measured pesticides in carpets, entryways, laundry areas, children's spaces, and children's urine. [3-4]	Demonstrates field-to-home-to-child transfer in a Midwestern population.	High pathway
PM2.5 ages 2-4	Each 2 μg/m³ increase during ages two to four was associated with a 3.59-point higher behavior-problem score and 2.63-point lower cognitive score. [16]	Identifies the exact toddler-to-preschool window as sensitive to particle pollution.	Strong
Agricultural Midwest PM	Agricultural ammonia was estimated to contribute 40% of Midwestern PM2.5 burden, about four times the national average contribution. [21]	Connects regional agricultural activity directly to a neurobehaviorally relevant pollutant.	Regional

Exposure or window	Human / regional finding	Why it matters in early childhood	Evidence
Lead and autism	Autism-specific guidance warns that persistent mouthing can extend lead risk and that irritability, wakefulness, constipation, withdrawal, or regression may be mistaken for autism. [26]	Exposure and symptoms can both remain hidden in children with communication or sensory differences.	Clinical

Evidence key: *High: consistent findings across multiple human cohorts. Strong: a large multi-cohort human study. Direct: exposure or behavior measured in the children themselves. High pathway: exposure routes measured directly in homes, child care, or children. Regional: atmospheric or regional monitoring data. Clinical: clinical guidance drawn from case-based review.*

> **FROM VICTORIA**
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> *An assortment of factors contributes to the severity of risk posed by the agriculture-dense Midwest. When season, wind, and even a person's age can alter that risk, how, then, can we truly measure the overall threat to humanity as a whole, or know that the benefits, which remain unverified, outweigh the consequences?*

2. Why the agricultural Midwest creates a distinct exposure environment

The Midwest's environmental-health concern is created by scale. Corn, soybean, sorghum, wheat, livestock, fertilizer, and pesticide use occupy large continuous landscapes rather than isolated parcels. Chemical application occurs alongside homes, roads, schools, wells, streams, reservoirs, and child-care settings. [3-5, 26-29]

Agricultural chemicals can move beyond the application site through airborne drift, volatilization, contaminated dust, rainfall, runoff, groundwater infiltration, occupational take-home transfer, and residues tracked indoors on shoes, clothing, equipment, and soil. EPA recognizes ingestion of contaminated soil, dust, and surface residues through hand-to-mouth and object-to-mouth behavior as an especially important pathway for young children. [2]

The regional exposure picture also includes pollutants that are not applied as pesticides. Fertilizer and livestock emissions release ammonia, which reacts in the atmosphere to form fine particulate matter. A 2024 atmospheric analysis estimated that agricultural

ammonia contributes 40% of the Midwestern PM2.5 burden, approximately four times its average contribution across the contiguous United States. [21]

The regional distinction

Isolated chemical exposures and single spills are not to be disregarded, for their impacts are far greater than we like to accept. What distinguishes the agricultural Midwest is that such exposures rarely stand alone: here, agricultural applications, atmospheric transport, household dust, water contamination, seasonal smoke, and early-childhood behavior overlap again and again across a large, continuous region.

How exposure becomes concentrated at the household level

- A residence near treated fields can receive airborne drift and dust deposition during repeated application periods.
- Farm work clothing, footwear, vehicles, and equipment can carry residues into entryways, laundry areas, carpets, and children's spaces.
- Carpet and settled dust can act as reservoirs for semi-volatile and particle-bound pesticides.
- Private wells and shallow groundwater can add waterborne agricultural chemicals to the same household environment.
- Spring burning, field dust, fertilizer emissions, livestock operations, and regional transport can add inhalation exposure.
- Children's smaller body mass, floor contact, mouthing, and higher intake relative to body weight magnify the dose delivered by the same environment. [1-2]

> **FROM VICTORIA**
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> *If pesticides have been detected nine to fourteen miles from the fields where they were applied, and some can linger indoors for weeks or even years, what, then, are the consequences of applying them again and again, season after season, across an entire region? And what are the impacts of long-term accumulated exposure on those who live within it? [5, 37]*

3. The developmental timeline: prenatal through age five

The evidence becomes most compelling when it is organized by developmental timing. Pregnancy is a period of rapid cell proliferation, migration, synapse formation, and organ development. After birth, the brain continues rapid growth while language, motor coordination, sleep regulation, inhibition, social engagement, and adaptive behavior are being established. [1]

Window	What the studies measured	Findings relevant to neurodevelopment
Pregnancy	Maternal biomarkers, residential proximity to pesticide applications, prenatal air-pollution estimates	Autism likelihood, intellectual-disability comorbidity, mental and motor development, attention, executive function, later IQ, language and behavioral outcomes. [6-10, 18, 36]
Birth-24 months	Infant/child exposure estimates; behavior, development and autism-symptom assessments	Mental development and pervasive-developmental problems at 24 months; infant neurodevelopment; early stereotypic-behavior and social/adaptive burden from particle exposure. [6, 19, 35]
Ages 2-4	Child urinary biomarkers, PM2.5 exposure, preschool CBCL, wristband sampling	Externalizing behavior, affective problems, ADHD-related traits, lower motor/social development, higher total behavior-problem scores, lower cognitive performance, and measurable pesticide mixtures across daily environments. [5, 11-16]
Age 5	Attention testing and preschool-to-school transition outcomes	Poorer attention and increased likelihood of clinically concerning ADHD-related attention scores following prenatal organophosphate exposure. [8]
Beyond age 5	Cognitive testing and symptom trajectories	Lower IQ at age seven and longitudinal associations between particulate exposure and more severe autism/ADHD symptom trajectories. [17, 36]

> **FROM VICTORIA**
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> *As they say, timing is everything, and the same is true of pesticides and herbicides. Exposure carries consequences for all people, yet our youngest are among the most vulnerable, and that vulnerability begins before birth, passing from mother to child through the womb to the developing fetus. The impacts may seem minute from day to day, or even year to year.*
>
> *Seen from an aerial view, an era view, what will these exposures tell us? What if children are changing, their developing brains altered by the pesticides and herbicides of the region they call home?*

4. Organophosphate pesticides: the strongest before-and-after-birth evidence

Organophosphates are insecticides designed to disrupt nervous-system signaling. Chlorpyrifos, diazinon, and malathion are among the compounds repeatedly evaluated in human neurodevelopmental research. The accumulated evidence is powerful because findings appear before birth, during toddlerhood, at preschool age, and later in childhood. [6-11, 34-36]

Prenatal exposure: findings visible by 24 months

In the CHAMACOS birth cohort, higher prenatal organophosphate metabolite levels were associated with poorer mental development and more parent-reported pervasive-developmental problems at 24 months. These outcomes were measured while children were still toddlers, rather than only becoming visible at school age. [6]

Prenatal chlorpyrifos: developmental and behavioral effects at age three

In a prospective inner-city cohort, children with high prenatal chlorpyrifos exposure scored 6.5 points lower on the Psychomotor Development Index and 3.3 points lower on the Mental Development Index at age three. The high-exposure group also had approximately five times the proportion of psychomotor delay and 2.4 times the proportion of mental delay, with significant effects for attention problems, ADHD-related problems, and pervasive-developmental-disorder-related problems. [7]

Attention at age five and cognition at age seven

At age five, higher prenatal organophosphate exposure was associated with poorer attention. In CHAMACOS, a tenfold increase in prenatal metabolites was associated with 5.1 times the odds of an ADHD Confidence Index score in the clinical-concern range on one computerized attention measure. [8]

By age seven, higher prenatal organophosphate exposure was associated with lower scores across major IQ domains. This persistence strengthens the interpretation that early

exposure can influence developmental trajectories rather than produce only a brief, immediately reversible behavioral change. [36]

Autism and agricultural proximity

A large population-based study of 2,961 children with autism and nearly 30,000 controls evaluated pesticide applications within 2,000 meters of the maternal residence. Prenatal proximity to glyphosate, chlorpyrifos, diazinon, malathion, avermectin, and permethrin was associated with increased autism odds. Associations were larger for autism accompanied by intellectual disability, and first-year exposures were also associated with increased odds for several compounds. [9]

A 2023 meta-analysis of 19 studies found maternal pesticide exposure associated with 19% higher pooled odds of autism and 20% higher pooled odds of ADHD. Organophosphate exposure was associated with 14% higher autism odds, while pyrethroid exposure was associated with 40% higher autism odds. [10]

Postnatal chlorpyrifos: the child's own biomarker at age three

In a prospective cohort of 377 children, higher postnatal urinary TCPy, a chlorpyrifos biomarker measured in the child, was associated with lower motor and social-development scores at age three. The study directly demonstrates that early-childhood internal exposure can correlate with preschool development after birth. [11]

The complete organophosphate picture

Prenatal organophosphate exposure has been associated with mental, motor, attention, ADHD-related, pervasive-developmental, autism-related, and later cognitive outcomes. A child's own postnatal chlorpyrifos biomarker has also been associated with lower motor and social development at age three. The vulnerable period spans both sides of birth. [6-11, 36]

FROM VICTORIA

Insecticides are designed to disrupt the nervous systems of the living things they target, and organophosphates do so by blocking an enzyme that human nerves depend on as well. We are different organisms, and the severity may differ, yet we are not separate from life on this planet. We are of the same world, and we are affected still.

Their toxicity to humans was documented before they were ever developed as insecticides, and warnings about repeated exposure were raised throughout the years that followed. Here we are, nearly a century later, experiencing the society-wide impact of these toxins, and yet, still, we use them. [38, 39]

5. Pyrethroid pesticides: behavior and attention during ages two through four

Pyrethroids are widely used in agriculture, household pest control, structural applications, lawn products, and mosquito management. Their relevance to the preschool years is unusually direct because several studies measured behavior or internal exposure during the exact ages when emotional regulation and inhibition are developing. [12-15]

Age two: externalizing and affective behavior

A prospective birth cohort assessed 683 children at age two using the Child Behavior Checklist. Higher prenatal pyrethroid biomarkers were associated with approximately 30% to 35% greater risk of externalizing behavior for commonly measured metabolites, with additional evidence involving affective problems. [12]

Ages two through four: ADHD-related traits

In the Odense Child Cohort, higher prenatal concentrations of the pyrethroid metabolite 3-PBA were associated with increased odds that children ages two through four would score above the 90th percentile on the preschool ADHD scale. [13]

Age four: current internal dose and current behavior

A study of 385 four-year-old children measured urinary 3-PBA and current ADHD-like behavior. Among boys, residential pyrethroid-product use was associated with a 51.6% higher symptom score, and children in the highest urinary-metabolite group had a 58% higher symptom score than those in the lowest group. [14]

Ages two through six as susceptible periods

A longitudinal cohort that measured childhood 3-PBA repeatedly identified pregnancy and ages two through six as susceptible periods for pyrethroid-related ADHD symptoms. Exposure measured at age two predicted increased symptoms at age six, while exposure at age four predicted increased symptoms at age eight. [15]

> **FROM VICTORIA**
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> *It is no secret that most of us treat the newest additions to our households with extra care. While we are mindful to avoid other potentially harmful substances around our infants and toddlers, many of us are unknowingly exposing them to pyrethroids through the household pest sprays, lawn treatments, and mosquito products we bring home. And if exposure at age two can still be seen in a child's behavior at age six, what, then, are we truly bringing home?*

6. The preschool exposure study: measurable pesticides remained despite ordinary routines

One of the most immediately understandable studies, conducted in Northern California, involved 125 preschool-age children who wore silicone wristbands across their child-care and home environments. The wristbands functioned as personal passive samplers, capturing the chemical mixture encountered during ordinary daily life. [5]

The pesticides commonly detected included bifenthrin, chlorpyrifos, cypermethrin, fipronil, and cis- and trans-permethrin. Exposures were higher in counties with greater agricultural or commercial pesticide use and when children lived near agricultural fields. [5]

The study also evaluated environmental and behavioral factors such as cleaning schedules and children's handwashing. Ordinary handwashing and routine cleaning did not consistently predict lower measured pesticide concentrations. The result shifts the prevention question away from whether a caregiver cleaned often enough and toward whether the surrounding environment continued to replenish the exposure. [5]

Why this finding is so compelling

Preschoolers carried measurable mixtures of insecticides across home and child care. Living near fields increased exposure, and ordinary washing or routine cleaning did not consistently correspond with lower measured levels. When the source remains active, hygiene alone may not fully interrupt the exposure pathway. [5]

This finding is especially relevant to agricultural regions because pesticide residues can continue arriving through air, dust, clothing, shoes, vehicles, treated surfaces, and nearby applications. Repeated environmental replenishment can outpace ordinary household cleaning.

> **FROM VICTORIA**
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> *Inspired by my son, Eli, and his love for Greek myth, I turn to the Hydra to make sense of this finding. The Hydra grew two heads for every one cut away. Cleaning a home beside a treated field follows the same pattern: the residue removed today returns with tomorrow's application. We may cut away head after head, but we will never be rid of this foe while it is still being applied.*

7. Midwestern homes and children: the Iowa exposure bridge

Iowa research provides the strongest direct bridge between Midwestern agricultural use, household contamination, and internal exposure in children. These studies move the

discussion beyond statewide pesticide-use maps by demonstrating chemicals inside homes and inside children's bodies. [3-4]

Pesticides inside Iowa homes

The NIH Agricultural Health Study sampled farm and nonfarm homes in Iowa. Chlorpyrifos, glyphosate, and 2,4-D were found in dust in most homes. Farm homes generally contained higher residues in air, dust, and hard-surface samples, and pesticides were detected more often in carpet dust than in air or on hard surfaces. Higher atrazine and metolachlor concentrations were associated with tracked dirt and work clothing. [3]

Residues were found in entry and laundry areas and were also detected in children's bedrooms and play spaces. Carpet dust functioned as a long-lived reservoir where children could contact chemicals repeatedly during floor play. [3]

Pesticides measured in Iowa children

Researchers measured urinary pesticide concentrations in 117 Iowa children and their parents. Children from farm households had significantly higher atrazine metabolite levels than children from nonfarm households. When fathers had recently applied atrazine or chlorpyrifos, their children had significantly higher urinary concentrations of those chemicals. [4]

The Iowa findings establish a complete pathway: agricultural application becomes residue in the home, household dust becomes a repeated contact medium, and the chemical or its metabolite becomes measurable inside the child. [3-4]

> **FROM VICTORIA**
>
> *What further confirmation do we need to protect our own species, our own children?*

8. Air pollution, agricultural ammonia, smoke, and autism symptom burden

Ages two through four are a PM2.5-sensitive window

A U.S. multicohort study of 1,967 mother-child pairs estimated air-pollution exposure across pregnancy and childhood. Each 2 μg/m^3 increase in PM2.5 exposure during ages two through four was associated with a 3.59-point higher Child Behavior Checklist Total Problems score and a 2.63-point lower cognitive score. The behavioral association was generally stronger in girls. [16]

Children who already have autism

A longitudinal study found that higher particulate-matter exposure was associated with more severe autism and ADHD symptoms over time. This directly addresses symptom burden after a developmental condition is already present. [17]

Research in children with autism also associated prenatal and first-year nitrogen dioxide exposure with lower cognitive and adaptive-function scores, including everyday living and socialization abilities. [18]

A 2025 study of children with autism found that PM2.5 exposure during the first two years, particularly in toddlers between 13 to 18 months was associated with greater stereotypic-behavior burden. Lower greenness combined with higher PM2.5 was associated with greater overall symptom severity and poorer relating or social-independence scores. [19]

Why the Midwest air pathway is distinctive

Agriculture is a major source of ammonia from fertilizer and animal waste. Atmospheric reactions convert ammonia into fine particulate matter. A 2024 analysis estimated that agricultural ammonia contributes 40% of the PM2.5 burden across the Midwestern United States, which is about four times the average contribution across the contiguous nation. [21]

Kansas adds a recurring seasonal smoke pathway. KDHE describes March and April as the major Flint Hills prescribed-burn period and reports that approximately 2.1 million acres are burned annually across the Kansas-Oklahoma Flint Hills. State advisories document smoke affecting central and eastern Kansas and reaching unhealthy air quality in localized areas. [22-23]

The symptom-burden chain

The Midwest has a disproportionate agriculture-related PM2.5 burden. Ages two through four are associated with measurable behavioral and cognitive differences from PM2.5 exposure. Among children with autism, particulate exposure has been associated with poorer adaptive functioning, more severe autism/ADHD symptom trajectories, and greater stereotypic-behavior burden. [16-21]

FROM VICTORIA

Particulate matter and I are ongoing rivals, and I intend to see this rivalry end with its dismissal. PM2.5 is about thirty times smaller than the width of a human hair, small enough to slip past the body's defenses, deep into the lungs and, for some particles, into the bloodstream: free rein, full clearance, an attack from within. Of all its components, the one most strongly linked to poorer learning and memory in U.S. children, ammonium nitrate, forms from agricultural fertilizer, and its largest contributions are found across the Midwest. I explore this rival in depth in my analysis, Why Fine-Particle Pollution Matters for Developing Autistic Children in the Midwest. [40, 41]

9. Lead exposure and the risk of mistaking toxic burden for autism-related behavior

Lead is a separate neurotoxic exposure that can coexist with pesticides and particulate pollution. Young children encounter lead primarily through deteriorating paint, contaminated soil, and settled household dust. EPA and state health agencies emphasize that ordinary crawling and hand-to-mouth behavior make children under six especially vulnerable. [1-2, 24]

Kansas provides a Midwestern example of under-five burden

A Kansas analysis of childhood surveillance data from 2005 through 2012 estimated an elevated blood-lead rate of 6.9% among children ages zero to five, compared with 3.2% nationally during corresponding years. Estimated rates reached 10.0% in rural ZIP codes and 15.1% in communities with fewer than 500 residents. [24]

Kansas health guidance states that children under six remain at increased risk, no safe blood-lead level has been identified, low levels can affect IQ, development, and behavior, and most affected children show no obvious physical symptoms. [25]

Autism-specific clinical guidance

A clinical review focused on autism and lead poisoning explains that oral sensory and hand-to-mouth behaviors can persist well beyond the age when they usually decline, extending exposure risk. The authors recommend enhanced or extended blood-lead monitoring for autistic preschoolers when lead hazards or persistent mouthing are present. [26]

The same review warns that lead burden can be missed because it may present as irritability, agitation, increased wakefulness, constipation or abdominal pain, withdrawal, lethargy, or developmental regression: changes that can be attributed to autism instead of investigated as an added medical and environmental burden. [26]

The diagnostic-overlap problem

An autistic child can have greater opportunity to ingest contaminated dust while also being less likely to communicate pain or have irritability, sleep change, gastrointestinal distress, withdrawal, or regression recognized as a separate exposure-related problem. [26]

> **FROM VICTORIA**
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> *Our era is well acquainted with the harm of lead exposure, yet it is far from behind us. It remains in the soil where children play, in the paint and dust of older homes, tracked indoors on shoes, and lifted by the wind across the open Midwest. In autistic children it can hide in plain sight, its symptoms mistaken for the diagnosis itself. No safe level of lead has ever been identified. [44]*

10. Water pathways: herbicides, neonicotinoids, nitrate, and groundwater mixtures

Midwestern water contamination adds another route to the cumulative exposure picture. Agricultural chemicals move into streams and reservoirs through runoff and rainfall and into aquifers through infiltration. Seasonal peaks after planting and rainfall can be obscured by annual averages. [27-30]

Atrazine and agricultural herbicides

Atrazine is a defining Corn Belt herbicide and a useful marker of regional agricultural chemical movement. USGS has documented atrazine and other herbicides in rain, surface water, shallow groundwater, and the High Plains aquifer. Kansas investigations found atrazine as the most frequently detected organic compound in south-central Kansas, with detections in approximately 55% of shallow-well samples and concentrations in the Little Arkansas River exceeding 3 µg/L during a substantial portion of the application season. [28-30]

Research on atrazine and autism in humans is still developing. Its widespread presence in Midwestern air and water makes it a documented indicator of how intensively used agricultural chemicals move through the region and join the broader exposure mixture, and a compound that warrants continued study.

Neonicotinoids in Iowa drinking water

USGS-supported research detected clothianidin, imidacloprid, and thiamethoxam throughout sampled finished Iowa drinking water after corn and soybean planting, at concentrations from 0.24 to 57.3 ng/L. Conventional treatment showed no apparent removal of clothianidin or imidacloprid and only partial removal of thiamethoxam, while granular activated carbon performed substantially better. [27]

The finding demonstrates that a pesticide can survive the route from treated agricultural land through source water and conventional treatment into finished drinking water. Human neurodevelopmental evidence for neonicotinoids remains emerging, but the exposure pathway is established. [27]

Nitrate and the High Plains aquifer

The High Plains aquifer underlies major portions of Nebraska, Kansas, and surrounding states. Historical USGS assessment found nitrate, pesticides, and salinity to be important water-quality concerns; 16% of nitrate observations exceeded the federal drinking-water standard, approximately 50 pesticides were detected, and occasional detection in deeper Ogallala groundwater showed that contamination pathways exist. [29]

Nitrate is most firmly linked with infant methemoglobinemia, a condition that reduces the blood's ability to carry oxygen, among other concerns for wellness. In this review it stands as evidence of persistent agricultural groundwater contamination, and as a co-exposure reaching the same households during the same developmental years.

> **FROM VICTORIA**
>
> *Is natural always organic? No, not always. We think of wells and running water as pure, yet they are not, and moreover, they are victims too, of everything we expose the land to.*
>
> *When the components beneath our homes can impact us, we cannot even seal ourselves and our families in a bubble, because the ground and the water beneath it can infiltrate us, through no fault of their own. So how, my friend, can I create sanctuary?* ***With awareness, and with the eradication of that which harms us.***

11. PFAS and additional behavioral burden

PFAS are persistent industrial and military-use contaminants with long biological half-lives. Midwestern communities may encounter them through military installations, airports, industrial sites, contaminated groundwater, food, dust, and consumer materials.

In the MARBLES cohort, prenatal PFAS mixtures were evaluated in children assessed at age three, including children with autism and other neurodevelopmental concerns. Higher PFAS mixture exposure was associated with greater sleep-problem and aggressive-behavior scores in neurodevelopmentally vulnerable groups. [31]

A separate prospective cohort that measured PFAS directly in children's blood at ages two and four reported associations between early-childhood PFAS exposure and later ADHD symptoms. [32]

These studies add sleep, aggression, and attention to the functional domains that may be shaped by chemical burden during the same early-childhood period already central to pesticide, lead, and air-pollution evidence.

> **FROM VICTORIA**
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> *PFAS, or forever chemicals. Forever. None of us can truly fathom how long that is, or what it means. Released since the 1940s, thousands of them now move through our water, air, and soil, and through the blood of people and animals all over the world. In under a century, they have become part of nearly every human body, building over time and reaching our children before birth.*
>
> *If research already records developmental delays and behavioral changes in children, weakened immunity, disrupted hormones, and some cancers, along with the sleep problems, aggression, and attention difficulties found here, what will the generations to come inherit as these chemicals continue to build up around them? [31, 32, 42, 43]*

12. How environmental burden can present in autistic toddlers and preschoolers

Environmental toxicants do not need to create an entirely new symptom to alter daily functioning. They can increase the frequency, intensity, duration, or recovery time of behaviors already present. In autistic children, the added burden may be visible through regulation, sleep, communication, social engagement, attention, inhibition, sensory tolerance, gastrointestinal comfort, or adaptive functioning. [17-19, 26, 31-32]

Observed difficulty	Relevant research domain	How added burden may appear (Evernorth interpretation)
Sleep disruption	PFAS-associated sleep problems; lead-related increased wakefulness; particle and respiratory irritation	Longer sleep onset, more night waking, fragmented sleep, greater next-day irritability and reduced regulation.
Meltdowns / externalizing	Age-two externalizing behavior, ADHD-related traits, irritability and agitation	Lower trigger threshold, increased intensity or duration, slower recovery, more difficulty accepting transitions or demands.
Aggression	Aggressive-behavior scores, agitation, poor inhibition, pain or gastrointestinal distress	More frequent or forceful hitting, throwing, biting, pushing, or aggression during overload or discomfort.

Observed difficulty	Relevant research domain	How added burden may appear (Evernorth interpretation)
Avoidance / withdrawal	Adaptive-function strain, fatigue, sensory burden, lead-associated withdrawal	Deeper demand avoidance, reduced social engagement, retreat from previously tolerated activities or settings.
Speech / communication delay	Mental and social-development scores, cognitive/adaptive effects	Slower gains, reduced available capacity for communication during overload, regression or loss of functional language under strain.
Dangerous impulsivity / low fear	Attention, ADHD-related behavior, inhibition and executive function	Running, climbing, throwing, bolting, or limited response to hazards can become more difficult to interrupt.
High apparent pain tolerance	Atypical pain communication; constipation, abdominal pain, headache or respiratory irritation	Pain may emerge behaviorally through aggression, avoidance, sleep change, withdrawal, or sudden dysregulation rather than a conventional complaint.
Repetitive / stereotypic behavior	PM2.5-associated stereotypic-behavior burden in children with autism	Increased repetition, rigidity, self-stimulation, or reduced flexibility during periods of environmental strain.

Persistent hand-to-mouth behavior as an exposure modifier

EPA's exposure framework explicitly incorporates contaminant concentration on the hand or object, contact rate, mouthing-event frequency, exposure time, and body weight. Repeated thumb sucking or object mouthing increases the number of direct hand-to-mouth transfer events from floors, dust, soil, furniture, toys, clothing, and other surfaces. [2]

This exposure pathway is especially important when semi-volatile pesticides or lead-bearing dust remain in carpets, entryways, window areas, or play spaces. It also explains why source reduction is more protective than relying exclusively on repeated handwashing.

FROM VICTORIA

While this section speaks of autistic children, it is something all parents must ponder. We cannot fully track, or give consent to, what changes our children's behavior, nor do we always know its cause. Are we being good parents? Are we too hard on them? Is this a tantrum? Is it the television, or some outside influence? Or is it an invisible foe that infiltrates our homes after it attacks the fields that grow our food? Cause and effect. Exposure and response. When, then, does this violation become important?

A REGIONAL REFERENCE

13. Regional evidence profiles: Kansas, Iowa, and Nebraska

Kansas

- Flint Hills prescribed burning releases concentrated particulate matter and ozone-forming pollutants across a predictable March-April period; approximately 2.1 million acres are burned annually. [22-23]
- Kansas water studies document atrazine, seasonal peaks after application, shallow-well detections, and agricultural groundwater vulnerability. [28, 30]
- Kansas childhood lead surveillance found a historical under-five burden above the national comparison rate, with higher estimates in rural and very small communities. [24-25]
- Military, industrial, refinery, and PFAS sites add localized contaminant pathways that can overlap with the broader agricultural environment.

Iowa

- NIH studies measured pesticides in air, hard surfaces, and household dust, with carpets acting as the most frequent reservoir. [3]
- Atrazine and chlorpyrifos biomarker levels increased in children following recent parental applications. [4]
- Neonicotinoids were detected in finished drinking water, and conventional treatment did not fully remove several compounds. [27]
- Iowa provides the clearest Midwestern field-to-home-to-child exposure evidence.

Nebraska

- Nebraska depends heavily on groundwater within an agricultural landscape where nitrate and pesticide contamination pathways are documented. [29]
- The Republican River and High Plains aquifer systems connect Nebraska with Kansas through shared agricultural water pathways.
- Irrigated row-crop production, shallow groundwater in some areas, and long contaminant residence times can sustain exposure beyond a single application season.

Across all three states, local risk varies by exact field proximity, well depth and source, prevailing wind, crop and livestock density, home age, flooring, ventilation, season, and whether residues are repeatedly carried indoors. The regional evidence shows why these location-level factors deserve evaluation before pregnancy and throughout early childhood.

> **FROM VICTORIA**
>
> *We live in a time when seeking fresh country air, once prescribed as a cure, can mean breathing more agricultural chemicals than the air of a big city. Each of these states has its own findings and its own burden to bear, yet these reflect only the research someone chose to conduct here. With findings such as these, should consistent testing be mandatory?*

14. Why source control matters more than relying on washing alone

Handwashing, wet cleaning, shoes-off practices, HEPA filtration, hard flooring, and careful laundering can reduce portions of exposure. They cannot fully counteract an environment that continually replenishes residues through nearby application, atmospheric transport, contaminated soil, smoke, water, or take-home pathways. [2-5]

The Northern California preschool wristband study is central to this point: routine handwashing and ordinary cleaning did not consistently predict lower measured pesticide exposure. The finding supports interventions that prevent chemicals from entering the child's environment in the first place, including agricultural buffers, pesticide-free child-care practices, integrated pest management, elimination of indoor pesticide applications, filtered water where indicated, and selection of lower-exposure housing and locations. [5]

Protective Hierarchy

1. Avoid or remove the source: Choose lower-application environments; avoid indoor pesticide use; identify lead, PFAS, industrial, smoke, and groundwater hazards before occupancy.

2. Interrupt transport: Shoes off, separate work clothing, exterior changing, protected laundry handling, hard-surface entryways, sealed cracks, and field-distance buffers.

3. Remove settled residues: HEPA vacuuming, damp dusting, hard flooring, washable play surfaces, and appropriate lead-safe remediation.

4. Reduce internal dose: Filtered water selected for the contaminant, frequent hand cleaning before eating, and reduced mouthing of contaminated objects where developmentally possible.

5. Recognize functional change: Track sleep, behavior, language, gastrointestinal comfort, respiratory symptoms, adaptive skills, and recovery patterns alongside changes in location or exposure.

> **FROM VICTORIA**
>
> *When we cannot wash away the exposure, the threat to ourselves, our families, our children, what, then, do we do? And when we clean away what we believe is a toxin with a cleaner riddled with toxins of its own, what are we truly doing?*

15. Evidence synthesis and precautionary conclusion

The complete evidence picture begins before birth and continues through infancy, toddlerhood, and the preschool years. Prenatal organophosphate and pyrethroid exposure has been associated with autism likelihood, developmental delay, pervasive-developmental problems, poorer attention, ADHD-related traits, and lower later cognitive performance. Postnatal pesticide biomarkers measured in children have been associated with lower motor and social development and substantially greater preschool behavioral symptom scores. [6-15, 36]

The exposure pathway is equally well documented. In Iowa, agricultural chemicals were found in household air, dust, carpets, entryways, laundry spaces, children's rooms, and children's urine. Preschool wristbands detected pesticide mixtures across ordinary daily life, with higher exposure near fields and in higher-use counties; routine handwashing and cleaning did not consistently predict lower levels. [3-5]

The Midwest adds a distinct air burden. Agricultural ammonia contributes an estimated 40% of Midwestern PM2.5, while Kansas burn season creates predictable particulate episodes. Ages two through four have been identified as a sensitive window for PM2.5-related behavioral and cognitive differences, and studies in children with autism associate particulate exposure with poorer adaptive functioning, more severe autism/ADHD symptom trajectories, and greater stereotypic-behavior burden. [16-23]

Lead, PFAS, neonicotinoids, nitrate, industrial contamination, and agricultural groundwater pathways add to the cumulative burden. Autism-specific clinical literature is especially important because environmental strain can be hidden within irritability, agitation, sleep disruption, constipation, withdrawal, aggression, avoidance, regression, or communication difficulty. [24-32]

Evernorth conclusion

From conception to age five, the developing brain is both more susceptible to its surroundings and more profoundly influenced by them, and the agricultural Midwest presents a concentrated combination of pesticide use, agricultural particle pollution, seasonal smoke, household dust transfer, contaminated water pathways, and older-housing lead hazards. For pregnancy, infancy, toddlerhood, and the preschool years, choosing lower-exposure environments is a scientifically supported precaution.

FROM VICTORIA

I end this with more questions, more avenues to explore, and more concern than when I began. This was my first comprehensive inquiry into neurodevelopment, and it will not be my last. What is applied in the Midwest travels, and no family is beyond its reach, which is why this research belongs to everyone. I invite you to continue exploring with me in the Evernorth Resource Library, the Continuum, where this work carries on. We believe in progress without the poison, and in purity for the people.

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Evidence scope

This review prioritizes human developmental studies, federal and state monitoring, and Midwestern exposure research. It presents the documented associations and exposure pathways as a cumulative case. Individual exposure and response vary by location, season, housing, water source, proximity, and biological susceptibility; the regional evidence supports precaution during pregnancy and the first five years of life.

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