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# WHY FINE-PARTICLE POLLUTION MATTERS

## FOR DEVELOPING AUTISTIC CHILDREN IN THE MIDWEST

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## What PM2.5 is and why it matters

PM2.5 is microscopic air pollution. The particles are 2.5 micrometers wide or smaller, making even the largest PM2.5 particle about 30 times smaller than the width of an average human hair (U.S. EPA, "Particulate Matter (PM) Basics"). Because they are so tiny, they can travel deep into the lungs, and some particles can enter the bloodstream. EPA identifies PM2.5 as the particle size posing the greatest health risk (U.S. EPA, "EJScreen Indicators - PM2.5").

What makes this particularly relevant in the agricultural Midwest is that agriculture itself helps create a substantial amount of this microscopic pollution.

Fertilizer use and animal waste release ammonia gas into the atmosphere. Once airborne, ammonia reacts with other compounds and helps form PM2.5 (Vo & Christiansen, 2024). This means agricultural pollution does not simply remain on a farm or beside a field. It becomes part of the regional air that people breathe in rural communities, towns, suburbs, and cities.

## The Midwest's distinctive PM2.5 burden

A 2024 study specifically examining the Midwestern United States found something striking: agricultural ammonia was responsible for an estimated 40% of the Midwest's PM2.5 burden. Its contribution to PM2.5 was approximately four times greater in the Midwest than its average contribution across the continental United States. Researchers also found that atmospheric ammonia increased 43% across the Midwest between 2007 and 2019. After 2014, previously declining winter PM2.5 and particulate-nitrate trends reversed alongside increasing ammonia emissions. The researchers concluded that agricultural ammonia plays a disproportionate role in determining the Midwest's PM2.5 burden and is hindering improvements in regional air quality (Vo & Christiansen, 2024, *ACS Earth and Space Chemistry*, DOI: 10.1021/acsearthspacechem.4c00180).

That distinction is important. It does not mean that every Kansas, Iowa, or Nebraska community has four times the total PM2.5 concentration of the rest of America. It means that agriculture contributes approximately four times as much to the Midwest's PM2.5 burden as agriculture contributes nationally on average.

## Ammonium nitrate: the agricultural component linked to cognitive harm

The specific PM2.5 component formed from agricultural ammonia - ammonium nitrate - matters because it is not just a respiratory concern. A 2024 U.S. study of 8,588 children ages 9–10 across 21 study sites nationwide, using data from the NIH Adolescent Brain Cognitive Development (ABCD) Study, found that ammonium nitrates in PM2.5 were the most robust predictor of poorer learning and memory performance among all PM2.5 components examined. The researchers described ammonium nitrates as "secondary aerosols related to agricultural fertilizer" and noted that the largest ammonium-nitrate source contributions were observed across the Midwest. This was the first study to link ammonium-nitrate exposure to cognitive deficits in U.S. children (Sukumaran et al., 2024, *Environmental Health Perspectives*, DOI: 10.1289/EHP14418).

More broadly, a 2024 meta-analysis of six studies representing 4,860 children across three continents found that every 1 μg/m³ increase in PM2.5 exposure was associated with a 0.27-point decrease in Full-Scale IQ. Without exception, each study reported a negative association between PM2.5 and children's cognitive function (Alter et al., 2024, *Environmental Health*, DOI: 10.1186/s12940-024-01122-x).

## PM2.5 and autism: the evidence

Research has examined PM2.5 exposure specifically in children who already have autism - and the findings span multiple countries, study designs, and outcome measures.

### *Symptom severity in diagnosed children*

A case-control study of 297 children ages three through six reconstructed their PM2.5 exposure during their first three years after birth. Among the 99 children with autism, researchers found a statistically significant positive relationship between PM2.5 exposure and scores on the Childhood Autism Rating Scale (CARS), a measure of autism symptom severity ($r = 0.259$, $p = 0.010$). Separately, in the full case-control sample, children in the highest PM2.5 exposure quartile had roughly four times the odds of an autism diagnosis compared to those in the lowest quartile (OR = 4.15, 95% CI: 2.04–9.45) (Geng et al., 2019, *International Journal of Developmental Neuroscience*, DOI: 10.1016/j.ijdevneu.2019.05.003).

It is important to note that this study was conducted in China, where ambient PM2.5 levels averaged approximately 89.8 μg/m³ for children with autism - roughly ten times the U.S. EPA's current annual standard of 9.0 μg/m³, revised in February 2024 (U.S. EPA, "National Ambient Air Quality Standards (NAAQS) for PM"). Whether the same severity-exposure relationship holds at the lower

concentrations typical of the United States remains an open question. However, multiple lines of U.S.-based and international research now provide corroborating evidence.

### *U.S. evidence: adaptive functioning deficits in autistic children*

A U.S. multisite study from the CDC-funded Study to Explore Early Development (SEED), covering six states - California, Colorado, Georgia, Maryland, North Carolina, and Pennsylvania - examined 658 children with autism and found that PM2.5 exposure was associated with measurable deficits in adaptive functioning, the practical everyday skills that children use to navigate daily life.

Among children with ASD, higher PM2.5 exposure during the first year of life was associated with significantly lower scores on the Vineland Adaptive Behavior Scales for daily living skills ($\beta = -1.73$ per 1 $\mu g/m^3$ increase, 95% CI: −3.04 to −0.42) and socialization ($\beta = -2.09$, 95% CI: −3.20 to −0.97). Third-trimester PM2.5 was associated with lower overall adaptive composite scores, daily living skills, and socialization. First-trimester exposure was associated with lower communication and daily living skills scores. The researchers concluded that late-pregnancy and early-life air pollution exposure "may negatively impact social and independent-skill development among children with ASD" (McGuinn et al., 2022, *International Journal of Environmental Research and Public Health*, DOI: 10.3390/ijerph19073748).

A separate analysis from the same SEED study found that PM2.5 exposure during the first year of life was associated with increased odds of an autism diagnosis overall (OR = 1.3, 95% CI: 1.0–1.6 per 1.6 $\mu g/m^3$ increase), at mean PM2.5 levels of approximately 9–16 $\mu g/m^3$ - much closer to U.S. ambient conditions than the levels in the Chinese study (McGuinn et al., 2020, *Epidemiology*, DOI: 10.1097/EDE.0000000000001109).

### *Longitudinal evidence: symptom severity over time*

A longitudinal study from the Netherlands tracked 2,750 children across six assessment waves from ages 10–12 through early adulthood (2001–2017). Researchers found that higher exposure to particulate matter was associated with more severe ASD symptoms, and that this association persisted across adolescent development. The same pattern held for ADHD symptoms. Notably, no other air pollutants or environmental noise produced consistent associations with symptom severity - only particulate matter did (Li et al., 2023, *Environmental Research*, DOI: 10.1016/j.envres.2023.115704).

### *Short-term exposure and acute symptom aggravation*

A nationwide Korean time-series study of daily hospital admissions for autism among children ages 5–14 found that short-term PM2.5 exposure was associated with a 17% higher risk of autism-related hospital admission for every 10 $\mu g/m^3$ increase in PM2.5 (RR = 1.17, 95% CI: 1.10–1.25). Admissions were for issues such as hyperactivity, aggression, and self-injury. The researchers concluded that "short-term exposure to air pollution affects ASD symptom aggravation" and that reducing exposure "should be considered for ASD symptom management" (Jung et al., 2022, *BMJ Open*, DOI: 10.1136/bmjopen-2021-058286).

### *Meta-analytic evidence on ASD risk*

A separate exposure-response meta-analysis from the Harvard T.H. Chan School of Public Health found that the risk of ASD increased by 64% for every 10 μg/m$^3$ increase in PM2.5 exposure during early childhood, and by 31% during prenatal periods, with the third trimester emerging as the most sensitive prenatal window. Notably, the authors reported that elevated ASD risk persisted at background PM2.5 concentrations as low as 8 μg/m$^3$ (Lin et al., 2021, *Environmental Research Letters*, DOI: 10.1088/1748-9326/abfcf7).

## What the evidence means taken together

The research points to a layered set of concerns:

- **Increased odds of an autism diagnosis.** Early-life PM2.5 exposure is associated with an increased likelihood of an ASD diagnosis - a finding supported by multiple U.S. studies and meta-analyses.
- **Greater symptom severity among children who already have autism.** Among diagnosed children, higher PM2.5 exposure has been associated with greater symptom severity on standardized measures (CARS scores), more severe ASD symptoms over time (longitudinal tracking), and acute symptom aggravation requiring hospitalization.
- **Measurable deficits in adaptive functioning.** U.S.-based research has found that PM2.5 exposure is associated with poorer daily living skills, socialization, and communication in children with ASD - the exact domains that matter most for independence and quality of life.
- **Cognitive harm from agricultural-source PM2.5.** U.S. research has specifically identified ammonium nitrate - the PM2.5 component formed from agricultural ammonia - as the most robust predictor of poorer learning and memory in children, with the largest contributions observed across the Midwest.

This makes the first several years particularly important. The concern is not simply whether pollution contributes to the initial development of autism. Research suggests that environmental air pollution may also relate to how strongly autism-associated difficulties are expressed during childhood, and to the development of practical adaptive skills.

For an autistic toddler, greater exposure during these years can matter because these are the years when communication, social interaction, attention, emotional regulation, sleep regulation, inhibition, sensory processing, and everyday adaptive skills are rapidly developing.

## Why Kansas deserves additional attention

Kansas sits within this agriculture-intensive Midwestern environment, but parts of Kansas also experience an additional recurring source of particle pollution: Flint Hills prescribed burning.

Kansas health officials report that approximately 2.1 million acres are burned across the Kansas-Oklahoma Flint Hills in an average year. KDHE states that these burns release large amounts

of particulate matter and other pollutants, that smoke can affect surrounding communities, and that children are among the populations particularly vulnerable to the resulting pollution (KDHE, "Health Advisory, Safety Tips for Prescribed Fire Season in Flint Hills").

So a child in Kansas can encounter PM2.5 from more than one regional source:

- Intensive agriculture  ammonia emissions  atmospheric PM2.5 formation (including ammonium nitrate, the component linked to learning and memory deficits in U.S. children)
- Flint Hills prescribed burning, especially March–April  smoke and particulate pollution additional PM exposure

And because PM2.5 becomes part of the surrounding air, none of this requires living on a farm.

## Conclusion: why the Midwest is different

The convergence of evidence points to a reality that is specific to the agricultural Midwest in a way it is not specific to most other regions of the country.

In most of the United States, PM2.5 comes primarily from traffic, industry, and power generation - sources that are increasingly regulated and, in many areas, declining. The Midwest is different. Here, agriculture is the dominant driver of fine-particle pollution, contributing an estimated 40% of the region's PM2.5 burden - four times agriculture's national average contribution (Vo & Christiansen, 2024). Unlike tailpipe emissions or smokestack output, agricultural ammonia is not regulated at the federal level, and atmospheric ammonia concentrations across the Midwest increased 43% between 2007 and 2019. Rather than improving, winter PM2.5 trends reversed after 2014.

The specific pollutant formed by this process - ammonium nitrate - is not a generic air contaminant. It is the PM2.5 component most robustly linked to poorer learning and memory in U.S. children, and the Midwest has the highest ammonium-nitrate concentrations in the country (Sukumaran et al., 2024). This means the pollutant most directly tied to cognitive harm is the one most concentrated in the air that Midwestern children breathe.

For autistic children, the implications are layered. PM2.5 exposure has been associated not only with increased odds of an autism diagnosis - supported by U.S. studies at exposure levels relevant to American communities (McGuinn et al., 2020; Lin et al., 2021) - but also with greater symptom severity among children who already have autism (Geng et al., 2019; Li et al., 2023), acute symptom aggravation severe enough to require hospitalization (Jung et al., 2022), and measurable deficits in the adaptive skills - daily living, socialization, communication - that determine a child's trajectory toward independence (McGuinn et al., 2022). A meta-analysis quantifying cognitive impact found that every 1 $\mu g/m^3$ increase in PM2.5 corresponded to a measurable decrease in children's IQ (Alter et al., 2024).

No other region of the United States combines this set of conditions: a dominant pollution source that is unregulated and increasing, a specific pollutant component that is both concentrated there and linked to cognitive harm, and a seasonal additional source - the Flint Hills burns - that the state's

own health department warns can harm surrounding communities and that children are especially vulnerable to. In Kansas, these layers overlap during the very years when a developing autistic child's brain is most sensitive to environmental insult.

None of this requires living on a farm, or even adjacent to one. PM2.5 becomes part of the regional air. The agricultural Midwest's fine-particle pollution environment is not an abstract environmental concern. For a child with autism growing up in this region, it is a measurable factor in the severity of their symptoms, the development of their adaptive skills, and the trajectory of their cognitive development - during the years when all of these are still being formed.

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**Suggested citation:** Vera, V. (2026). *Why Fine-Particle Pollution Matters for Developing Autistic Children in the Midwest.* Evernorth Foundation. evernorthfoundation.org