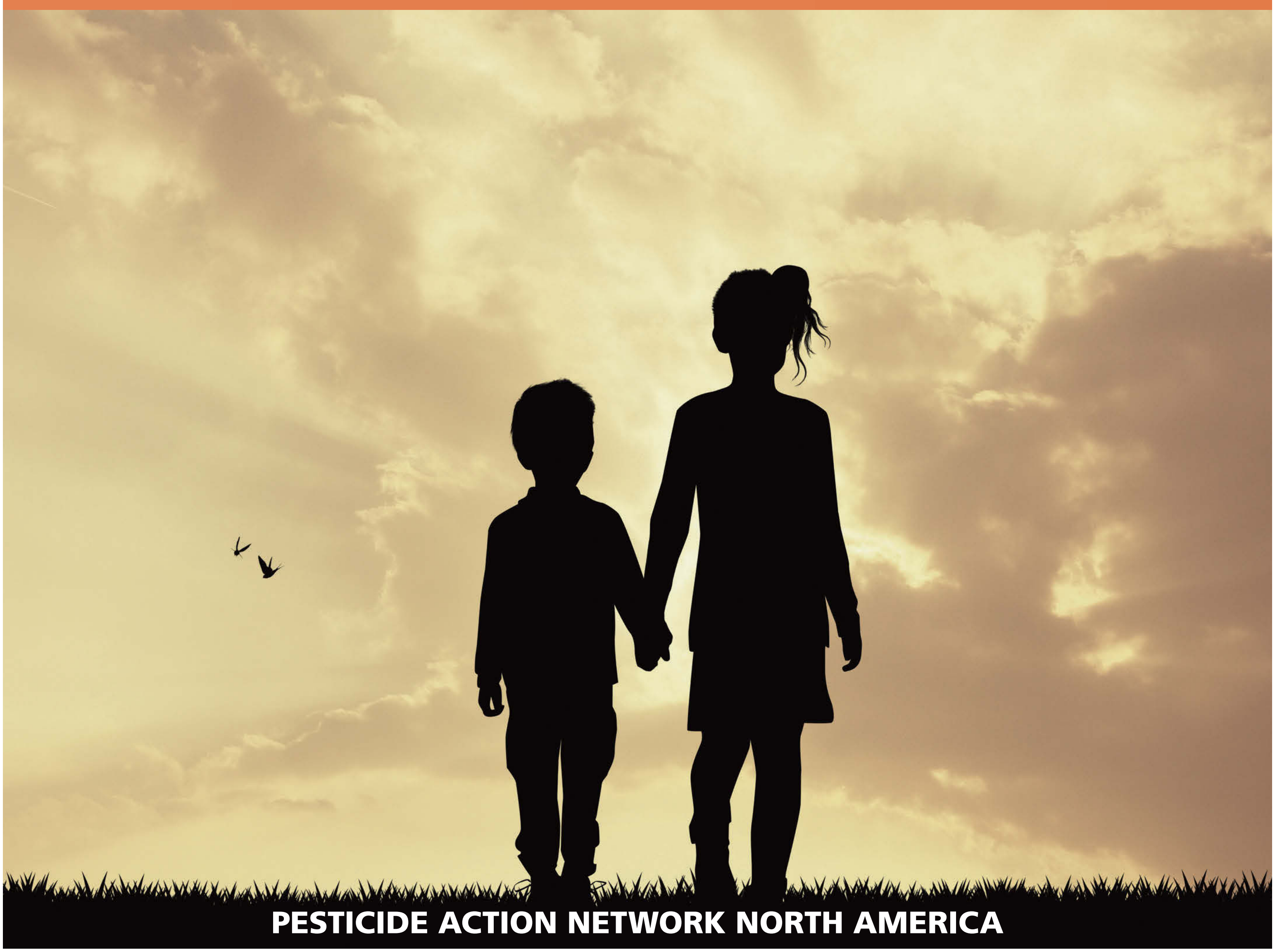
Kids on the Frontline

How pesticides are undermining the health of rural children



PESTICIDE ACTION NETWORK NORTH AMERICA

Pesticide Action Network North America

Pesticide Action Network (PAN) works to create a just, thriving food system. PAN works in partnership with those on the frontlines to tackle the pesticide problem—and reclaim the future of food and farming. PAN North America is one of five regional centers worldwide, linking local and international consumer, labor, health, environment and agriculture groups into a global citizens' action network. Together, we challenge the proliferation of pesticides, defend basic rights to health and environmental quality, and promote the transition to a just and viable system of food and farming.

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Kids on the Frontline follows up on PAN's 2012 report, *A Generation in Jeopardy.* Both are available at www.panna.org/kids.

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Kids on the Frontline

Executive Summary

A little over 100 years ago, Congress enacted the first U.S. pesticide law. The Insecticide Act of 1910 put labeling guidelines in place to protect farmers from unscrupulous vendors attempting to sell pesticide products that didn't perform as advertised.

To this day, we control pesticides through a system of registration and labeling, with a primary goal of getting products to market. The result? Each year, more than 680 million pounds of pesticides are applied to agricultural fields across the country. This 2007 figure—the most recent government estimates available—climbs to more than a billion when common non-agricultural pesticide uses are included.

We believe this is too much. Ever-stronger science shows that even at low levels of exposure, many of these chemicals are harmful to human health—and children's developing minds and bodies are particularly vulnerable. It is also increasingly clear that alternative, less chemical-intensive approaches to farming are not only viable, but would strengthen the resilience of agricultural production.

Put simply, there is no need for our food and farming system to put our children's health at risk from chemical exposure.

Kids on the Frontline builds on the findings of *A Generation in Jeopardy,* our 2012 report summarizing the state of the science linking pesticide exposure and children's health harms. In addition to highlighting the latest scientific findings, this new report focuses in on the particular health risks pesticides pose to children in rural agricultural communities.

Rural children experience the same chemical exposures faced by children in communities across the country from pesticide residues on food and applications in schools, parks and homes. They face additional exposures when agricultural chemicals contaminate water supplies or drift from nearby fields. These rural exposures and their impacts on children's health are the primary focus of this report. We examine the particular vulnerabilities of children in rural communities, highlight the results of studies in rural and agricultural areas, and present specific data on four agricultural states—California, Hawai'i, Iowa and Minnesota—that tell distinct stories of pesticide exposure in rural communities.

Key findings

Scientists have understood for decades that children are particularly vulnerable to the harms of pesticide exposure. Quickly growing bodies take in more of everything; they eat, breathe and drink more, pound for pound, than adults. As physiological systems undergo rapid changes from the womb through adolescence, interference from pesticides and industrial chemicals—even at very low levels—can derail the process in ways that lead to significant health harms.

Ever-stronger science shows that even at very low levels of exposure, pesticides are harming children's health.

For children, the timing of these exposures is often particularly important. At critical moments of development, even very low levels of pesticide exposure can derail biological processes in ways that have harmful, potentially lifelong effects.

In our review of government health trend data and recent academic research, we found the following:

Overall, childhood health problems continue to climb. Childhood cancer incidence continues to rise (see Figure A), as do rates of autism spectrum disorder, attention deficit hyperactivity disorder and other developmental disabilities. Some birth defects are also on the rise.

Fast-rising childhood cancers have strong links to pesticides. Evidence linking pesticide exposure to increased risk of leukemia and brain tumors continues to mount, with new "meta-analysis" studies pointing to higher risks among children in rural agricultural areas. Incidence of these two cancers is rising more quickly than other types of childhood cancer.

More science links pesticides and neurodevelopmental harms. The body of evidence linking prenatal pesticide exposure to childhood brain and nervous system harms was already very strong in 2012, and it has gotten stronger. New studies link increased risk of developmental disorders and delays—including autism spectrum disorder—to prenatal proximity to agricultural fields where pesticides are sprayed.

Rural children's "double dose" of pesticide exposure is cause for concern. Children in agricultural communities are exposed to pesticides above and beyond the widely shared exposures from food residues and applications in schools, parks, homes and gardens. In some cases, these children also experience economic and social stressors that can exacerbate the health harms of agricultural chemicals. Across the country, rural children are on the frontlines of pesticide exposure.

Recommendations

The best way to protect children from pesticide harms is to dramatically reduce the volume of use nationwide. We believe this shift is both achievable and long overdue.

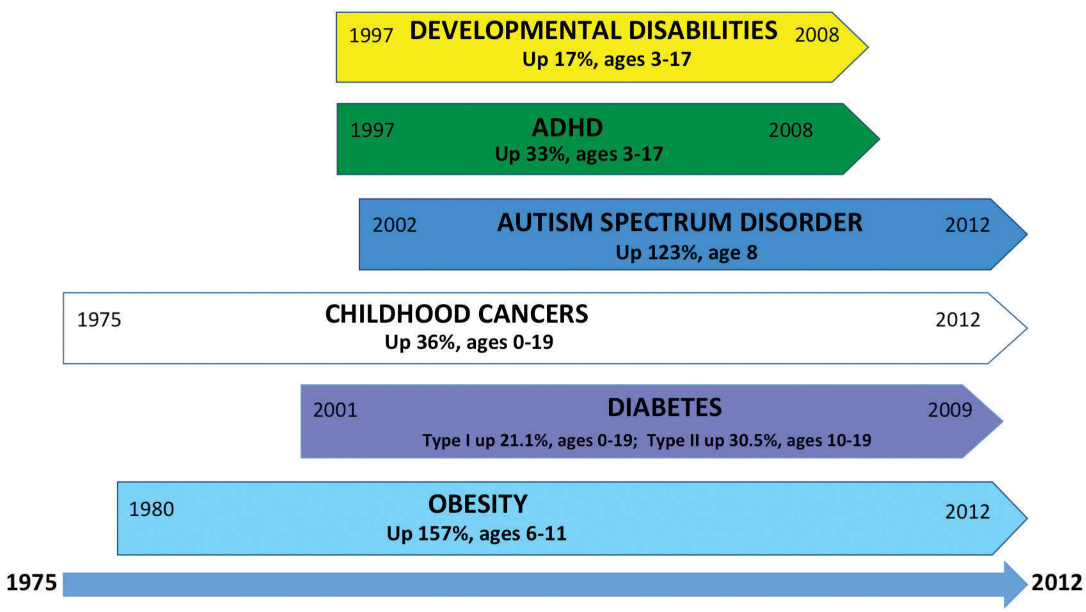
The burden of protecting children from dangerous chemicals cannot rest with individual families; policy change is required. Our recommendations below reflect both the current momentum toward building a healthier national system of food and farming, and the growing urgency of the pesticide problem. Though non-farm pesticide applications can also put children in harm's way, these recommendations focus specifically on protecting children from exposure to agricultural pesticides.

1. **Reduce overall pesticide use.** It's time to set an ambitious national use reduction goal for agricultural pesticides. Once this goal is in place, policymakers at all levels should act quickly to implement strong policies and programs to reach the goal—including, among other measures, publicly accessible use reporting systems to track progress.

2. **Protect children first.** Our national use reduction goals should prioritize action on those pesticides most harmful to children. In addition, protective pesticide-free buffer zones should be established around schools, daycare centers and other sensitive sites in rural agricultural areas across the country.

3. **Invest in healthy, innovative farming.** We need to provide significant and meaningful support, incentives and recognition for farmers stepping

Figure A: Childhood Health Harms on the Rise, 1975–2012



Public health statistics show steady increases in many childhood diseases and disorders over the past 30 years. Those highlighted are just some of the health harms on the rise.

Sources: SEER Cancer Statistics Review 1975-2012, National Cancer Institute; Boyle, Coleen A., et al. "Trends in the Prevalence of Developmental Disabilities in US Children, 1997–2008." *Pediatrics* 127, no. 6 (June 2011): 1034–42. doi:10.1542/peds.2010–2989; Ogden, Cynthia L., et al. "Prevalence of Childhood and Adult Obesity in the United States, 2011–2012." JAMA 311, no. 8 (February 26, 2014): 806. doi:10.1001/jama.2014; Dabelea, Dana, et al. "Prevalence of Type 1 and Type 2 Diabetes Among Children and Adolescents From 2001 to 2009." JAMA 311, no. 17 (May 7, 2014): 1778. doi:10.1001/jama.2014.3201.

off the pesticide treadmill. National and state programs must prioritize investment in healthy, sustainable and resilient agricultural production.

These commonsense measures are both ambitious and achievable. The current, continuous increase in pesticide use ignores accumulating scientific evidence of human health harms. This is unacceptable.

What's standing in the way?

Our current system of industrial agriculture and pest control relies on chemical inputs sold by a handful of corporations. These multinational entities wield tremendous control over how we grow our food, from setting research agendas in public institutions to production and sale of farm inputs including seeds, fertilizers and pest management products.

Not surprisingly, these same corporations also hold significant sway in the policy arena, investing millions of dollars every year to influence voters and policy-makers at the local, state and federal levels. Their aim is to protect the market for pesticides, seeds and other agrichemicals. As public concern about the health impacts of pesticide products has grown in recent years, the pesticide industry has also invested heavily in public relations campaigns to influence the national conversation about food and farming.

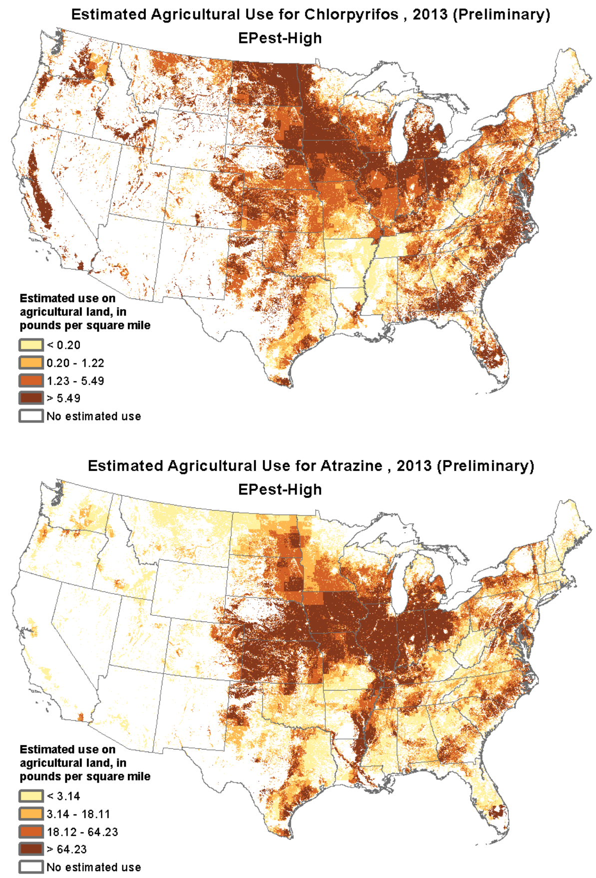
The result is a system of food and farming that serves the interests of these corporations well.

It does not, however, adequately protect public health or serve the common good. Farmers, farmworkers and their families are regularly exposed to chemicals known to harm human health. The health of children in rural communities is compromised by near continuous exposure to pesticides where they live, learn and play.

We are increasingly optimistic that the commonsense changes we propose are within reach. As the science linking pesticides with children's health harms grows ever stronger, awareness of the problem, as well as support for real solutions, continues to grow. In addition, on-the-ground evidence from the U.S. and around the world shows us that implementing our recommendations would boost—rather than undermine—the quality and quantity of food available.

We can and must fix this broken system. It's time to support farming practices that sustain our agricultural economy and produce abundant, healthy food that is accessible to all.

Figure B: Estimated Agricultural Use for Two Pesticides, 2013



These maps from the U.S. Geological Service (USGS) show national use patterns for two widely used pesticides, out of more than 1,200 currently registered for use in the United States. Chlorpyrifos is an insecticide used on a wide range of crops across the country; atrazine is an herbicide heavily used on corn, soy and other row crops.

Sources: Thelin, G.P., and W.W. Stone. "Estimation of Annual Agricultural Pesticide Use for Counties of the Conterminous United States, 1992–2009." U.S. Geological Survey Scientific Investigations Report, 2013–5009. USGS, 2013; "U.S. Geological Survey, National Water-Quality Assessment (NAWQA) Program." *Pesticide National Synthesis Project,* April 14, 2016. http://water.usgs.gov/nawqa/pnsp/usage/maps/about.php#limitations.

Note: USGS estimates use of about 480 pesticides based on a combination of use data compiled by proprietary surveys of farms and county-reported harvested crop acreage. Estimations based on neighboring counties were used for areas that did not report harvested acreage. The reliability of these estimates generally decreases with the scale of use. These maps reflect the higher end of these estimates for use in 2013.

1 Widespread Use & Exposure

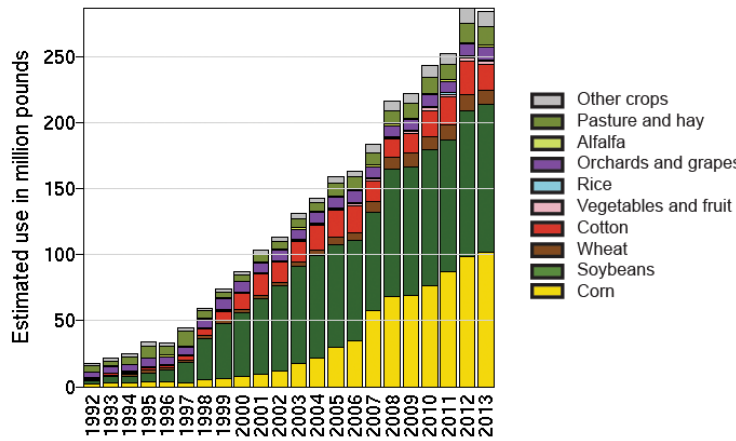
Use of agricultural pesticides in the U.S. has increased steadily since the middle of the last century. As reliance on pesticides continues to rise—including hundreds of fungicides, insecticides and herbicides—children across the country are exposed to a near-constant barrage of these chemicals in the air they breathe, the water they drink and the food they eat.

The numbers tell a sobering story. Since 1945, overall use of pesticides has grown from less than 200 million to more than 1.1 billion pounds of "active ingredient" per year, with 1,235 active ingredients included in 16,810 pesticide formulations.[1,2] This figure underestimates the total volume of product being used, as it does not account for the "inert" ingredients—which, in many cases, are also known to impact human health.

An estimated 684 million pounds of total active ingredient were used in agricultural fields in 2007, the most recent market data available from the U.S. Environmental Protection Agency (EPA).[2] Trends in overall pesticide use since 1960 on five major crops (corn, soybeans, cotton, wheat, and potatoes) are shown in Figure 1-1; Figure 1-2 illustrates the steep increase since the early 1990s in use of Monsanto's flagship herbicide glyphosate.

Globally, industry analysts point to a 289 percent rise in pesticide sales between 2000 and 2010, with worldwide sales expected to climb from $44.2 billion in 2010 to $68.5 billion in 2017. An estimated $12.1 billion in 2016 sales are expected in the U.S. alone.[3]

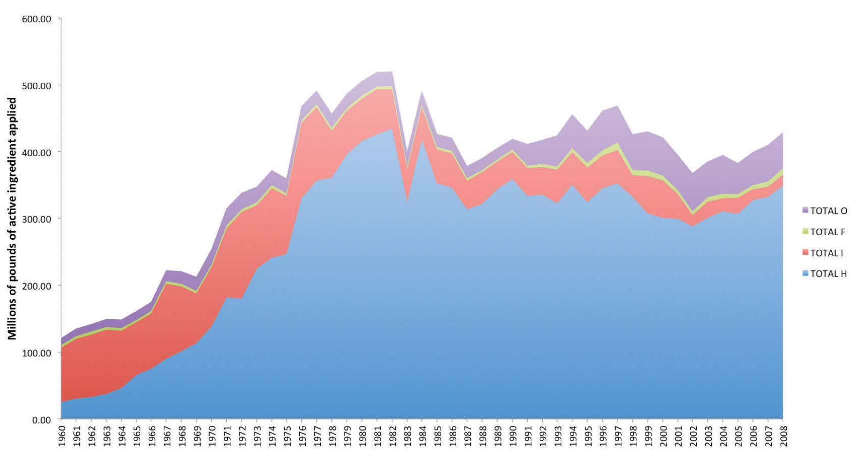
Figure 1-2: Glyphosate Use by Year & Crop



Source: "U.S. Geological Survey, National Water-Quality Assessment (NAWQA) Program." *Pesticide National Synthesis Project,* April 14, 2016. http://water.usgs.gov/nawqa/pnsp/usage/maps/about.php#limitations.

Some of this recent increase is driven by rising use of genetically engineered (GE) seeds, many of which have been modified to be herbicide resistant. According to one analysis of government data, GE crops resulted in a 527 million pound increase in U.S. herbicide use between 1996 and 2011.[4] It should be noted that the same "Big 6" corporations who develop GE seeds—Monsanto, Dow, Dupont, Syngenta, Bayer and BASF—also produce the herbicides that accompany them; the chemicals and seeds are a package deal.

Figure 1-1: Trends in Pesticide Use on Five Major Crops, 1960–2008



Trends in pesticide use on five major crops: corn, soybeans, cotton, wheat and potatoes, as measured by total pesticide quantity applied. H=herbicides; I=insecticides; F=fungicides; O=other pesticides.

Source: Pesticide Use in U.S. Agriculture: 21 Selected Crops, 1960–2008, EIB-124, U.S. Department of Agriculture, Economic Research Service, May 2014. Authors: Fernandez-Cornejo, et al. Note: Examples of other pesticide types are defoliants and desiccants. It should be noted that at least one major desiccant use is non-pesticidal: the use of glyphosate to desiccate wheat prior to harvest.

How pesticides are used

According to EPA, more than 78 million U.S. households—roughly 74 percent—report using home and garden pesticides, including weedkillers, insecticides and chemical pet products to control fleas and ticks.[5] Pesticides are also applied in school buildings, playing fields and playgrounds, hospitals and other buildings.[6,7]

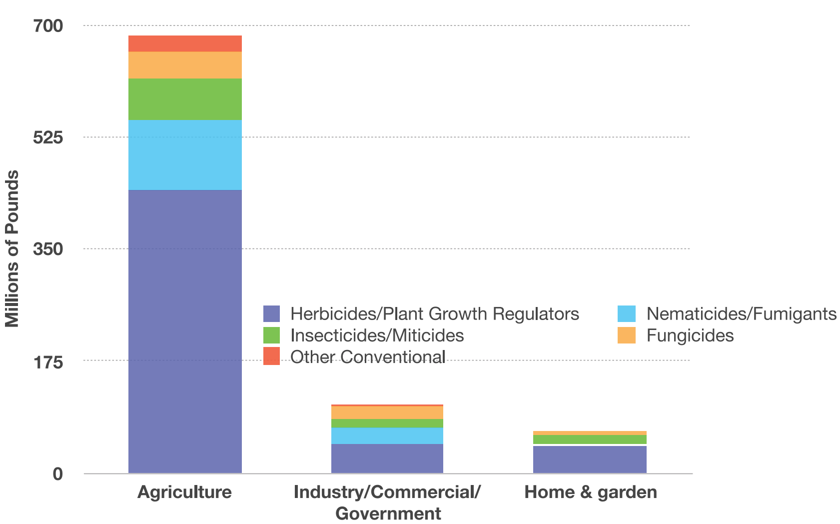
However, the majority of pesticides—more than 80 percent—are used in agricultural fields (see Figure 1-3 and Table 1-1). Herbicides such as Monsanto's glyphosate and Syngenta's atrazine are by far the highest by volume. Next are soil fumigant products, which are injected as a gas or applied via irrigation into soil to kill weeds, insects and soil-born plant pathogens like bacteria and nematodes. These broad-spectrum biocides can be extremely volatile, and often drift from fields where they are applied both during and after application (see Sidebar 1-1).

A variety of insecticides are also in widespread agricultural use, including organophosphates (OPs), pyrethroids and neonicotinoids ("neonics"). These can be applied in a variety of ways, from aerial spraying to drip irrigation. Neonics are "systemic" insecticides, often applied at the root as a drench or used as a seed coating, and taken up through the plant's vascular system; some fungicides are applied this way as well. Systemic pesticides in food cannot be washed off.[8] Neonics are now some of the most widely used insecticides in the world and have become infamous for their impacts on bees and other pollinators vital to agriculture.[9,10]

How children are exposed

From womb to home to classroom, environments we would like to consider "safe" often bring children into contact with pesticides that have been linked to health harms. Children in rural, agricultural communities face a range of additional exposures that put them at even higher risk. We explore issues specific to rural children in Chapter 2; here we outline common pesticide exposures shared by children across the country.

Figure 1-3: Amount of Conventional Pesticide Used in the U.S., 2007



Source: U.S. EPA. "Pesticides Industry Sales and Usage: 2006 and 2007 Market Estimates." Washington, DC 20460: Biological and Economic Analysis Division, Office of Pesticide Programs, Office of Chemical Safety and Pollution Prevention, U.S. EPA, February 2011.

Table 1-1: Pesticide Usage in All Market Sectors, 2007

Pesticide Class	Active Ingredient (millions of lbs)
Herbicides	531
Insecticides	93
Fungicides	70
Other	439
Total	**1,133**

Herbicides are the most commonly used type of pesticide in the U.S., with 531 million pounds of active ingredient applied in 2007.

Source: Pesticide Industry Sales & Usage, *2006 and 2007 Market Estimates*, U.S. EPA, Washington, DC Feb 2011. See www.epa.gov/opp00001/pestsales/07pestsales/market_estimates2007.pdf.

Studies show that when a woman is exposed to pesticides during pregnancy, these chemicals—along with those that have already accumulated in her body—can and do cross the placental barrier.[11,12] The resulting pesticide load that newborns bring with them into the world is well documented. In one study, scientists found pesticides and their breakdown products in umbilical cord blood of 80–100 percent of newborn infants tested.[13]

In the months after birth, infants often test new sights and smells by touching and bringing objects to their mouths. If pesticides are used in the home, infant exposure is nearly impossible to avoid. Toddlers and young children continue to explore the world in very hands-on ways. Pesticides used to coat the wood of playground structures, keep landscaping tidy or parks weed-free can end up on small fingers—which often end up in small mouths.[14]

Schoolchildren can also be exposed. Pesticides used either in or near school buildings can settle on desks, books, counters and walls; chemical residues can then remain in the school environment for days.[15,16,17] Some pyrethroid insecticides, for instance, can persist in the environment for more than a year—or even longer if they are not exposed to sunlight.[18]

According to the American Academy of Pediatrics, residues on food are a primary source of pesticide exposure for children across the country.[19] While pesticides are generally found at very low levels on food, few studies have estimated just how much children are exposed to via diet.[20] Several studies have shown that when children shift from conventional to organic diets, the level

Pesticide residues on food are a primary source of childhood exposure, according to the American Academy of Pediatrics.

1-1 Pesticide Drift

Pesticide drift is the movement of pesticides off the site of application. Drift can occur due to applicator error, but even when used as directed, pesticides can—and often do—drift off site due to factors beyond human control, like the direction and speed of the wind.

There are two primary types of drift:

- Spray drift can occur during application, in the form of liquid droplets being blown by the wind. Spray drift can also land on soil, where it "sticks" to soil particles and is then carried as dust on the wind or via other routes to other locations.
- Volatilization drift is when pesticides rise into the air in a gaseous form ("volatilize") hours or even days after application. To understand this type of drift, think of cutting an onion; the vapor from the onion rises into the air and, although you can't see the vapor, you know it is there because your eyes begin to water. Fumigants are known for their propensity to volatilize; other pesticides volatilize to varying degrees depending on their physical properties.

When pesticides drift indoors, they can stay in the environment longer since they are no longer exposed to rain and sunlight that can break them down or wash them away. Additionally, breakdown products (or metabolites) are sometimes still chemically active after pesticide drift, and they can be more toxic than the original chemical compound.

Sources: PAN issue brief, "Pesticide Drift: In the air & in our communities," available at http://www.panna.org/resources/if-youve-been-drifted and Linde, Clark D. "Physico-Chemical Properties and Environmental Fate of Pesticides." Sacramento, CA: Environmental Hazards Assessment Program, January 1994.

of certain pesticides—and related breakdown products—drops significantly in children's bodies.[21,22,23]

Low-level exposures, long-term harms

High levels of pesticide exposure can cause acute poisoning. The symptoms of such exposures vary widely, but in some cases cause severe, immediate health harms. While childhood pesticide poisonings are a serious concern,[24] this report focuses on longer-term health harms linked with chronic, low-level exposures.

The impacts of chronic exposure to pesticides are often discovered years—sometimes decades—after the products have been on the market. Historically, as scientists have discovered the harms of one class of pesticides, pesticide manufacturers respond by creating and promoting another, "safer" class of pesticides—which are often, in turn, discovered to cause health harms years later.

Organophosphate (OP) pesticides, for example, were introduced as an alternative to long-lasting organochlorine products (e.g., DDT). As the health harms of OP pesticides emerged, pyrethroids and neonics were introduced as alternatives—which are now proving to have unexpected health effects as well. Children are particularly vulnerable to these health harms, in some cases, at extremely low-level exposures. We outline the specifics of these vulnerabilities and exposures in the following chapters.

1-2 Compromising Nature's Finest

Human breast milk is without doubt the best source of nutrition for young infants, offering the perfect combination of fats, carbohydrates and proteins for developing babies. It also offers protection from infection, increases resistance to chronic disease and contributes to the emotional wellbeing of both infant and mother.

Decades of breast milk sampling also leaves little doubt that around the world, nature's perfect food for infants is compromised by pesticides and other toxic chemicals. The chemicals found in a mother's milk include both long-lasting pesticides and industrial pollutants that have accumulated over the mother's lifetime (which the body tends to store in fatty tissues), and shorter-lived chemicals that a woman is exposed to during pregnancy and breastfeeding.

Sources: Norén, K., and D. Meironyté. "Certain Organochlorine and Organobromine Contaminants in Swedish Human Milk in Perspective of Past 20-30 Years." *Chemosphere* 40, no. 9–11 (June 2000): 1111–23; Natural Resources Defense Council. "Healthy Milk, Healthy Baby: Chemical Pollution and Mother's Milk," n.d. www.nrdc.org/breastmilk.

2 Rural Children on the Frontline

It is clear that on any given day, a child may absorb a wide range of potentially harmful pesticides—just as their young bodies are most vulnerable.[25] Children in rural agricultural communities not only face additional exposures from use in nearby fields, but in some cases they are also more susceptible to pesticide harms than other children.

Rural pesticide exposures

A groundbreaking 2014 report from the Department of Public Health in California—one of the few states where detailed pesticide use data are publicly available—clearly illustrates the pesticide exposure problem in rural communities. The study found that hundreds of thousands of children in the state's rural counties—nearly 500,000 by some estimates—attend school within a quarter mile of fields where "pesticides of public health concern" are applied.[26]

Many of the most toxic pesticides are also the most drift-prone, floating into nearby homes and neighboring fields as well as schools. A study in agricultural counties in Washington state found that rural families living near agricultural fields had higher levels of OP pesticide breakdown products in their bodies than those living further away.[27]

The health harms of breathing these pesticides—"inhalation exposure"—is often overlooked or underestimated by government agencies, despite the fact that inhalation exposure is likely to routinely occur in places where agricultural pesticides are used. In one California exposure study, air sampling data indicated that 50 percent of families in the areas studied were exposed to fumigant pesticides at or above levels linked to human health harms.[28] Another recent study confirmed routine exposure to multiple fumigants at the same time, and examined the potential additive and synergistic effects of these real-world exposures (see Sidebar 3-1 on p. 13).[29]

Direct exposure to drifting pesticides is not the only way children are exposed near application sites. Children can also take in pesticide residues that settle on playgrounds, on lawns or in homes—sometimes days or even weeks after the chemicals were used in nearby fields.[30,31,32]

Scientists recently reviewed 35 studies published between 1995–2013, that examined pesticides in household dust in agricultural areas. Overall, the studies found that pesticides drifting from fields are a significant source of dust contamination.[33] In one Iowa study, dust samples in 25 farm and 25 non-farm homes were compared; levels were higher in farm homes for all pesticides measured.[34]

Drifting pesticides can contaminate water, and water contamination can also occur when pesticides wash off fields into surface water and leach into groundwater—both of which can affect drinking water supplies for rural families.[35,36,37]

The health harms of breathing pesticides—"inhalation exposure"—are often underestimated by government agencies.

Agricultural states across the country have faced the challenge of pesticide-laden water supplies for years. In one landmark class action lawsuit, the Syngenta Corporation was forced to reimburse thousands of community water districts in at least a half dozen states for the costs of cleaning up water contaminated with the herbicide, atrazine.[38] Atrazine has been linked to low birth weights, birth defects and some kinds of cancer.[39,40,41]

Children of farmers and farmworkers face another very specific, well documented type of pesticide exposure that is often overlooked or underestimated. "Take home" exposures occur when family members who work with pesticides on the job carry residue home in their vehicles and on their clothing, shoes and skin. Several studies have found that this is likely to be a significant source of exposure for children.[34,42,43,44,45]

Studies have also shown that farmworker children engage in activities that can expose them to high levels of pesticides, such as swimming in irrigation ditches and playing in or near agricultural fields after pesticide applications.[46]

And finally, some children are exposed to pesticides as they work in agricultural fields. For example, in July 2015 in Indiana, a crew of teenagers who were detasseling* corn

* Detasseling is done by hand in cornfields to control pollination and to generate hybrid corn. Fields are often planted with two varieties of corn, so the pollen-producing flowers from one variety are removed and placed on the ground. The pollen-producing flowers on the other variety of plants are left intact, and will then fertilize the other variety, producing a hybrid, which can improve yields.

2-1 Children in the Fields

In 2015, EPA updated protections for farmworkers in the field. One of the critical gains in the new Worker Protection Standard (WPS) is that children under the age of 18 are no longer allowed to handle pesticides on the job, although an exemption for this requirement exists in Texas. Given the risks associated with these exposures,* this is a tremendous victory for children's health.

Yet children employed as farmworkers still risk exposure to pesticides on the job. Despite the new WPS, children under 12 may, with parental consent, work outside of school hours on a farm where employees are exempt from federal minimum wage provisions.

Documenting the exact number of child workers in U.S. agriculture is difficult, and estimates vary widely. A Human Rights Watch report published in 2000 put the number somewhere between 300,000 and 800,000.

* The Agricultural Health Study (AHS) examines some of these risks. The AHS is a prospective cohort study of 57,311 private and commercial pesticide applicators licensed to apply restricted-use pesticides in Iowa and North Carolina. See Agricultural Health Study, http://aghealth.nih.gov.

Sources: Environmental Protection Agency. *Agricultural Worker Protection Standard Revisions.* FRL–9931–81 Pesticides. Vol. 40 CFR 170, 2016; U.S. Department of Labor, Employment Standards Administration, Wage and Hour Division. *Child Labor Requirements in Agricultural Occupations under the Fair Labor Standards Act.* Vol. WH-1295, 200; Arcury, Thomas A., et al. "Safety and Injury Characteristics of Youth Farmworkers in North Carolina: A Pilot Study." *Journal of Agromedicine* 19, no. 4 (October 2, 2014): 354–63. doi:10.1080/1059924X.2014.945712.

went to the hospital for decontamination after getting hit by fungicide from an aerial application intended for a neighboring field.[47] Specific rules vary from state to state, but federal law allows children under 12 to do field work outside of school hours on farms where their parents are employed (see Sidebar 2-1).[48,49]

Impacts on growing minds & bodies

Children are more vulnerable than adults to pesticide harms for a number of reasons. In general, children take in more from their environment. In their first six months of life, for example, children drink roughly 15 times more water than the average adult per pound of body weight.[50] Up to around age 12, a child's breathing rate is roughly twice that of an adult—which means a child will inhale roughly double the pesticides in the air from drift or household use.[51]

At the same time, a child's biological defense mechanisms are not fully developed. For example, the blood-brain barrier, which provides the adult nervous system some protection from toxic substances, is not yet in place during the first six months of life.[52] Adult levels of gastric acid—which can also provide some protection from toxic chemicals—are not reached until a child is about two years old.[53]

Children's developing bodies are particularly vulnerable to pesticide harms.

In addition, the liver and kidneys—the body's primary detoxifying organs—are not yet fully developed in children, leaving them less equipped to process and excrete harmful chemicals. Levels of enzymes that help the body process pesticides are also not yet at full strength. The abundance or effectiveness of these protective enzymes can vary tremendously. Some newborns are as much as 164 times more vulnerable than the least sensitive adults to harms of the OP insecticide chlorpyrifos (see Sidebar 4-1 on p. 17).[54]

Exposure in the womb can be particularly harmful. Fetal development is almost entirely controlled by hormones acting at very low levels to trigger and control growth of the various bodily systems. Chemicals known as endocrine disruptors—including many pesticides—can mimic hormones or otherwise affect hormonal function, interfering with fetal developmental processes. According to the Endocrine Society, exposure to endocrine disruptors in the womb "may lay the foundations for disease in later life," including neurodevelopmental effects, cancer and reproductive harms.[55]

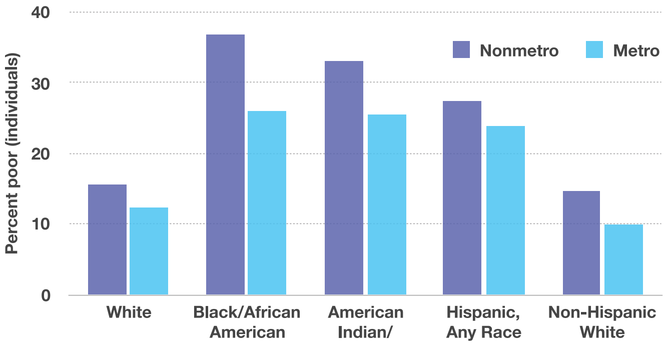
Particular challenges for rural children

Rural children's exposures to health-harming pesticides often come on top social and economic challenges commonly faced in rural communities, including higher levels of poverty,* food insecurity and lack of access to adequate health care.

These issues may be contributing to the significant health disparities between urban and rural communities. Studies show that adults in rural areas experience higher rates of cancer, heart disease, diabetes and other chronic diseases than those in cities.[56,57] A recent study found that the death rate among non-Hispanic whites is rising in rural and small-

* Poverty lines are adjusted annually to correct for inflation. Any individual with income less than that deemed sufficient to purchase basic needs of food, shelter, clothing, and other essential goods and services is classified as poor. As of 2016, the poverty line for a family of four was $24,300. See https://aspe.hhs.gov/poverty-guidelines.

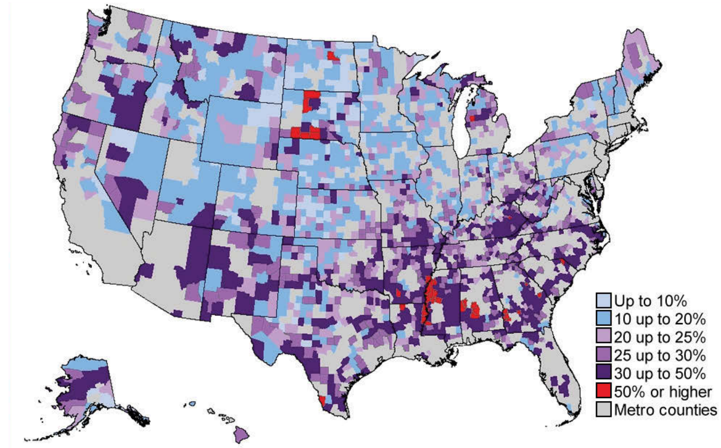
Figure 2-1: Poverty Rates by Race/Ethnicity & Metro/Nonmetro Residence, 2014



Poverty rates by race and ethnicity with metropolitan (metro, or what we think of as "urban") and nonmetropolitan (nonmetro, or "rural") populations. USDA relies on metropolitan (metro) and nonmetropolitan (nonmetro) areas as defined by Office of Management and Budget. It is not clear why Asian Americans are not currently tracked in the USDA's poverty dataset. See http://www.ers.usda.gov/briefing/rurality.

Source: U.S. Department of Agriculture. "Rural Poverty & Well-Being: Poverty Demographics." Economic Research Service using data from the U.S. Census Bureau, American Community Survey, 2014. Accessed April 13, 2016. http://www.ers.usda.gov/topics/rural-economy-population/rural-poverty-well-being/poverty-demographics.aspx.

Figure 2-2: Rural Child Poverty Rates by County, 2010–14



Source: U.S. Department of Agriculture. "Rural Poverty & Well-Being: Poverty Demographics." Economic Research Service using data from the U.S. Census Bureau, American Community Survey, 2014. Accessed April 13, 2016. http://www.ers.usda.gov/topics/rural-economy-population/rural-poverty-well-being/poverty-demographics.aspx. USDA relies on metropolitan (metro) and nonmetropolitan (nonmetro) areas as defined by Office of Management and Budget. See http://www.ers.usda.gov/briefing/rurality/

town areas; among women, the increase is more than 40 percent.[58,59]

According to national census data, children in rural areas are more likely to live in poor families. USDA data from 2014 shows 25 percent of children in rural (nonmetropolitan) areas were poor, compared to about 21 percent of urban (metropolitan) area children.[*60] Additionally, 2014 annual census data tells us that there are significant differences in childhood poverty rates along racial/ethnic lines in rural areas, as well as differences from region to region (see Figure 2-1, Figure 2-2 and Sidebar 2-2).

According to public health specialists, poverty is a socioeconomic, "nonchemical" stressor that can undermine physiological resilience.[61] In addition, poverty is acknowledged as a "social determinant of health" which can affect health outcomes.[62] Thus, poverty—and stressful situations that come with it—may increase susceptibility to disease and influence the health and well-being of children.[61] According to the American Academy of Pediatrics, poverty contributes to child health disparities and "has a profound effect on specific circumstances, such as birth weight, infant mortality, language development, chronic illness, environmental exposure, nutrition and injury."[63] Overall, about 37 percent of all U.S. children live in poverty at some point in their lives.[64]

Low income levels can also contribute to lack of consistent access to food, or "food insecurity." In California, one study

* Throughout this report, we use the terminology used by the institution or organization reporting these data. For instance, USDA relies on metropolitan (metro) and nonmetropolitan (nonmetro) areas as defined by Office of Management and Budget. See http://www.ers.usda.gov/briefing/rurality/

2-2 Data Gap: Rural people of color & health

Much research has documented health disparities among racial and ethnic groups, but few studies examine rural populations of color in particular. For example, annual national tracking statistics present health indicators by race/ethnicity or rural/urban residence, but not by the combination of the two.

In this way rural "racial minorities become an invisible population assumed to mirror urban population groups," according to Glover et al. Conversely, rural health research centers do present health indicators by race/ethnicity and rural residence, but do not provide the same indicators for the urban counterparts of those groups for comparison purposes.

In general, reviews of federally funded clinical trials in different areas of health—like lung disease or cancer—indicate that populations of color are underrepresented and understudied. Though these communities share a disproportionate burden of exposure to agricultural chemicals, they are not receiving the benefit that might come from public health studies—including shifts in public policy or other interventions to reduce disease risks.

Sources: (CRHP) Center for Rural Health Practice, "Bridging the Health Divide: The Rural Public Health Research Agenda. April 2004.; Glover, S., C.G. et al. "Disparities in Access to Care Among Rural Working-Age Adults." *The Journal of Rural Health* 2004 20(3): 193–205; Probst, J.C., et al. Minorities in Rural America: An Overview of Population Characteristics. University of South Carolina Rural Health Research Center 2002; LaVeist, T. A., et al. "Estimating the Economic Burden of Racial Health Inequalities in the United States." *International Journal of Health Services* 41, no. 2 (April 1, 2011): 231–38. doi:10.2190/HS.41.2.c.

Table 2-1: National & Selected State Rural* & Urban Poverty, Education & Employment

Population Characteristic	National		California†		Hawai'i		Iowa		Minnesota	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
% Population (2014)	14.5	85.5	2.1	97.9	18.6	81.4	41.4	58.6	22.7	77.3
Poverty (2013)	18.5	15.4	18.2	16.8	17.4	9.8	12.4	12.8	12.3	10.9
Unemployment (2014)	6.4	6.1	8.5	7.5	5.4	4.1	4.6	4.3	4.7	3.9
Completion of High School Only (2013)‡	36.3	26.7	26.4	20.6	31.5	27.3	38.1	28.8	35.0	24.3
Completion of College (2009–2013)	17.9	30.8	21.8	30.9	25.5	31.2	18.3	31.5	20.0	36.5

Source: U.S. Department of Agriculture. Economic Research Service. http://www.ers.usda.gov/data-products/state-fact-sheets/.aspx. Accessed November 21, 2015.

* When analyzing conditions in the "rural" U.S., USDA's Economic Research Service studies nonmetropolitan (or nonmetro) conditions. Nonmetro counties include some combination of open countryside, rural towns (places with fewer than 2,500 people) and urban areas with populations ranging from 2,500 to 49,999 that are not part of larger labor market areas (metropolitan areas). See http://www.ers.usda.gov/topics/rural-economy-population/rural-classifications.aspx.

† The state of California defines rural counties as those with more than 80% of their land mass defined as a rural or frontier. According to this definition, there are 44 rural counties in California, which represent about 80 percent of the state's 156,000 square miles, and 14 percent of the population. (http://www.dhcs.ca.gov/services/rural/Documents/CSRHAPresentationNov132012.pdf). U.S. Census and USDA data rely on population-based definitions of rural, which is reflected in the table above. In a state as densely populated as California, a population-based designation for "rural" areas results in many counties falling within a "metropolitan" designation.

‡ All statistics for education are for persons 25 years of age and old.

found that counties with mostly rural and/or agricultural-based economies had the highest rates of food insecurity in the state.[65] Availability of healthy food can also be a challenge in rural communities. The Centers for Disease Control (CDC) estimates that people who live in rural communities are four times less likely to have access to a "healthy food retailer"* than those in urban areas.[66]

Research has shown that hunger and malnutrition at any point in life can have both short and long-term effects on health.[67] Health issues may thus be compounded when children who are living in poverty, and/or are food insecure, are also exposed to pesticides and other pollutants. These factors can contribute to cumulative impacts on the health of rural communities.[68]

Education levels tend to be lower in rural communities as well (see Table 2-1 for data on the states profiled in Chapter 5). Public health officials consider both income and education levels to be primary social determinants of health; research indicates that those with less formal education tend to also be less healthy.[69,70]

Adding in another factor, rural families can also face limited access to health care and a shortage of healthcare providers.[71,72] In 2010, 34 percent of the rural† counties in the U.S. (704 of 2,052) were designated "Health Profession Shortage Areas" (HPSAs), with populations of color in rural communities again bearing the brunt of the shortage. Multiple studies have shown that the burden of HPSAs falls disproportionately to counties where populations of color comprise the majority.[72,73]

Limited access to health insurance further exacerbates the problem. People working in the primary forms of rural employment—agriculture, mining, manufacturing, and forestry—are less likely to have employer-provided insurance or to be unionized. They are also less likely to be eligible for health insurance and to take it if eligible.[74,75] According to CDC, rural people of color are among those least likely to be insured nationwide.[76] Since the advent of the Affordable Care Act, the greatest increases of insured persons have occurred within rural populations and among populations of color.[77] However, significant barriers remain for rural populations to gain access to insurance.[78,79]

Overall, rural families and children face significant challenges when it comes to health. Since rural communities are often surrounded by cropland, the health challenges faced in these communities are compounded by the harms of exposure to hazardous pesticides. In Chapter 5, we highlight a handful of agricultural states, each telling a different story of pesticide exposure for children on the frontlines in rural communities.

Exposure to pesticides in the womb can lead to lifelong health harms, including effects on the brain, cancer and reproductive problems.

* Healthier food retailers are defined by CDC as "supermarkets, large grocery stores, supercenters and warehouse clubs, and fruit and vegetable specialty stores."

† The Department of Health and Human Services report cited here, "The Health and Well-Being of Children in Rural Areas: A Portrait of the Nation 2007," had two classifications for rural areas, large rural (populations of 10,0000 to 49,999 persons) and small rural areas (2,500 to 9,999 persons).

3 Increasing Cancer Risk

In 2010, the President's Cancer Panel report concluded that the contribution of environmental contaminants to cancer has been "grossly underestimated," and called for urgent action to reduce current widespread exposure to carcinogens. The Panel's chair, Dr. LaSalle Leffall, urged preventive measures to protect public health:

> *"The increasing number of known or suspected environmental carcinogens compels us to action, even though we may currently lack irrefutable proof of harm."*[80]

The need for action seems particularly urgent when it comes to childhood cancers. Over the past 40 years, the incidence of childhood cancers has been steadily rising, and the upward trend has been persistent. Between 1975 and 2012, the number of children diagnosed with all forms of invasive cancer increased more than 35 percent. Between 1992 and 2012, more than 234,000 U.S. children were diagnosed.[81]

In 2015, an estimated 10,380 new cases of cancer were diagnosed among children under 14—and more than 1,000 children were expected to die from the disease.[82] While survival rates have risen as treatments improve, cancer remains the leading cause of death from disease among U.S. children.

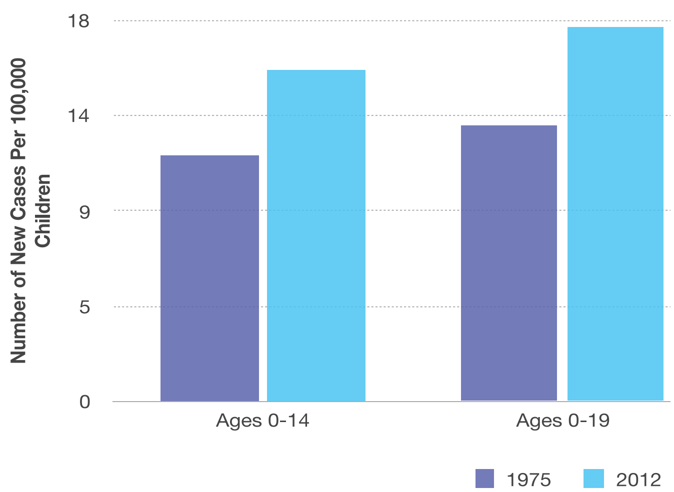
Acute lymphocytic leukemia (ALL) and brain and other central nervous system (CNS) tumors are now the most common types of childhood cancer (see Table 3-1). Leukemia and brain cancer rates in children have risen between 40 and 50 percent since 1975 (see Figure 3-1).[83] According to CDC, leukemia and brain tumors are also the cancer types found most often among children between one and four years of age.[81] For all types of childhood cancers, both white children and non-white Hispanic children have higher incidences, while African-American children have lower rates of survival.[83,84] The reasons for these differences in incidence and survival are not well understood; as noted in Chapter 2, studies suggest that factors such as socioeconomic status and health insurance access may influence disparities in disease treatment and survival.

Data comparing cancer incidence among rural and urban children are not available. However, many studies have linked both residence in agricultural areas and herbicide exposure to increased cancer risk. According to state cancer profiles maintained by CDC and the National Cancer Institute, Iowa and Nebraska—agricultural states with heavy herbicide use—are among 10 states with childhood cancer rates above the national average (for Iowa data, see Figure 3-2).*

Scientists agree that cancers can have multiple and often interacting causes. One recent review underscores the complexity of cancer causation, pointing to the potential for cancer-causing effects of low-level exposures to a range of

* The other states with above-average rates of cancer for children under 20 years of age are Connecticut, Delaware, Maine, Massachusetts, Michigan, New Hampshire, New Jersey, New York and Pennsylvania.

Figure 3-1: Cancer Incidence Rates, U.S. Children, 1975 & 2012



Cancer incidence rates from 1975 and 2012 are shown comparing two age groups, ages 0–14 and ages 0–19. Incidence is the number of new cases occurring per 100,000 children.

Source: SEER Cancer Statistics Review 1975–2012, National Cancer Institute

Living in rural, agricultural areas increases the risk of childhood leukemia.

Figure 3-2: Historical Trends in Childhood Cancer Incidence in Iowa, 1975–2012

During 1975-2012, the annual percentage change was slightly rising. Incidence data provided by the SEER Program, see http://seer.cancer.gov.

Source: This graph and the notes from the caption were obtained from http://statecancerprofiles.cancer.gov/quick-profiles/index.php?statename=iowa.

Table 3-1:
Most Common Childhood Cancers

- Leukemia
- Brain and other nervous system tumors
- Neuroblastoma
- Wilms' tumor
- Lymphoma

The types of cancers that occur most often in children are different from those seen in adults.

Source: American Cancer Society

chemicals—some known to be carcinogens and some not—acting via different pathways and synergistically to increase cancer risk.[85] Other studies indicate that genetic factors may make some individuals more susceptible than others to the effects of environmental carcinogens.[86,87]

As we highlighted in *A Generation in Jeopardy,* many studies have linked pesticide exposure to childhood leukemia, brain tumors and neuroblastoma. Some evidence suggests pesticide exposure may also be associated with other types of childhood cancer as well, including non-Hodgkin lymphoma, Wilms' tumor and Ewing's sarcoma.*

Recent scientific evidence

In reviewing the most recent evidence on pesticides and cancer, we found that several new studies, including "meta-analysis"† studies (summarized below) confirm earlier findings. These analyses provide further evidence that:

- Pesticide exposure during pregnancy increases the risk of cancer outcomes in a child;
- Parental exposure before conception for both parents increases risk of leukemia and brain tumors in children;
- A father's occupational pesticide exposure before conception is strongly linked to increased cancer risk in his children, suggesting damage to developing sperm; and
- Living in rural agricultural areas increases risk of childhood leukemia.

* Both Wilms' tumor and Ewing's sarcoma are rare cancers.

† Meta-analysis studies examine statistical associations between an exposure and disease by combining the results from multiple studies that examine the same exposures and health outcomes in different populations.

Highlights of this research—with a particular focus on children in rural areas—are summarized below. More detailed descriptions and additional studies, including those indicating increased risk from exposure to household pesticide use, are included in Appendix A.

- Researchers in a 2015 study found that living near production of specific crops increased the likelihood of both acute lymphoid leukemias (ALL) and acute myeloid leukemia (AML). They analyzed county-level agricultural census data and cancer incidence data for children ages 0–4 from cancer registries in six Midwest states: Iowa, Illinois, Indiana, Michigan, Ohio and Missouri. They found increases in both types of leukemia for children living near production of dry beans and sugarbeets. Children living near oat production had increased risk of AML. As of the time of the paper's analysis, the top pesticides used on oats were the herbicides 2,4-D, glyphosate, and MCPA. Less common herbicides were used on sugarbeets, including desmedipham and clopyralid.[88]
- In a 2008 study of 25 states, researchers found that counties with high cropland density (60 percent cropland or more) showed a significantly increased risk for all the types of childhood cancer examined, including liver tumors, kidney tumors and different types of nervous system tumors. They also found specific risks associated with acute myeloid leukemia and soybean cropland density, and increased risk for neuroblastomas linked to both corn and soybean cropland density. Cropland density was assessed as percentage of acreage devoted to crop production in each county.[89]
- A 2014 meta-analysis paper reviewed global data from the Childhood Leukemia International Consortium, analyzing 12 studies that examined

links between parental exposures to agricultural pesticides and leukemia incidence (both ALL and AML). Across the studies, which included more than 10,000 leukemia cases and more than 25,000 controls, the strongest links were between a mother's pesticide exposure during pregnancy and incidence of AML. The father's occupational exposure around the time of conception increased the risk of ALL.[90]

- Follow-up research from the Agricultural Health Study analyzed results from over 17,000 children of Iowa pesticide applicators and found an increased risk of childhood cancer. Risk of all lymphomas—including Hodgkin lymphoma—was increased, and among children whose fathers had used the pesticides aldrin, dichlorvos, or a carbamate prenatally, the odds of cancer were increased.[91]
- A 2011 meta-analysis of 40 studies found elevated risk of several childhood cancers linked to pesticide exposure (both occupational and household). The research showed increased risk of both lymphoma and leukemia in children whose mothers were exposed to pesticides during pregnancy, and increased childhood brain cancer risk when a father was exposed either during pregnancy or after birth. Leukemia risk was elevated if either the mother or father was exposed to pesticides during pregnancy. When both parents were exposed prenatally, the risk of leukemia was even higher.[92]
- Another meta-analysis released in 2014 found that pesticide exposures both before conception and during pregnancy—of either parent—increased brain tumor risk. This effect was particularly strong among children whose mothers had farm-related pesticide exposure during pregnancy and those whose fathers were exposed before conception.[93] These findings support those of a similar meta-analysis of parental occupational pesticide exposure and brain tumor risk conducted in 2013.[94]

While our review focused on studies investigating childhood cancer outcomes, it is worth noting that a number of studies have found links between prenatal or childhood pesticide exposures and incidence of cancers later in life. For example, according to the President's Cancer Panel, girls exposed to DDT before they reach puberty are five times more likely to develop breast cancer in middle age,[95] and a 2015 study confirmed a link between in utero DDT exposure and increased breast cancer risk.[96] While DDT is banned for use in the U.S., it is still in use in parts of the world.

3-1 Cumulative Risk: A public health concern

Scientists at the Sustainable Technology and Policy Program at University of California, Los Angeles, (UCLA) recently examined the cumulative risks of exposure to multiple fumigant pesticides.

Fumigant pesticides are toxic, volatile and used to manage pests in soil. Used in high volumes, fumigants are often injected into the ground as gasses and, as such, are particularly prone to drift—even across long distances. Fumigants are responsible for a large proportion of pesticide-related exposure illness in California. In addition to exposure illness, several fumigants are known to be carcinogenic. In the state of California, many of these fumigants are used near schools attended by predominantly Hispanic children, as discussed in a recent report on agricultural pesticide use in the state.

Cumulative risk is the risk associated with exposure to multiple chemicals. The UCLA report focused particularly on synergistic effects, the interaction of two or more chemicals resulting in greater toxicity than the sum of each alone. Looking at the impact of exposure to three fumigants, alone and in combination, researchers found that:

- Some California residents and farmworkers are regularly exposed to two or more fumigants at the same time;
- These pesticides interact in ways that can increase risks to human health, including cancer; and
- California's pesticide regulators are not assessing the risk of cumulative exposure, which they are required to do.

The fumigants discussed in the report are currently used on high-value crops such as strawberries, tomatoes, stone fruits and tree nuts. In 2013, in California, 12.1 million pounds of the three fumigants studied were used.

Sources: Zaunbrecher, Virginia, et al. "Exposure and Interaction: The Potential Health Impacts of Using Multiple Pesticides." University of California, Los Angeles: Sustainable Technology & Policy Program, 2016 and California Department of Public Health, "Agricultural Pesticide Use near Public Schools in California." California Environmental Health Tracking Program, April 2014.

Pesticide exposure during pregnancy increases risk of childhood leukemia, lymphoma and brain tumors.

3-2 When Is There Enough Evidence to Act?

Scientific studies often identify a "link" or "association" between exposure to a particular pesticide and a specific human health harm. Individual studies do not, however, demonstrate causation.

Identifying disease causation is not a simple matter. Identifying a single risk factor for a disease may not be appropriate, as some diseases are influenced by a number of factors, including genetics and environmental exposures. In addition, scientific evidence on the harms of a pesticide or other environmental contaminant may come from disparate fields, such as endocrine disruption and chemistry. An adverse effect, or harm, may be demonstrated in studies from one field but not the other. How do we assess and integrate scientific evidence to make a decision?

A "weight of the evidence" approach can be used to determine if many studies, when reviewed as a whole, provide stronger conclusions than one study alone. However, there is not widespread consensus about how to define this concept.

One approach is the systematic review, which is a pre-defined and multi-step process that allows for identifying, selecting, assessing, and putting together evidence from scientific studies. The advantage of a systematic review is that there is a transparent process that documents the basis for scientific judgments.

Sources: Basketter, David, et al. "Application of a Weight of Evidence Approach to Assessing Discordant Sensitisation Datasets: Implications for REACH." *Regulatory Toxicology and Pharmacology*: RTP 55, no. 1 (October 2009): 90–96. doi:10.1016/j.yrtph.2009.06.005; National Toxicology Program. "OHAT Systematic Review." Accessed April 22, 2016. https://ntp.niehs. nih.gov/pubhealth/hat/noms/index-2.html; Vandenberg, Laura N., et al. "Hormones and Endocrine-Disrupting Chemicals: Low-Dose Effects and Nonmonotonic Dose Responses." *Endocrine Reviews* 33, no. 3 (June 2012): 378–455. doi:10.1210/ er.2011-1050.;Woodruff, Tracey J., and Patrice Sutton. "The Navigation Guide Systematic Review Methodology: A Rigorous and Transparent Method for Translating Environmental Health Science into Better Health Outcomes." *Environmental Health Perspectives*, June 25, 2014. doi:10.1289/ehp.1307175.

As we noted in our 2012 report, the association between pesticide exposures and childhood cancer outcomes may be underestimated, as data are limited and studies focus on certain cancers more than others.[97,98,99]

Overall, the evidence linking pesticide exposure with increased risk of several childhood cancers is increasingly strong, particularly for children in rural communities—who face exposures from agricultural use, in-home applications and chemical residues on produce (see Sidebar 3-2). Parents may be able to reduce risk by doing what they can to avoid pesticide exposure before and during pregnancy, but the overall problem of rising childhood cancer must be addressed at a broader level. Policy change is needed.

Science linking pesticides with increased cancer risk is particularly strong for rural children.

4 Altering Brain Development

Development of the human brain begins in the womb and continues into early adulthood. Many complex processes take place over the course of these years to establish the structure and function of this intricate organ, involving tens of billions of nerve cells making trillions of connections.

Scientists are increasingly clear about just how vulnerable this process is, and how easily disrupted. Studies show that exposure to neurotoxic chemicals during critical moments of development can fundamentally alter brain development and architecture. Chemicals that disrupt the hormone system—and particularly those affecting thyroid hormone, which plays a critical role in brain development—can also cause lasting damage.

Some 15 percent of all U.S. children—one of every six—have one or more developmental disabilities, according to the most recent data collected by CDC researchers.* Over the time period studied (1997–2008) this represents a jump of 17 percent—and for some disorders, the numbers are rising even more rapidly.[100,101]

The number of diagnosed cases of attention deficit/hyperactivity disorder (ADHD), for example, has risen sharply over the past two decades. ADHD diagnoses increased an average of three percent every year from 1997 to 2006, and an average 5.5 percent per year from 2003 to 2009 (see Figure 4-1), for an overall rise of nearly 50 percent over 15 years.[102] CDC estimates that today, more than 11 percent of U.S. children have been diagnosed with ADHD.[103]

The jump in the rate of autism spectrum disorders (ASD) has been even more dramatic. According to CDC's latest estimates—based on 2012 surveys of eight-year-olds in 14 states—one in every 68 children in the U.S. is on the autism spectrum. This represents a 123 percent increase in just ten years. Boys are much more likely to be on the spectrum, with one in 42 affected, compared to one in every 189 girls.[104,105]

Data from the National Health Interview Surveys show that ASD prevalence among boys age three to 17 years increased 261 percent between 1997–2008. Prevalence among girls, while much lower than boys overall, rose even more quickly; over the same period, there was an increase of more than 385 percent (see Figure 4-2).[100,106] While shifts in diagnosis may account for some portion of the increase in ASD, experts agree this does not fully explain the dramatic and disturbing upward trend.[107]

Scientists now point to a combination of genetic and environmental factors to explain the rapid rise of developmental, learning and behavioral disorders.[101,108,109] Some children, for example, may have a genetic susceptibility to ADHD or ASD, but it may only develop if they are exposed to a triggering chemical during a certain period of brain development. Other children may be genetically programmed to produce less of a common detoxifying enzyme, leaving their brain and nervous system more susceptible to harm from neurotoxic pesticides.[110,111]

* Developmental disabilities include autism spectrum disorders, attention deficit disorders, hearing loss, intellectual impairment and vision loss.

Even at very low levels, early life exposures to certain pesticides can cause permanent injury to a child's developing brain.

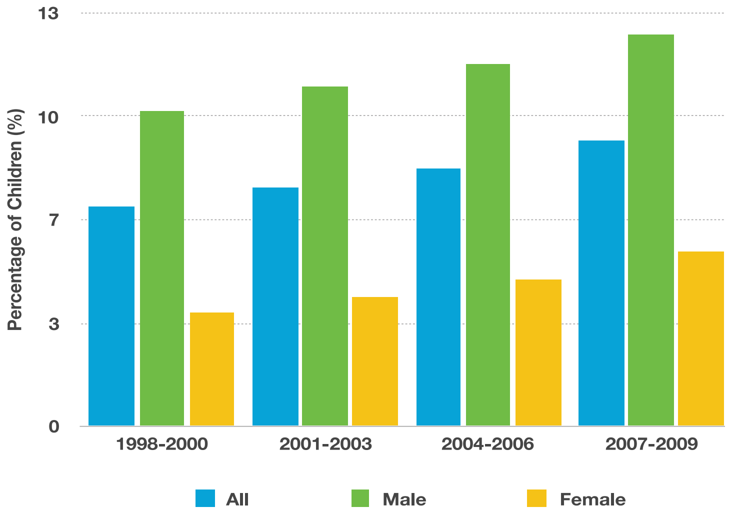
According to recent research, the chemical/gene interaction can cross generational boundaries as well. Scientists in the field of epigenetics have found that genetic mutations in parents, occurring in response to chemical exposures, can increase the risk of neurodevelopmental disorders for their children.[112,113]

As we highlighted in our 2012 report, strong science links pesticide exposures during fetal development, infancy and childhood to declines in the cognitive abilities of children. Evidence continues to mount, and the latest studies point to significantly increased risk of exposure for children in rural communities.

Recent scientific evidence

Recent studies exploring the role of pesticides in undermining children's neurodevelopment strongly reinforce the findings we highlighted in 2012. Prenatal and early childhood exposure to a range of common pesticides increases the risk of developmental disorders and delays. Even at very low levels, these early life exposures can cause permanent injuries to the developing human brain—which is particularly vulnerable to toxic chemicals.[114] Children whose brain infrastructure

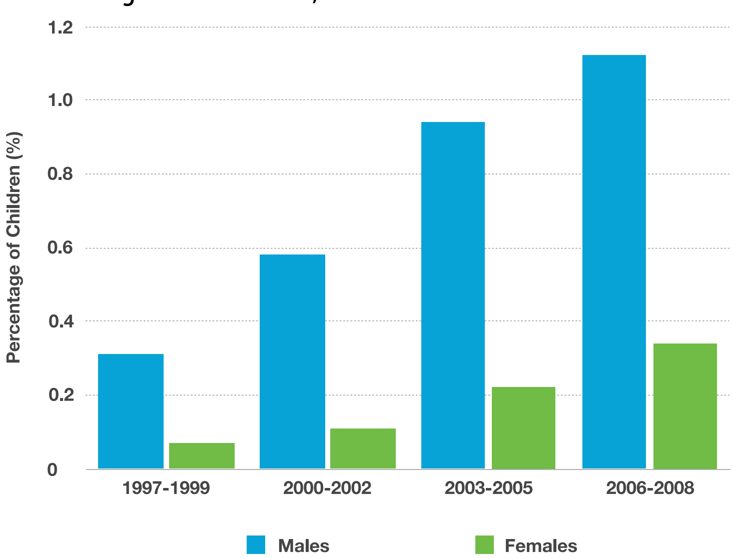
Figure 4-1: Children Aged 5–17 Years Ever Diagnosed with ADHD in the U.S., 1998–2009



ADHD prevalence is shown between 1998 and 2009 for U.S. children ages 5–17. Prevalence is the proportion of children having ADHD.

Source: Data Brief 70. Attention deficit hyperactivity disorder among children aged 5–17 years in the United States, 1998–2009. CDC/NCHS, Health Data Interactive and National Health Interview Survey.

Figure 4-2: Prevalence of Autism Spectrum Disorder Among Children Aged 3 to 17 Years, 1997–2008



Prevalence of children on the autism spectrum in U.S. children ages 3 to 17 years is shown above from 1997 to 2008. Prevalence is the proportion of children who are on the autism spectrum.

Source: C. Boyle et al., "Trends in the Prevalence of Developmental Disabilities in U.S. Children, 1997–2008"

or nervous system fail to undergo typical development may be adversely affected the rest of their lives.

One paper reviewed the findings of more than two dozen studies published between 2002 and 2012, and found that "all but one of the 27 studies evaluated showed some negative effects of pesticides on neurobehavioral development."[115] In another study, children in Oregon and North Carolina living in agricultural communities were found to perform more poorly on neurobehavioral tests than children in non-agricultural communities.[116]

A few of the more recent studies are summarized below—including those examining impacts of proximity to agricultural fields, prenatal exposure and pesticides measured in children's bodies. More detailed descriptions and additional studies, including relevant animal research, are found in Appendix A.

- In 2014, researchers at UC Davis released results from a 10-year study investigating pregnancy exposures and health outcomes for 1,600 children, most living in California's Central Valley. Women who lived within about a mile of agricultural fields where OP insecticides were applied during pregnancy had a 60 percent increased risk of having children with an autism spectrum disorder. Close proximity to fields where pyrethroids were applied pre-conception or during the third trimester also increased risk for both ASD and developmental disabilities.[117]
- A 2014 New York study of 136 children found that exposure to OPs during pregnancy was associated with increased impairments in social responsiveness, a common component of multiple neuropsychiatric conditions, including ASD, ADHD, depression and mood disorders.[118]
- Researchers in New York investigated prenatal exposure to the OP pesticide chlorpyrifos in a 2015 study and found an association with tremors in 11-year-old children in the upper quartile of exposure, which may be a sign of the insecticide's long-term effects on nervous system function.[119]
- A 2015 study linked higher levels of pyrethroid metabolites in children's bodies (as measured by the CDC) with increased rates of ADHD. Hyperactivity-impulsive symptoms increased by 50 percent for every ten-fold increase in metabolite levels.[120] Earlier research has linked OP metabolite levels in children's bodies with higher rates of ADHD.[121]

The societal implications of reduced cognitive abilities across an entire generation are nothing short of staggering. Historically, similar concerns about lead poisoning spurred dramatic policy shifts to protect public health.[122] As pediatric researcher Dr. Bruce Lanphear notes in his educational video *Little Things Matter,* a shift of a few less IQ points on a societal level represents tremendous economic, cultural and social costs.[123]

Health professionals and educators across the country have indicated concern that our current policies don't adequately protect our children as their nervous systems develop.[124] While children in rural communities are particularly at risk from exposure to agricultural pesticides, low-level exposures on food may be changing the brain architecture of children in communities across the country. As noted by the American Academy of Pediatrics, for many children "diet may be the most influential source" of pesticide exposure.[125]

The health impacts from pesticides used in our current system of food and farming has profound consequences for individuals, families, society—and future generations.

4-1 Variable Vulnerability

Individual's biological responses to pesticides can vary widely—a factor that is often overlooked or underestimated by regulators.

For example, one key human enzyme, known as paraoxonase 1 (or "PON1"), helps the body process and clear pesticides—particularly OPs—from our bodies. The level and effectiveness of the PON1 enzyme vary widely between individuals, which means that some people are more susceptible to OPs.

In addition, researchers say infants have very low levels of this enzyme up to age two, and children don't reach adult PON1 levels until about age seven. Children are thus less capable of processing OPs, and newborns may be especially vulnerable.

Sources: Huen, Karen, et al. "Effects of PON Polymorphisms and Haplotypes on Molecular Phenotype in Mexican-American Mothers and Children." *Environmental and Molecular Mutagenesis* 52, no. 2 (March 2011): 105–16. doi:10.1002/em.20567; and Huen, Karen, et al. "Developmental Changes in PON1 Enzyme Activity in Young Children and Effects of PON1 Polymorphisms." *Environmental Health Perspectives* 117, no. 10 (October 2009): 1632–38. doi:10.1289/ehp.0900870.

4-2 Misfiring Neurons & Altered Brain Architecture

While scientists are still researching how exactly pesticides cause neurodevelopmental harms, they have identified many ways that the chemicals can interfere with nerve cell function and development. These potential mechanisms of harm include:

Neurotransmitter interference: OP pesticides inhibit acetylcholinesterase, an enzyme that degrades—and thus controls the levels of—a neurotransmitter called acetylcholine. When the enzyme is blocked, acetylcholine does not degrade and the neurotransmitter continues to stimulate the nerve cell. This changes the normal functioning of the nervous system, affecting how nerve cells communicate with each other.

Derailed development of brain cells: OPs have been shown to interfere with neural cell replication, differentiation and survival. One 2011 study found associations between chlorpyrifos and effects on the architecture of children's brains. OPs have also been shown to directly target and affect expression of the genes that control cell replication, and the timing of cell death. These effects occur at much lower levels of exposure than the acetylcholinesterase inhibition described above. EPA is currently considering new methods of evaluating the neurodevelopmental risks of OPs.

Altered channels: Voltage-sensitive sodium channels allow sodium to flow into a nerve cell, controlling how a neuron fires and transmits signals along the nerve. Pyrethroid insecticides can cause sodium channels to open and close more slowly, changing how the nerve cell normally responds—either inducing repetitive firing or causing the nerve cell not to fire at all. Pyrethroids can also decrease the number of open chloride channels in nerve cells, which is how a nerve cell controls its ability to fire.

Sources: Burr, S. A. "Structure-Activity and Interaction Effects of 14 Different Pyrethroids on Voltage-Gated Chloride Ion Channels." *Toxicological Sciences* 77, no. 2 (January 12, 2004): 341–46. doi:10.1093/toxsci/kfh027; Holland, Nina, et al. "Paraoxonase Polymorphisms, Haplotypes, and Enzyme Activity in Latino Mothers and Newborns." Environmental Health Perspectives 114, no. 7 (July 2006): 985–91; Huen, Karen, et al. "Effects of PON Polymorphisms and Haplotypes on Molecular Phenotype in Mexican-American Mothers and Children." *Environmental and Molecular Mutagenesis* 52, no. 2 (March 2011): 105–16. doi:10.1002/em.20567; Rauh, V. A., et al. "Brain Anomalies in Children Exposed Prenatally to a Common Organophosphate Pesticide." Proceedings of the National Academy of Sciences 109, no. 20 (May 15, 2012): 7871–76. doi:10.1073/pnas.1203396109; Shafer, Timothy J., et al. "Developmental Neurotoxicity of Pyrethroid Insecticides: Critical Review and Future Research Needs." *Environmental Health Perspectives* 113, no. 2 (February 2005): 123–36; Slotkin, Theodore A., and Frederic J. Seidler. "Developmental Neurotoxicity of Organophosphates Targets Cell Cycle and Apoptosis, Revealed by Transcriptional Profiles in Vivo and in Vitro." Neurotoxicology and Teratology 34, no. 2 (March 2012): 232–41. doi:10.1016/j.ntt.2011.12.001.

5 Four Farming States in Focus

Rural children are clearly on the frontlines of exposure to agricultural pesticides, and particularly vulnerable to the harms they present. Exposures vary tremendously in different regions across the country, depending on patterns of agricultural production and pesticide use. The demographics and economic profiles of rural communities also vary widely from state to state.

As outlined in Chapter 2, families in rural communities generally face higher levels of poverty, food insecurity and other challenges that can amplify the impacts of chemical exposures. In some states—such as California and Hawai'i—the rural communities most heavily impacted by pesticide exposure are also populations of color, who are often underserved by public policy processes.

In this chapter we explore this complex landscape, highlighting what is known—and unknown—about pesticide use and exposure in rural agricultural communities. In terms of health outcomes, we focus specifically on the increased risk of chronic diseases and disorders, but it should be noted that acute exposures are also cause for serious concern.

We focus on four farming states—California, Hawai'i, Iowa and Minnesota—that tell distinct stories of farming patterns and pesticide exposures (see Table 5-1). Though not comprehensive, these four profiles, presented in alphabetical order below, reflect similar on-the-ground realities in other farming states across the country. Three of the four states profiled are among the top five in the country in terms of agricultural income (see Table 5-2). In the final section below, we present a brief overview of regional farming patterns, pesticide use and potential impacts on rural communities in other states.

Table 5-1: Farmland Acreage in the U.S. & by State

	Total farmland, 2012 (acres)	Number of farms, 2012
U.S.	914,527,657	2,109,303
California	25,569,001	77,857
Hawai'i	1,129,317	7,000
Iowa	30,622,731	88,637
Minnesota	26,035,838	74,542

Sources: Total Farmland: http://www.ers.usda.gov/data-products/state-fact-sheets/state-data.aspx?StateFIPS=00: Number of Farms: Information found on http://www.ers.usda.gov/data-products/state-fact-sheets/state-data.aspx?StateFIPS=00

Table 5-2: Top 5 Agricultural States in Cash Receipts, 2013

State	Rank	Total value (billion USD)	Number of farms in state as of 2012	Total acreage of state (in millions)
California	1	46.4	77,857	101
Iowa	2	31.2	88,637	36
Nebraska	3	23.6	49,969	49.2
Minnesota	4	22.3	74,542	54
Texas	5	21.6	248,809	171

Sources: California Agricultural Statistics, 2013 crop year; http://www.icip.iastate.edu/tables/agriculture/farms-by-state and http://www.statemaster.com/graph/geo_lan_acr_tot-geography-land-acreage-total, accessed February 11, 2016.

California

Although the majority of California's 38 million residents live in urban areas, more than 5.2 million people in the state (nearly 14 percent) live in rural counties based on state data.[126] The rural poverty rate in California is higher than in urban areas, and similar to the national rate (15.6 percent) in rural areas (see Table 2-1 on p. 10).[127] In 2011, 10.6 percent of rural Californians reported having no health insurance, compared to 8.7 percent in urban areas.[128]

The ethnic breakdown in rural areas is similar to the state overall, with an estimated 54.4 percent white non-Hispanic, and 36.4 percent Hispanic (any race) residents in 2010.[185] The percentage of other ethnic groups, particularly African American and Asian, is much lower in rural areas than in cities.

Just over 25 million of California's 101 million total acres are dedicated to agriculture, with more than 77,000 farms in the state. The average farm size (327 acres) is well below the national average (435 acres). This is in part because of the emphasis on high-value "specialty crops" in California, which can be more lucrative on smaller farms than field crops. California has the largest agricultural economy in the country, generating more than $46 billion in 2013 (see Table 5-2).

California has three primary agricultural regions: the Central Valley, the Central Coast and southern California. There is a wide range of crops grown in each of these regions. In general field crops (such as rice, alfalfa and cotton) and orchards are found in the Central Valley, specialty crops like grapes and berries grow along the Central Coast (which includes Napa and Sonoma counties); and citrus and avocado are common crops in southern California.

In all three of these regions, rural communities are often in close proximity to agricultural production. This is particularly the case in the Central Coast region, where high-value specialty crops like strawberries, lettuce and broccoli are grown on relatively small plots of land, often very near schools or residential areas. This proximity has clear implications for pesticide exposures for rural families.

Table 5-3: Top Synthetic Pesticides Used in California by Volume, 2012

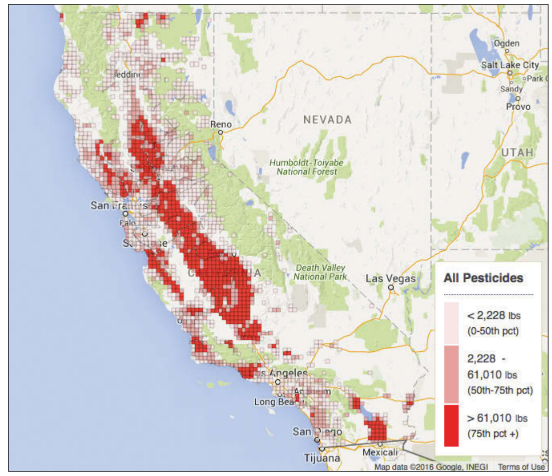
Pesticide	Volume (million lbs)	Type	Associated health effects*
1,3-dichloropropene	12.0	Fumigant	Acute toxicity, carcinogen
Chloropicrin	9.0	Fumigant	Acute toxicity†
Metam sodium	8.4	Fumigant	Carcinogen, reproductive or developmental toxicant
Metam potassium (Potassium n-methyldithiocarbamate)	8.3	Fumigant	Acute toxicity, carcinogen, reproductive or developmental toxicant
Glyphosate, potassium salt	5.4	Herbicide	"Probable" carcinogen‡
Glyphosate, isopropylene salt	5.0	Herbicide	"Probable" carcinogen‡
Methyl bromide	3.9	Fumigant	Acute toxicity, reproductive or developmental toxicant
Propanil	2.2	Herbicide	Slight toxicity, suspected endocrine disruptor, possible carcinogen

* 2013 California use reporting data and associated health effects accessed on Pesticideinfo.org and Pesticide Action Network's whatsonmyfood.org.

† Though chloropicrin is not listed as a carcinogen by U.S. EPA, debate over the carcinogenicity of chloropicrin between California's Department of Pesticide Regulation (DPR) management and other California EPA scientists is discussed in PAN's report, "Air Monitoring in Watsonville, California, November 3–12, 2014, " available at http://www.panna.org/resources/air-monitoring-watsonville.

‡ The World Health Organization listed glyphosate as a probable carcinogen in 2015.

Figure 5-1: Pesticide Use Patterns in California



This map shows intensity of pesticide use for all pesticides in the state of California.

Source: California Department of Public Health. "Pesticide Mapping Tool: Agricultural Pesticide Use in California," April 13, 2016. http://cehtp.org/page/pesticides.

Crops & pesticides

California is the top U.S. producer of more than 80 crops. In terms of acreage, the top five crops in the "Golden State" are alfalfa, almonds, grapes, rice and wheat.[129] California also boasts more organic farms than any other state, with more than 2,800 operators on 687,000 acres registered organic as of 2014.[130] The vast majority of the state's agricultural lands, however, are conventionally farmed.

California's pesticide use reporting system has been in place since 1990, providing county- and crop-level information for pesticide applications. These data provide a clear picture of pesticide usage and potential pesticide exposures, including trends and hotspots throughout the state.[131] That said, there are still gaps and delays in reporting.

The top crops in terms of overall volume of pesticides applied are grapes (both wine and table), almonds and strawberries. In terms of intensity of application rate (pounds/acre), the top crops are raspberries, sweet potatoes and lemons.

A range of pesticides are applied to these high volume crops. The top chemicals applied in strawberry production, for example, include soil fumigants such as metam sodium and chloropricrin, the fungicide captan and the insecticide malathion. The top pesticides applied by volume for all crops are soil fumigants, which are most commonly applied to soil via injection or drip line before planting (see Table 5-3).

The top counties in terms of overall volume of pesticides applied are the Central Valley counties of Fresno, Kern and Tulare (see Figure 5-1).

Exposure & children's health

In 2014, the California Department of Public Health released a study of applications of "pesticides of public health concern" in 15 rural counties. They found that Hispanic children were 46 percent more likely than white children to attend schools within a quarter of a mile from fields where pesticides of public health concern were applied—and were 91 percent more likely than white children to attend schools near high levels of pesticide use.[26] Overall, more than 400,000 children in these 15 counties attend school near fields where pesticides of concern are applied.

In addition to the data available from the state's use reporting system, California's Department of Pesticide Regulation put an Air Monitoring Network (AMN) in place in 2011 to track 37 chemicals (32 pesticides and five breakdown products) in three agricultural communities. In 2014, 23 of the 37 chemicals were detected in at least one air sample; one soil fumigant—1,3-dichloropropene, a probable carcinogen—was found at levels that exceed the EPA standard for lifetime risk for cancer for adults.*

Community monitoring data from PAN Drift Catcher projects has also documented pesticide exposure (see Sidebar 5-1). In one 2006 study, Drift Catcher data were combined with biomonitoring data to document expousure to the insecticide chlorpyrifos for ten households in the Central Valley community of Lindsay.[132] A 2014 Drift Catcher project in the Central Coast community of Watsonville documented the carcinogenic fumigant chlo-

* The AMN has some limitations, as its sampling plan is not designed to assess exposures during peak application times. In addition, two of the three monitoring locations are not located at sites that are heavily populated or traveled, making it difficult to assess what exposures might be in areas where community members are more likely to be exposed.

Drift-prone pesticides used near California communities put the health of rural children at risk.

ropicrin drifting into a home from nearby strawberry fields at concentrations that pose an elevated risk of cancer.[133]

The volume of drift-prone pesticides used near communities throughout the state is a cause for concern for California's rural children. Seven of the top eight pesticides used in the state are considered probable carcinogens by health officials; the eighth, the herbicide propanil, is "possibly" carcinogenic as well. A recent UCLA study found that simultaneous exposure to multiple fumigant pesticides increased cancer risk among both adults and children (see Sidebar 3-1 in Chapter 3).[134]

Even with use data available, direct correlations between exposure and health outcomes cannot be made. Yet statistics on the health outcomes that are most closely linked to pesticide exposures illustrate disturbing trends.

Overall, cancer incidence for California children under 20 years of age are the same as the national rate according to CDC data; for 18 of the state's 58 counties, however, the rates are well above average, ranging from 18.2 to 23.0 cases per 100,000 (compared to 17.4 per 100,000 nationwide).[*] Napa County had the highest incidence of childhood cancer in the state, and overall incidence for boys was higher than girls; 26.9 per 100,000 in Napa County, 18.5 per 100,000 statewide.[168]

The overall childhood asthma rate in California is above the CDC national average for children age 0–17 (15.4 vs 8.6 percent).[135] Ten of the 11 counties with rates over 20 percent are rural, agricultural counties; Merced County had the highest rate at 32.5 percent.[†] As outlined in Appendix A, some studies have linked pesticide exposure with increased risk of childhood asthma.

Several key studies documenting effects on neurodevelopment and exposure to organophosphates have been conducted in rural California communities. One of these studies shows links between OPs and an increased risk of autism spectrum disorders (ASD) in the Central Valley. Correlations between prenatal OP pesticide exposures and reduced IQ and other developmental delays were also documented in the Central Coast region (see Chapter 4 and Appendix A for details).[117,136,137]

5-1 Community Air Monitoring: PAN's Drift Catcher

When community members experience pesticide drift, they often have little evidence other than personal observation. PAN's Drift Catcher is a simple air monitoring tool that changes this dynamic, putting hard data in the hands of affected communities.

The Drift Catcher device consists of a vacuum pump connecting to tubing that draws air through a pair of sample tubes. The tool's design is based on air monitoring equipment used by the California Air Resources Board. Community partners are trained to use the device and track the sampling time period and note weather conditions on a data sheet.

PAN's Drift Catcher has been used in at least a dozen states in targeted air monitoring projects. It is best suited to capturing pesticides that volatilize, rising into the air as vapor during an application and in the days following. Samples are taken during peak times of pesticide application, providing data on exposure to the highest levels of pesticides in the air.

For those living in agricultural communities where the bulk of pesticide exposures occur, the Drift Catcher has been an effective tool in answering community members' questions and supporting policy protections from drift exposure. In one of PAN's most notable Drift Catcher projects, the community of Tulare County, California, won protective buffer zones after documenting pesticides in their air.

For more information, see www.panna.org/drift.

Hawai'i

About 18 percent of Hawai'i's total population of 1.4 million live in rural areas. According to the USDA's Economic Research Service, the income disparity between urban and rural residents is greater in Hawai'i than in any of the other

* Sixteen of the 18 counties with higher cancer incidence have rural areas. California is so populous that many areas are mixed, with rural populations residing in large counties that hold both a mixture of rural and urban areas.

† Other counties with childhood asthma rates above 20 percent, from highest to lowest prevalence, include Sutter, San Francisco, San Joaquin, Kings, Butte, Tehama, Glenn, Colusa, San Bernardino and Fresno.

states profiled in this report. Those in rural areas average $10,000/year less than their urban counterparts in income; 17.2 percent of the rural population falls below the poverty line, compared to 9.8 percent in urban areas of the state.[138]

The rural population is as diverse as the population overall on Hawai‘i’s eight islands with 24.9 percent Asians, 21.5 percent of two or more races, 31.1 percent white not Hispanic and 10.5 percent Hispanic in rural areas.[185]

More than 7,500 farms are operated in Hawai‘i, on 1.1 million acres (27 percent) of the total 4.1 million acres of the eight islands; the majority of farm acres are pastureland. An estimated 10 percent of the total "farmed" acreage is planted cropland on the islands, with an average farm size of 149 acres, much smaller than the national average of 435. In 2012, the "agriculture, forestry, fishing and hunting" sector comprised just 0.52 percent of the state's GDP.[139]

A significant portion of cultivated land—roughly 25 percent—is leased by five of the six largest pesticide/biotech corporations for seed crop testing and production (see Table 5-4).

Crops & pesticides

The islands' top acreage crops as of 2014 were high-value exports: sugar cane, macadamia nuts and coffee. These three crops combined total 41,000 planted acres.[140] Hawai‘i's organic sector is small but growing rapidly, with 121 certified farms on more than 3,000 acres in 2014, up from 98 farms in 2011.[141,142]

While there is no pesticide use reporting required in Hawai‘i, use data from California show that the top chemicals commonly applied in sugarcane production are herbicides, including glyphosate and atrazine. A wide range of pesticides are registered for use on coffee in Hawai‘i, including 18 insecticide active ingredients, eight fungicides, seven herbicides and many product mixtures.[143] Like coffee, macadamia nuts are mostly grown on the "Big Island" of Hawai‘i. Guidelines for production include use of the herbicides atrazine and glyphosate and the insecticide malathion, among others.[144]

Not captured in USDA crop data for Hawai‘i, however, is another significant and far more pesticide-intensive use of agricultural lands: field trials for genetically engineered (GE) crops. From 2010 to 2013, the U.S. Department of Agriculture granted over 100 permits to seed and pesticide corporations for field trials in Hawai‘i—more than anywhere else in the country. In 2014, the seed trials were taking place on 24,700 acres.[145] On the island of Kaua‘i alone, 15,000 acres are under "test field" production, many near houses and schools.*

* In addition to field trials, lines of pure, inbred corn seed known as "parent seed" are grown that can subsequently be used by commercial breeders, who cross lines to make hybrid corn seeds that are sold to farmers or other customers. Hanson, Terri R. Civil No. CV12-00231 LEK BMK. Jim Aana, et al. Plaintiffs, vs. Pioneer Hi-Bred International, Inc. Defendants. Deposition of Jill Suga, Taken on behalf of Plaintiffs at 2970 Kele Street, Suite 210, Lihue, Hawai‘i 96766, March 21, 2013.

Table 5-4: Land Use for Seed Crop operations in Hawai‘i

Corporation	Acreage owned or leased	Islands
Monsanto	8,480	Moloka‘i, Maui, O‘ahu
Dupont/Pioneer	7,644	Kaua‘i, O‘ahu
Dow Chemical	4,060	Moloka‘i, Kaua‘i
Syngenta	3,675	Kaua‘i, O’ahu
BASF	1,175	Kaua‘i
Total	**25,034**	

Source: Pesticides in Paradise, CFS & Honolulu, Kaua‘i, and Maui Real Property Assessment Division, 2015

A recent report by the Hawai‘i Center for Food Safety noted that in 2013, Hawai‘i supplied less than 12 percent of its local food needs, and led the nation in GE crop field trials. In 2014, GE testing was conducted on 1,141 sites; tested crops are mainly corn (67 percent) or soybeans (24 percent).[145]

According to the Hawai‘i Department of Agriculture, biotech corporations are by far the largest users of "restricted use" pesticides (RUPs) on the island of Kaua‘i, with 18 tons of 22 different RUPs applied in 2012. As researchers at the Center for Food Safety note, "81 percent of RUP active ingredients by weight were applied on corn and 19 percent on coffee, with negligible amounts" used on sugarcane, soybeans and other crops.[145]

Because of the continuous growing season in Hawai‘i, pesticide applications are nearly year-round. The crops grow quickly in the tropical climate, as do weeds.[146] On their test fields in Hawai‘i, for example, Dupont/Pioneer applied pesticides about two thirds of the days between 2007 and 2012, with an average of 8–16 pesticides applied each time. In

Pesticides have been documented in the air, water and house dust on several islands in Hawai‘i.

comparison, the "average" acre of corn in the mainland based on 2010 USDA data had about three pesticides applied in the growing season—in contrast, 24.8 pesticides were applied on a set of test fields located on Kaua'i.[147,148]

Exposure & children's health

Pesticide exposures from drift, water and contaminated house dust have been documented on several islands in Hawai'i. In a University of Hawai'i study released in 2013, pesticides—including chlorpyrifos and some persistent organic pollutants—were detected in the air inside and outside schools in every sample taken at three different Kaua'i school sites over a two-year period.[149]

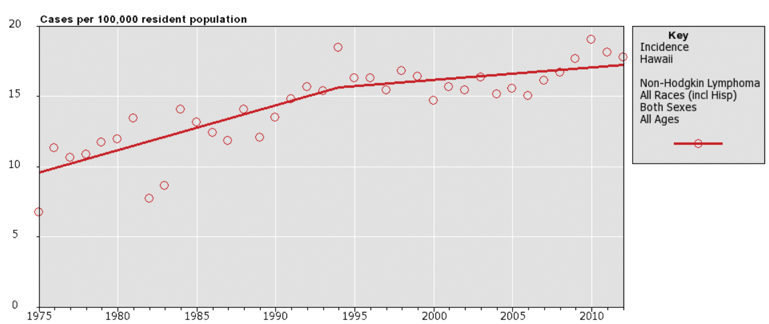
State officials have also documented pesticides in surface water; a statewide sampling project found at least one pesticide in each of 24 watersheds and streams tested. The herbicide atrazine was found in 80 percent of the samples taken, as reported in a draft report by the state.[150]

In terms of children's health trends, the overall incidence of childhood cancer in Hawai'i is well below the national average. These rates, however, are climbing for all age groups; leukemia and non-Hodgkin lymphoma have risen in recent years (see Figure 5-2). According to CDC data, childhood asthma rates in Hawai'i are significantly above average, with lifetime prevalence for children under 17 at 18.6 percent and current asthma prevalence at 12.7 percent, compared with a 13.3 percent and 9.0 percent average, respectively, in the 38 other states monitored.[151]

Anecdotal evidence points to a reason for concern for children's health in Hawai'i's rural communities. Researchers from the Hawai'i Center for Food Safety highlight "hotspot" concerns regarding both birth defects and cancer:

> "Dr. James Raelson and his colleague Dr. Chatkupt, practicing pediatricians on Kaua'i, have noted an unusually high incidence of rare birth defects involving malformations of the heart in Kaua'i over the past seven years, at roughly ten times the national rate…. Kaua'i physicians and residents have also noted a "cancer cluster" in Waimea—37 cases in a neighborhood of just 800 – which is said to be 10 times the statewide cancer rate."[145]

Figure 5-2: Historical Incidence of Leukemia & Non-Hodgkin Lymphoma in Hawai'i, 1975–2012



During 1975–2012, the annual percentage change (APC) in the rate of leukemia was slightly rising: 0.7 with a 95% confidence interval from 0.4 to 1.1. During 1975–1994, the APC in the rate of non-Hodgkin lymphoma was rising: 2.6 with a 95% confidence interval from 1.5 to 3.7. During 1994–2012, the APC in the rate of non-Hodgkin lymphoma was slightly rising: 0.6 with a 95% confidence interval from -0.2 to 1.3.

Source: Incidence data provided by the SEER Program, see http://seer.cancer.gov. Rates were calculated by the National Cancer Institute. This graph and the notes from the caption were obtained from http://statecancerprofiles.cancer.gov/.

5-2 The Rise of GE Crops & Herbicides

The most widely planted genetically engineered (GE) crops in the U.S. are corn, soybeans and cotton that have been engineered to tolerate herbicide applications. Other types of GE crops are Bt corn and cotton, which are engineered to produce their own endogenous toxin that targets insect pests. In the first 16 years following the introduction of genetically engineered (GE) crops in 1996, total herbicide use in the U.S. increased by 527 million pounds.

The largest share of the GE seed market is held by Monsanto's "RoundUp Ready" glyphosate-resistant crops. The resulting widespread use of glyphosate has led to herbicide-resistant "superweeds," which have become a significant problem for farmers across the Midwest. In response, both Monsanto and Dow have developed new lines of GE crops engineered for use with chemical mixtures, including the antiquated, drift-prone herbicides 2,4-D and dicamba.

Widespread use of Dow's "Enlist Duo," a combination of glyphosate and 2,4-D designed to accompany a new line of GE corn and soy, is expected to increase usage of 2,4-D by 30-fold over 2010 use levels by 2019.

Sources: PAN blog by Linda Wells, http://www.panna.org/blog/what-epa-didnt-know-about-enlist-duo, December 16, 2015. Benbrook, Charles M. "Impacts of Genetically Engineered Crops on Pesticide Use in the U.S.—the First Sixteen Years." *Environmental Sciences Europe* 24, no. 1 (2012): 24. doi:10.1186/2190-4715-24-24; Newman, Jesse. "EPA Seeks to Revoke Approval of Dow Chemical's Enlist Duo Herbicide." *The Wall Street Journal,* November 25, 2015, sec. Business. http://www.wsj.com/articles/epa-revokes-approval-of-dow-chemicals-enlist-duo-herbicide-1448469843.

Iowa

Well over a million of Iowa's three million residents live in rural areas, a significantly higher percentage than the national average (40 vs 14 percent). Overall, the poverty rate is below the national average in Iowa (12 vs 15 percent), with little variation between rural and urban areas.[127] Education levels are slightly lower in rural communities, as is access to health care.[152,153]

More than half of the state's population growth between 2000 and 2010 is accounted for by increasing Hispanic populations, which increased by 84 percent during this period.[185]

Agriculture is integral to Iowa's economy. Nationwide, it is second only to California in terms of the value of agricultural production and net farm income,[154] with farming representing more than 30 percent of the Iowa economy.[155] Farming continues to hold deep cultural importance in Iowa as well, touching the lives of many families. The state has more than 88,000 individual farms—the third highest number in the nation—covering more than 30 million of the state's 36 million acres.

Table 5-5: Top 5 Pesticides Applied to U.S. Corn Planted Acres, 2014 Crop Year

Active ingredient	Volume (million lbs)	Type	Associated health effects*
Atrazine	45.2	Herbicide	Slight toxicity, carcinogen, suspected endocrine disruptor
Glyphosate isopropylamine salt	27.2	Herbicide	"Probable" carcinogen†
Acetochlor	28.7	Herbicide	Slight toxicity, carcinogen, suspected endocrine disruptor*
S-Metolachlor	23.6	Herbicide	Possible carcinogen, suspected endocrine disruptor
Glyphosate potassium salt	22.6	Herbicide	"Probable" carcinogen†

The vast majority of pesticides used on corn were herbicides, with 97% of corn acreage having herbicide applications. Insecticides (13%) and fungicides (12%) were applied to less acreage.

* For information on health effects, see pesticideinfo.org.

† The World Health Organization listed glyphosate as a probable carcinogen in 2015.

Source: U.S. Department of Agriculture. "NASS Highlights: 2014 Agricultural Chemical Use Survey, Corn," May 1, 2015. http://www.nass.usda.gov/Publications/Highlights/.

Crops & pesticides

Iowa is ranked first in the country in production of both corn and soybeans. Combined, these two crops cover more than 23 of the state's 30 million planted acres. Although organic production is growing rapidly in Iowa—the number of certified farms nearly doubled between 2000 and 2010—the vast majority of Iowa's crops are produced with synthetic pesticides.[152]

Over the past 15 years, corn and soy farming has largely shifted to varieties that are genetically modified.[4,156] Many of these crops are designed for use with repeated applications of herbicide, resulting in dramatic increases in these chemicals (see Sidebar 5-2). Since specific pesticide use data are not available for Iowa, we highlight here national use rates and application patterns for corn and soy, the primary crops grown in the state.

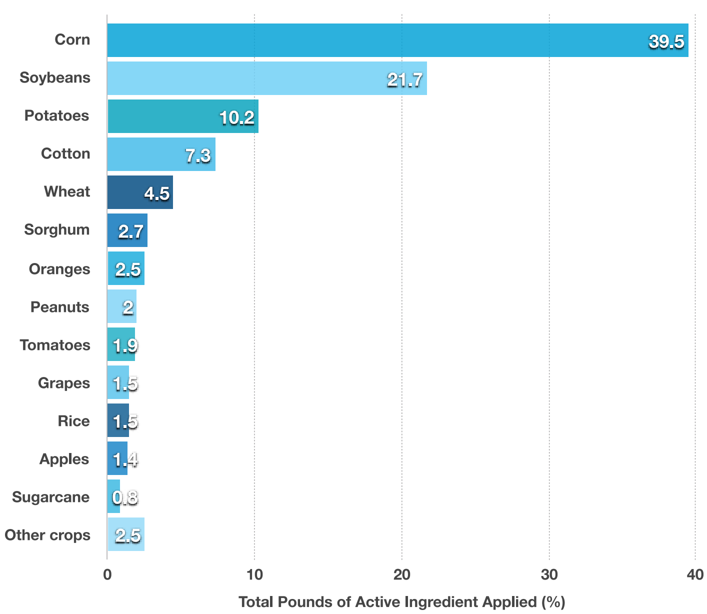
According to USDA's "Chemical Use Survey" data for corn collected in 2014, herbicides are applied to 97 percent of cornfields across the country (see Table 5-5).[157] More than 1,000 herbicide products are currently registered for use on corn, and more than 300 for soybeans.[158] The 2015 Herbicide Guide for Corn and Soybean Production from Iowa State University mentions 46 "package mix" herbicide products for corn, and 39 for soybeans; each of these products includes 2–3 active chemical ingredients.[159]

A number of insecticides are used in soy and corn production as well, including soil insecticides to combat the corn rootworm and neonicotinoid (neonic) seed treatments intended to control aphids and other sucking insects.[*] [160] According to the most recent USDA data, corn and soy combined account for more than 60 percent of all pesticide use nationwide and cover more than 50 percent of harvested cropland (see Figures 5-3 and 5-4).[161]

In 2014, glyphosate (the active ingredient in Monsanto's RoundUp) was applied to 62 percent of all conventional

* In a 2014 report, EPA analysts found that neonic seed treatments "provide negligible overall benefits to soybean production in most situations."

Figure 5-3: U.S. Pesticide Use by Crop, 2008



Combined, 21 crops account for about 72% of the total conventional pesticide use in U.S. agriculture. "Conventional pesticides" include those developed and produced primarily or only for use as pesticides and excludes sulfur and petroleum distillate, among others. The "Other crops" category includes: lettuce, pears, sweet corn, barley, peaches, grapefruit, pecans and lemons.

Source: Pesticide Use in U.S. Agriculture: 21 Selected Crops, 1960-2008, EIB-124, U.S. Department of Agriculture, Economic Research Service, May 2014. Authors: Fernandez-Cornejo, Jorge, Richard Nehring, Craig Osteen, Seth Wechsler, Andrew Martin, and Alex Vialou.

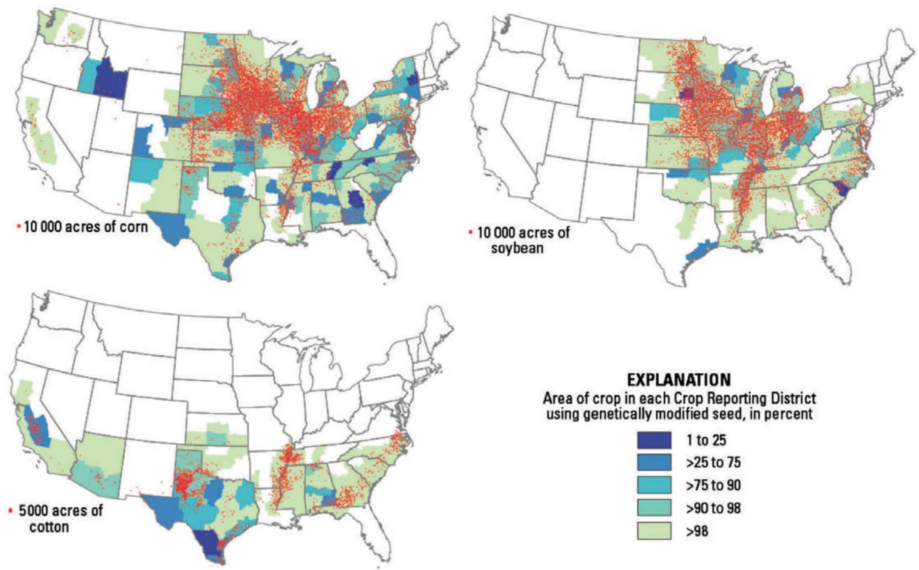
corn acres planted in the U.S.* Atrazine was a close second, applied to 55 percent of planted fields. According to USGS estimates, Iowa is among the states with the heaviest use of these herbicides nationwide.[157]

Exposure & children's health

Without state-level pesticide use reporting, detailed and accurate data on the type, volume and location of pesticides applied in Iowa are not available. Potential exposures for children in agricultural areas can be estimated, however, by considering the national use patterns in corn and soy production outlined above, and what is known about exposure pathways.

Herbicide drift has been documented by farmers across Iowa and is a common route of exposure for rural communities. This drift is also a problem for farmers growing crops vulnerable to herbicides. According to an analysis from Practical Farmers of Iowa, 58 cases of crop damage from spray drift were officially reported between 2008 and 2012. Because there are significant barriers to reporting, this figure likely understates the actual number of cases.[162]

Figure 5-4: Trends in Pesticide Use on Soybean, Corn and Cotton Since the Introduction of a Major Genetically Modified Crop in the U.S.



Planting of GE corn, soy and cotton engineered to tolerate herbicide applications is widespread. This figure shows the percentage of crops planted with seed in 2009 that had a genetically modified glyphosate resistance trait. This map is mapped by crop reporting district and overlain by crop density.

Source: Coupe, Richard H, and Paul D Capel. "Trends in Pesticide Use on Soybean, Corn and Cotton since the Introduction of Major Genetically Modified Crops in the United States: Pesticide Use on US Soybean, Corn and Cotton since the Introduction of GM Crops." *Pest Management Science* 72, no. 5 (May 2016): 1013–22. doi:10.1002/ps.4082.

Widespread herbicide use has also resulted in water contamination. In 2011, researchers tested both the air and water at various locations in Mississippi and Iowa; they found glyphosate in most air samples and in every stream sampled.[163] Atrazine has consistently been documented in Iowa water samples as well,[164] and a 2014 study from USGS found neonic insecticides in water samples across the state.[165]

Given the widespread cultivation of herbicide-intensive crops, and the documentation of pesticides in Iowa's air and water, there is reason for concern about the potential health impacts on rural children (see Figure 5-7 on page 27). Both glyphosate and atrazine exposure have been linked to increased risk of several types of cancer, including non-Hodgkin lymphoma.[41,166] Atrazine exposure during pregnancy has also been linked to increased risk of birth defects, and researchers have found that in vertebrate animal models, glyphosate can induce effects on embryos parallel to birth defects observed in human populations.[40,167]

Though direct correlations cannot be made, statistics on the health outcomes that have been linked to pesticide exposure illustrate disturbing trends. The incidence of childhood cancer in Iowa, for example, increased steadily between 1975 and 2012 (see Figure 3-2 in Chapter 3). Between 2008 and 2012, cancer rates for children under 20 were slightly above the national average in Iowa (18.4 vs 17.4 cases per 100,000), according to data collected by CDC. Incidence rates were slightly higher (19.4) among boys.[168]

Rates of Iowa children age 4–17 diagnosed with ADHD are also above the national average (see Figure 5-5), and the percentage of students with intellectual disabilities is more than double the national rate (2.43 vs 0.96 percent).[103,169] According to the National Birth Defects Prevention Network, birth defect rates for 10 of the 12 conditions tracked are slightly above the national average in Iowa as well.[170 †]

Minnesota

Rural residents in Minnesota constitute just over 20 percent of the population; 1.2 million of the state's 5.5 million people live in rural communities, many in agricultural areas. Rural income levels are significantly lower and poverty rates higher than in urban areas (12.3 vs 10.9 percent). Education levels are somewhat lower and unemployment rates slightly higher in rural areas as well.[171]

* Including both glyphosate isopropylamine salt and glyphosate potassium salt.

† See Appendix A for summaries of studies linking increased risk of specific types of birth defects to pre-natal pesticide exposure.

The ethnic makeup of rural communities differs from statewide breakdowns. Overall, non-Hispanic white Minnesotans make up the majority in the state population (81 percent) and are 91 percent of the rural population.[172,185] In rural Minnesota, these numbers are nine and 91 percent, respectively.

With 74,000 farms, Minnesota is among the top 10 farming states in the country. Twenty-six million of the state's 51 million acres of land are under agricultural production.[173] Of the remainder, eight million acres are forests and wildlife management acres owned by the state, and 3.4 million acres are Native American tribal lands, national parklands and forests. The "land of 10,000 lakes" has 2.6 million acres of surface water.

Crops & pesticides

Corn, soy and wheat are grown on the majority (69 percent) of farmed acres, just over 18 million combined. Minnesota ranks third in the nation for soy and spring wheat production, and fourth in the country for corn. Though the total number of farms under organic production remains small (599 operations in 2012), Minnesota ranks seventh in the nation in total organic acreage with over 150,000 acres planted, and first in organic production of both corn and soy.[174,175]

Other significant crops grown in the state include sugarbeets, alfalfa, oats, dried beans, barley, sweet corn, peas, sunflowers and potatoes. As of 2014, Minnesota was tied with Michigan for seventh in the country with 43,000 acres of potato production, following Idaho, Washington, North Dakota, Wisconsin, Colorado and Maine.[176]

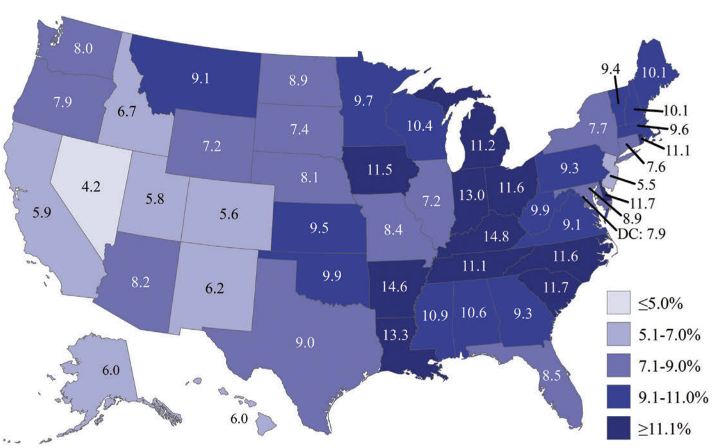
In addition to the herbicides commonly used on corn and soy as described in the Iowa section above, USDA data indicates that more than 97 percent of spring wheat fields are treated with herbicides. Forty-nine percent were also treated with fungicides, and 12 percent with insecticides.[177] An increasingly common practice is an additional "non-pesticidal" use of the herbicide glyphosate to desiccate wheat before harvest.

Conventional potato production is particularly chemical-intensive, according to USDA data (see Figure 5-6). The top three chemicals used in potato fields are the herbicide metribuzin and the fungicides chlorothalonil and mancozeb. OP insecticides, such as dimethoate, are also commonly used in potato production.[176] Soil fumigants such as metam sodium, which are prone to drift off-site, are generally applied at very high rates per acre.[178]

Exposure & children's health

Pesticide use reporting is not required in Minnesota, so specific information about the location and volume of use is not available. However, use patterns for the primary crops based on USDA's Chemical Use Surveys give an approximation of potential exposures in agricultural communities. In addition, the Minnesota Department of Agriculture publishes annual pesticide sales data for the state. The top eight pesticides

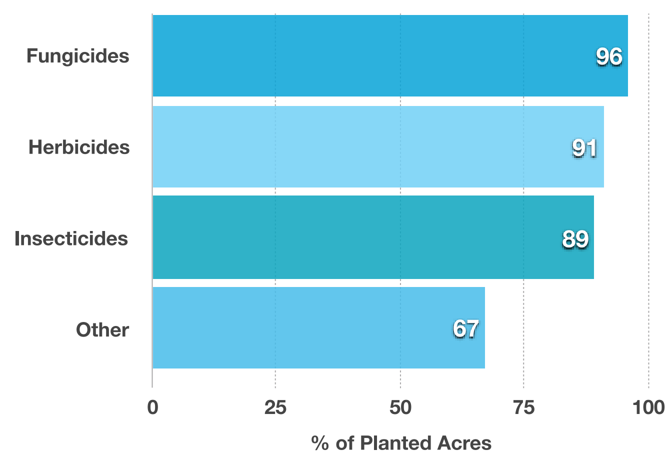
Figure 5-5: Prevalence Estimates of Youth ages 4–17 with ADHD by State, 2011



Numbers in white are weighted prevalence estimates of parent-reported attention-deficit/hyperactivity disorder (ADHD) among children and adolescents four to 17 years of age. These data are from the National Survey of Children's Health, 2011.

Source: Visser, Susanna N., et al. "Trends in the Parent-Report of Health Care Provider-Diagnosed and Medicated Attention-Deficit/Hyperactivity Disorder: United States, 2003–2011." *Journal of the American Academy of Child & Adolescent Psychiatry* 53, no. 1 (January 2014): 34–46.e2. doi:10.1016/j.jaac.2013.09.001. See http://www.cdc.gov/ncbddd/adhd/features/key-findings-adhd72013.html

Figure 5-6: Pesticides Applied to Fall Potato Planted Acres, 2014*



The percentage of acres with pesticides applied is shown here, for potatoes harvested in the fall of 2014.

Source: USDA NASS

* The one-year period beginning after the 2013 harvest and ending after the 2014 harvest.

Six of the top eight pesticides used in Minnesota have been linked to cancer.

Table 5-6: 2011 Agricultural Pesticide Sales in Minnesota

Pesticide	Volume (million lbs)	Type	Associated health effects
Glyphosate	27	Herbicide	"Probable" carcinogen*
Metam sodium	5.8	Fumigant	Carcinogen, acute toxicity, developmental or reproductive toxicant, suspected endocrine disruptor
Acetochlor	3.9	Herbicide	Slight toxicity, carcinogen, suspected endocrine disruptor
S-Metolachlor	1.8	Herbicide	Possible carcinogen, suspected endocrine disruptor
Propionic acid	1.0	Herbicide	Acute toxicity
Chlorpyrifos	0.79	Insecticide	Cholinesterase inhibitor, moderate toxicity, suspected endocrine disruptor
Atrazine	0.75	Herbicide	Slight toxicity, carcinogen, suspected endocrine disruptor
2,4-D	0.72	Herbicide	Moderate toxicity, possible carcinogen, suspected endocrine disruptor

Sources: Minnesota Department of Agriculture sales data, http://www2.mda.state.mn.us/webapp/lis/chemsold_default.jsp and for associated health effects, see Pesticide Action Network's whatsonmyfood.org & pesticideinfo.org.

* The World Health Organization listed glyphosate as a probable carcinogen in 2015.

used in the state in 2011 (the most recent data available) are listed in Table 5-6.

In the corn and soy producing areas of the state, rural children face exposure to herbicides from both drift and water contamination. Farming is more diversified in the northwestern region, with spring wheat, sugarbeet and potatoes making up some of the major crops. Communities may face a wide range of exposures in this region. Both sugarbeets and potatoes, for example, tend to have higher total pesticide application rates than most field crops.*

Some data are available documenting pesticide drift from potato fields. From 2006 to 2009, PAN worked with communities to conduct air monitoring using the Drift Catcher (see Sidebar 5-2) at 19 sites in northern Minnesota. The community monitoring project documented drift from several sources, including potato fields. The fungicide chlorothalonil, which is frequently used on potatoes in Minnesota's wet climate, was found in 217 of the 340 air samples taken (64 percent). Four other pesticides were detected in samples taken during that time period, including the fungicide pentachloronitrobenzene and the herbicide 2,4-dichlorophenoxyacetic acid (2,4-D). Forty-two of the 340 samples taken (12 percent) were found to contain more than one pesticide.[179]

Minnesota's Department of Agriculture collects data on pesticides in ground and surface waters throughout the state. Data from 2014 found 37 different pesticides or their breakdown products in groundwater. The herbicide metachlor was found most often; none of the detections was above "safe" drinking water standards. Surface water samples found the

* According to California use data, typical total pesticide application is 1.24 pounds per acre for sugarbeets and 3.57 pounds per acre for potatoes. This compares to 0.21 pounds acre for corn and 0.29 pounds acre for wheat.

Table 5-7: Minnesota childhood cancer incidence 2008–2012

Cancer type	Minnesota rate	U.S. rate
Childhood cancer (<20)	18.2	17.4
Leukemia	16.0	13.2
Non-Hodgkin lymphoma	23.0	19.2

Source: CDC state cancer profiles

OP insecticide chlorpyrifos at levels exceeding both the acute and chronic standards; in a small number of samples (47 of 1,034). The agency also found several pesticides—2,4-D, dichlorvos, dimethenamid, and atrazine—at levels over 50 percent of reference values† for acute, chronic and other human health standards for exposures set by EPA.[180]

Six of the top eight pesticides used in Minnesota have been linked to cancer (see Table 5-6).

In addition, six of the top pesticides used in the state are suspected endocrine disruptors, and three have been linked to developmental harms or birth defects.

While direct correlations to pesticide exposure cannot be inferred, statistics on the childhood health trends in Minnesota give cause for concern. The state's childhood cancer rate is slightly above the national average, and incidence rates for leukemia and non-Hodgkin lymphoma are

† When pesticide samples exceed 50% reference values in surface water, the state of Minnesota must also determine the length of time for which that reference value is exceeded, in order to compare to "chronic" exposure reference values. Reference values are derived using risk assessment (RA) of an individual pesticide that can be used as a basis for determining a "safe" level of exposure. Agencies can derive different reference values based on their different RA approaches. For instance, different assumptions might be made by an agency with regards to inhalation toxicity of a specific pesticide, by accounting for the different breathing rates of adults and infants.

even more elevated (see Table 5-7). The rate of children diagnosed with ASD in Minnesota is slightly higher than the national average as well (2.7 vs 1.8 percent), although the state Department of Health notes that prevalence data are limited.* As in Iowa, the rates of many of the birth defects—nine of the 12 tracked by the National Birth Defects Prevention Network—are also above the national average.[181]

National pesticide exposures

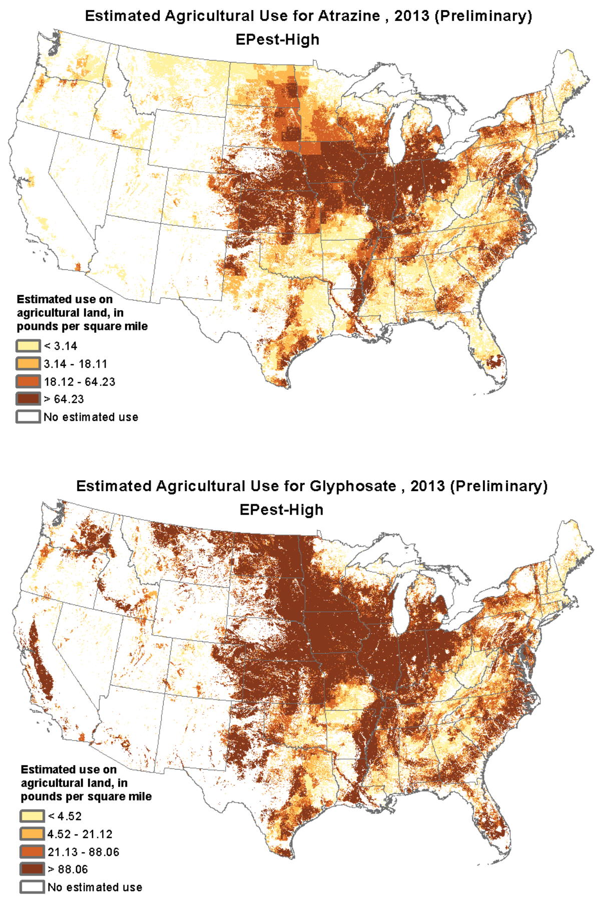
Cropping and pesticide use patterns in these four agricultural states reflect similar on-the-ground realities in farming communities across the country. For example, the dramatic increases in herbicide use accompanying adoption of GE corn and soy that we see in Minnesota and Iowa are similar in other corn-producing states such as Nebraska, Illinois and Indiana.

The intensive use of pesticides for potato production has implications for rural communities in Idaho, Washington, North Dakota, Maine and beyond. And the heavy use of a range of pesticides on orchards and specialty crops in California illustrates potential patterns of pesticide use from Florida to Michigan, from Oregon to the New England states.

What we haven't captured here is risk associated with crops like tobacco in the southeastern states (especially North Carolina), and cotton, which is grown primarily in Texas and Georgia. Both of these non-food field crops are notoriously chemical-intensive. It is worth noting that children in these regions may be especially vulnerable to the harms of pesticide exposures, as rural childhood poverty in the Southeast region is particularly high.[182]

National USGS maps of two widely used pesticides further illustrate the range of pesticide exposures faced across the country (see Figure 5-7). Based on what scientists now understand both about the physiological and developmental vulnerabilities of children to pesticide exposures, and the multiple exposure pathways for families in rural areas, we believe significant changes are needed.

Figure 5-7: Estimated Agricultural Use for Two Pesticides, 2013



These maps from the U.S. Geological Service (USGS) show national use patterns for two widely used pesticides of more than 1,200 registered for use in the United States. Glyphosate and atrazine are herbicides heavily used on corn, soy and other row crops.

Sources: Thelin, G.P., and W.W. Stone. "Estimation of Annual Agricultural Pesticide Use for Counties of the Conterminous United States, 1992–2009." *U.S. Geological Survey Scientific Investigations Report*, 2013–5009. USGS, 2013; "U.S. Geological Survey, National Water-Quality Assessment (NAWQA) Program." *Pesticide National Synthesis Project*, April 14, 2016. http://water.usgs.gov/nawqa/pnsp/usage/maps/about.php#limitations.

Note: USGS estimates use of about 480 pesticides based on a combination of use data compiled by proprietary surveys of farms and county-reported harvested crop acreage. Estimations based on neighboring counties were used for areas that did not report harvested acreage. The reliability of these estimates generally decreases with the scale of use. These maps reflect the higher end of these estimates for use in 2013.

* The Somali population in the Twin Cities is known to have particularly high rates of ASD (see http://rtc.umn.edu/autism/); however these elevated numbers do not fully account for the statewide elevation in autism prevalence.

6 Time for a Healthier Food System

As a nation, we value the wellbeing of our children. Poll after poll shows more than 80 percent of Americans believe that keeping our children healthy is a top priority.[183]

And yet, we continue to use hundreds of millions of pounds of pesticides every year on farms across the country. These chemicals—as science continues to demonstrate—can derail brain and body development, increase risk of cancers, and rob our children of their full potential.

It's time our food system reflected the value we place on our children's health. The health risks created by our current pesticide-reliant methods of industrial agriculture represent an unnecessary, unacceptable and urgent public health problem (see Sidebar 6-1).

In this report we focus in on the particular risks pesticides pose for children in rural farming communities on the frontlines of pesticide exposure. These children, who are often already facing hurdles of poverty, face disproportionate risks to their health. They take in chemicals above and beyond common residues on food—which the American Academy of Pediatrics has identified as an urgent public health concern in its own right.[19]

6-1 Pesticide Rules Prioritize Profit

The Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), passed by Congress in 1947, is our primary national pesticide law. It has been updated several times in the last 65 years as the health and environmental effects of pesticides came into light, most significantly in 1972 and again in 1996—yet it remains fundamentally flawed. The current process:

- Does not allow for quick response to emerging science;
- Does not assess risk based on real-world exposures to multiple pesticides or peak use;
- Does not fully consider the variability of health impacts, especially for children and other vulnerable populations;
- Relies heavily on corporate safety data that are not peer-reviewed;
- Does not encourage the safest form of pest control or management; and
- Does not in any way encourage adoption of the safest pest management methods.

In addition, enforcement of guidelines or restrictions specified on product labels is relegated to state governments that rarely have adequate resources for the job. When it comes to protecting children from harmful pesticide exposures, our current rules do not provide the tools for the job.

Our food and farming system can and must protect children's health, support rural economies and ensure a healthy and abundant food supply.

The fact is, if we take the steps needed to protect rural children from exposure to agricultural pesticides, all children will be better protected. The best and surest way to keep children safe from pesticide harms is to dramatically reduce the volume of use nationwide. The necessary steps to make this change a reality are both achievable and long overdue. Many other countries are already moving in this direction. From France to Denmark to India, state and national governments are setting ambitious goals to increase organic production, and put technical and financial resources in place to help their farmers shift away from pesticide reliance.

Given the fact that there are many proven ways to prevent and manage pest problems[184] without widespread reliance on harmful chemicals, the choice is clear. It is time to build a system of food and farming that protects and promotes the wellbeing of our children, while also supporting thriving rural economies and ensuring a safe and healthy food supply.

Our recommendations

Informed household food choices can help protect families and expand the market for food that is produced without harmful pesticides, encouraging more farmers to make this shift. Indeed, organic production has for years been the fastest growing agricultural sector, gaining ground by 20 percent on average every year. And yet supply is not keeping up with demand, and organic acreage still makes up a tiny fraction of overall food production.*

* USDA reports 400 million acres in cropland in 2012; just over three million of these were certified organic. http://www.ers.usda.gov/topics/farm-economy/land-use,-land-value-tenure/major-land-uses.aspx. Accessed February 11, 2016.

As we noted in our 2012 *A Generation in Jeopardy* report, the burden of protecting children from dangerous chemicals cannot rest solely with individual families; policy change is required. Our revised recommendations below reflect both the increasing urgency of the challenge we face, and the growing opportunities for progress.

1. Reduce overall pesticide use

It's time to set an ambitious national use reduction goal for agricultural pesticides. Once this goal is in place, policymakers at all levels should act quickly to implement strong policies and programs to reach the goal.

By reducing our overall reliance on pesticides, we will not only limit children's exposure during their most vulnerable years, we will also cut the levels of these chemicals in the bodies of men and women of childbearing age—which, as the science clearly shows, is critical to protecting the health of their offspring. We must set a clear, time-bound goal, then identify the steps needed to reach it. We recommend the following policymaker actions:

- **Establish a concrete use reduction target.** Federal officials should set an aggressive national pesticide use reduction goal (e.g., 50 percent within the next 10 years).
- **Establish streamlined use reporting systems.** To track and reward progress toward this goal, publicly accessible pesticide use reporting systems should be established in states across the country.
- **Block new bad actors.** EPA should deny any registration (including short-term "conditional" registrations*) of harmful new pesticides that scientific studies and independent safety testing suggest may be neurodevelopmental or reproductive toxicants, endocrine disruptors, human carcinogens or highly acutely toxic.

2. Protect children first

Our national use reduction goals should prioritize action on those pesticides most harmful to children. To provide immediate protections, pesticide-free buffer zones should be established around schools, daycare centers and other sensitive sites in rural agricultural areas across the country.

As we work toward our national use reduction goals, the current generation of children must be protected

* Under EPA's conditional registration program, new active ingredients and new uses of existing products are temporarily registered pending additional data. As of 2015, more than 150 pesticides had conditional registration status. See www.epa.gov/sites/production/files/2015-09/documents/conditional_registration_status_for_ad_bddp_rd_7-23.pdf

6-2 "Terrible 20" Child-Harming Pesticides

Based on strong evidence of both problematic health outcomes and exposure, PAN International scientists have identified a subset of chemicals from their global "Highly Hazardous Pesticide" list that are particularly hazardous for children.

These "Terrible 20" pesticides are being targeted for urgent action by children's health advocates around the world. Sixteen of the 20 targeted pesticides remain in use in the U.S.; in some cases use is widespread.

"Terrible 20" Pesticides Still Used in U.S.

Pesticide	Type	Primary crops	Health harms	Number of countries where banned*
Atrazine	Herbicide	Corn, soy	Birth defects, cancer, suspected endocrine disruption	37
Carbaryl	Insecticide	Tomatoes, olives, oranges, apples	Cancer, endocrine disruption, developmental toxicant	32
Chlorothalonil	Fungicide	Potatoes, almonds, tomatoes	Cancer	2
Chlorpyrifos	Insecticide	Almonds, walnuts, citrus, vegetables	Neurotoxicant	1
Cypermethrin	Insecticide	Onions, garlic, lettuce, broccoli	Cancer, endocrine disruption	0
Deltamethrin	Insecticide	Almonds, carrots, corn	Endocrine disruption	0
Diazinon	Insecticide	Tomatoes, spinach, apples, peaches	Neurotoxicant, developmental toxicant, endocrine disruption	29
Dichlorvos	Insecticide	Structural & commodity fumigation, beans, almonds	Cancer, neurotoxicant, endocrine disruption	30
Lambda-cyhalothrin	Insecticide	Hay, pistachios, rice, lettuce	Endocrine disruption	28†
Malathion	Insecticide	Strawberries, cherries, walnuts, lettuce	Cancer, neurotoxicant, endocrine disruption	1
Mancozeb	Fungicide	Potatoes, walnuts, lettuce, pears	Cancer, developmental toxicant, endocrine disruption	1
Maneb	Fungicide	Potatoes, lettuce, grapes, broccoli	Cancer, developmental toxicant, endocrine disruption	1
Methyl parathion	Insecticide	Walnuts, potatoes, grapes	Neurotoxicant, endocrine disruption	26
Paraquat	Herbicide	Almonds, cotton, grapes	Endocrine disruption	35
Permethrin	Insecticide	Pistachios, lettuce	Cancer, endocrine disruption	29
Propoxur	Insecticide	Structural, landscape	Cancer, neurotoxicant	29

Terrible 20 pesticides no longer in use in the U.S: DDT, methamidophos, monocrotophos and parathion. For the full PAN International list of Highly Hazardous Pesticides and the full PAN International Consolidated List of Bans (PAN CL), see http://pan-international.org/resources/.

* The PAN CL is not complete, as many countries do not publish lists of banned pesticides, and/or do not notify the Secretariat of the Rotterdam Convention, which is the only international body that keeps track of such bans.

† Not banned in any country, but is not approved in the European Union.

from exposure to harmful pesticides. We recommend rapid implementation of the following measures:

- **Phase out the worst.** EPA (and states with the authority to do so) should immediately phase out the 16 highly hazardous pesticides still in use in the U.S. that are on the "Terrible 20" list of chemicals known to be particularly harmful to children (see Sidebar 6-2).
- **Create protective buffer zones.** State legislators should establish—or give local governments authority to establish—protective pesticide-free buffer zones around schools, daycare centers and residential neighborhoods in agricultural areas. Mobilizing resources to support sustainable farming should be prioritized for these zones.
- **Ensure healthy school lunches.** Local school districts, state agencies and USDA's Farm-to-School program should set goals to incorporate a growing percentage of organic produce in school lunches, and provide schools with incentives to procure fresh, local fruits and vegetables that have been grown without pesticides known to harm children's health.

3. Invest in healthy, innovative farming

We must provide significant and meaningful support, incentives and recognition for farmers stepping off the pesticide treadmill. National and state programs must prioritize investment in healthy, sustainable and resilient agricultural production.

Investing in and rewarding farmers who already grow food without relying on chemicals that harm children's health must be a national priority. Conventional growers need support and incentives as they shift away from pesticide reliance to more knowledge-intensive, agroecological practices that build healthy soil and rely on biological processes.

This includes robust and accessible programs providing hands-on field training and technical advice from independent experts, as well as financial support and incentives. We recommend the following specific actions:

- **Funnel resources to farmers.** Federal and state officials should mobilize and coordinate existing resources to help farmers shift away from pesticide reliance—and provide additional support for farmers who have already made this shift. Research, outreach and education programs should be ramped up in complementary ways with this aim.
- **Increase investment in innovative farming.** Congress should authorize significant funding to support sustainable farming practices that reduce use of harmful pesticides, including USDA and land grant university programs. Existing programs receive a small fraction of the funding supplied to programs serving conventional growers.

The surest way to keep children safe from pesticide harms is to dramatically reduce the volume of use nationwide.

- **Source for children's health.** Public institutions at all levels—local, state and federal—should require that their food suppliers limit use of pesticides that harm children's health, and set specific goals for procurement of locally produced, pesticide-free food. France is currently considering a goal of 40 percent.

We are increasingly optimistic that these commonsense changes are within reach. As the science linking pesticides with children's health harms has become even stronger, both awareness of the problem and support for real solutions continues to grow.

Public health professionals are speaking out more urgently about the implications of their research linking pesticide exposures to increased childhood cancers, altered brain structure, cognitive disorders and other harms. Increasingly strong science documents intergenerational impacts of exposure, underscoring the urgency of acting now to protect future generations. It is also increasingly clear that the impacts of these childhood health harms are both very personal—directly affecting families across the country—and have long-term, society-wide implications. Widespread pesticide exposure is undermining the potential of an entire generation of children.

At the same time, popular awareness and understanding of the "field to fork" impacts of our chemical-dependent food system has deepened. And despite increasingly aggressive pressure from the pesticide/biotech corporations like Dow and Monsanto, policymakers in cities, states and even federal agencies are increasingly open to considering food and farming policies that protect children's health.

It will take strong public pressure to make the significant changes needed, but the time is ripe to muster the political will to build a truly healthy, thriving food and farming system.

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Appendix A: **Key Study Summaries**

The body of scientific literature exploring how pesticides affect children's health is wide, deep and decades long. Our goal is to provide a snapshot of recent key findings that—taken together—provide compelling reason for concern about the impact of pesticides on our children's health.

In Chapters 3 and 4 we highlight a few of the key findings linking pesticide exposures with childhood cancers and neurodevelopmental harms. Here we provide a bit more detail on some of the key studies included in the report, as well as additional studies on these and other health outcomes—focusing primarily on the impacts of prenatal and childhood exposure in rural communities of agricultural pesticide use. Study descriptions are organized alphabetically by health effect, and alphabetically by author within each category.

Asthma & respiratory function

Hernández A.F., T. Parrón and R. Alarcón. "Pesticides and asthma." ***Curr Opin Allergy Clin Immunol*** **2011 11(2): 90–96.**

Hernández et al. performed a review of clinical and epidemiological studies that link exposure to pesticides, asthma attacks and an increased risk of developing asthma. The authors concluded that while many pesticides are sensitizers or irritants, their potential to sensitize is limited. Pesticides may, however, increase the risk of developing asthma, exacerbate a previous asthmatic condition or trigger asthma attacks by increasing bronchial hyper-responsiveness.

Raanan, Rachel, Kim G. Harley, John R. Balmes, Asa Bradman, Michael Lipsett, and Brenda Eskenazi. "Early-Life Exposure to Organophosphate Pesticides and Pediatric Respiratory Symptoms in the CHAMACOS Cohort." ***Environ Health Persp*****, November 4, 2014. doi:10.1289/ehp.1408235.**

Participants in this study included 359 mothers and children from the CHAMACOS birth cohort in Salinas, California. Dialkylphosphate (DAP) metabolites of OP pesticides, specifically diethyl (DE) and dimethyl (DM) phosphate metabolites, were measured in urine from mothers twice during pregnancy (mean = 13 and 26 weeks gestation) and from children five times during childhood (0.5–5 years). Associations of these prenatal and childhood OP metabolite concentrations with respiratory symptoms were assessed, adjusting for potential confounding factors such as maternal smoking during pregnancy and secondhand tobacco smoke. The strongest association was found between respiratory symptoms and total DAP and DE exposure in the second half of pregnancy. The authors concluded that prenatal and early-life exposure to some OP pesticides was associated with respiratory symptoms consistent with possible asthma in childhood.

Raanan, Rachel, John R Balmes, Kim G Harley, Robert B Gunier, Sheryl Magzamen, Asa Bradman, and Brenda Eskenazi. "Decreased Lung Function in 7-Year-Old Children with Early-Life Organophosphate Exposure." ***Thorax*****, December 3, 2015, thoraxjnl – 2014–206622. doi:10.1136/thoraxjnl-2014-206622.**

The authors evaluated associations between early-life OP exposure and lung function of children living in an agricultural community using biomarkers and pulmonary lung function tests in children. Participants were 279 children from the CHAMACOS longitudinal birth cohort in California. OP exposure was determined by urinary diethyl and dimethyl dialkylphosphate metabolites, which were measured five times during childhood (6–60 months). Spirometry (a test of lung function) was performed at age seven. The researchers controlled for confounding factors such as maternal smoking during pregnancy. The authors found lower forced expiratory volume and forced vital capacity (both markers of lung function) per 10-fold increase of total dialkylphosphate levels. Early-life OP exposure was adversely associated with 7-year-old children's lung function.

Salam MT, Y.F. Li, B. Langholz, F.D. Gilliland."Early-life environmental risk factors for asthma: findings from the Children's Health Study." ***Environ Health Persp*** **2003 112(6): 760–765.**

Researchers from the University of Southern California selected 4,244 subjects from the Children's Health Study conducted in 12 southern California communities, some of which had proximity to farmland, to measure the relationship between childhood environmental exposures and asthma risk. Matching those subjects diagnosed with asthma before age five with asthma-free counterparts that acted as controls (matched for age, sex, community of residence, and *in utero* exposure to maternal smoking), the authors concluded that pesticide exposures during the first year of life are associated with an increase in the risk for early-onset persistent asthma. Compared to never-exposed children, children exposed to herbicides within the first year of life had a 4.6-fold increased risk of asthma and children exposed to any pesticides had a 2.4-fold increase in risk.

Birth defects & birth outcomes

Note: A number of studies showing no associations were not included in these summaries.

Agopian, A.J., Philip J. Lupo, Mark A. Canfield, and Peter H. Langlois. "Case-Control Study of Maternal Residential Atrazine Exposure and Male Genital Malformations." ***American Journal of Medical Genetics Part A*** **161, no. 5 (May 2013): 977–82. doi:10.1002/ajmg.a.35815.**

USGS estimates of atrazine applications in Texas were compared with Texas Birth Defects Study records of male genital malformation in a case-control study. Women with medium-low or medium levels of residential atrazine exposure had significantly increased odds of having offspring with any male genital malformation compared to low levels of atrazine use. Interestingly, they also observed a non-monotonic (non-linear) dose response in their results. Those with high levels of exposure were at a significantly decreased risk compared to those with low levels of exposure. Results for hypospadias, small penis, and cryptorchidism were consistent with an inverted U-shaped risk curve. Atrazine has been shown to induce hypospadias, specifically in rats.

Agopian, A.J., Yi Cai, Peter H. Langlois, Mark A. Canfield, and Philip J. Lupo. "Maternal Residential Atrazine Exposure and Risk for Choanal Atresia and Stenosis in Offspring." ***The Journal of Pediatrics*** **162, no. 3 (March 2013): 581–86. doi:10.1016/j.jpeds.2012.08.012.**

In Texas, county-level estimates of atrazine exposure obtained from the USGS based on crop type and application rates in nearby fields were assigned to cases of the birth defect choanal atresia and stenosis. Data for this case-control study consisted of 280 nonsyndromic birth defects cases and randomly selected, population-based controls delivered during 1999 to 2008. The offspring of mothers with high levels of estimated exposure had a two-fold increased risk of the defects compared to those with low exposure levels. Choanal atresia and stenosis is a birth defect characterized by complete blockage and narrowing of regions of the airway, and often requires multiple surgeries to be corrected.

Garry V.F., M.E. Harkins, L.L. Erickson, L.K. Long-Simpson, S.E. Holland and B.L. Burroughs. "Birth defects, season of conception, and sex of children born to pesticide applicators living in the Red River Valley of Minnesota, USA." ***Environ Health Persp*** **2002. 110(3): 441–449.**

Researchers in Minnesota examined reproductive health outcomes from 1,532 children including 695 farm families with parent-reported birth defects. Researchers determined that conception in the springtime led to significantly more children born with birth defects, compared to children conceived in any other season. Their data support the hypothesis that environmental agents present in the spring, like herbicides, are associated with an increased risk of birth defects. In addition, increased odds of being born with neurobehavioral effects were associated with the use of the herbicide glyphosate, and a male predominance in sex ratio was associated with use and exposure to fungicides.

Markel, Troy A., Cathy Proctor, Jun Ying, and Paul D. Winchester. "Environmental Pesticides Increase the Risk of Developing Hypertrophic Pyloric Stenosis." *Journal of Pediatric Surgery* 50, no. 8 (August 2015): 1283–88. doi:10.1016/j.jpedsurg.2014.12.009.

Hypertrophic pyloric stenosis (HPS) is a defect noted within the first several weeks of life that results in enlargement of the pyloric muscle between the stomach and the small intestine. The authors hypothesized that agricultural pesticides would be associated with an increased incidence of pyloric stenosis. USGS estimates for county pesticide use in the state of Indiana from 2005-2009 were used to categorize low, medium, or high exposure levels. Indiana's Birth Defects Registry and Indiana Department of Health data were used to compare cases of HPS. Total pesticide levels in the county of residence correlated significantly with the incidence of HPS; notably the herbicides glyphosate and atrazine were each significantly correlated.

Rocheleau, C.M, P.A. Romitti and L.K. Dennis. "Pesticides and Hypospadias: a Meta-analysis." *Journal of Pediatric Urology*. Feb 2009 5(1): 17–24.

Hypospadia affects development of the penis, characterized by abnormal positioning of the opening of the urethra, which ranges in severity of effect. A meta-analysis of studies published in English from 1966 through 2008 from Canada, Denmark, Italy, Netherlands, Norway, Spain, and the U.S. indicated a 36 percent increased risk of hypospadia with maternal occupational exposure to agricultural pesticides and a 19 percent increased risk of hypospadias with paternal occupational exposure. Residential pesticide exposure was not evaluated.

Winchester PD, Huskins J, Ying J. 2009. Agrichemicals in surface water and birth defects in the United States. *Acta Paediatr* 98(4): 664–669.

Researchers from Indiana and Ohio compared water data from the USGS National Water Quality Assessment (NAWQA)—measuring the levels of nitrates, atrazine, and other pesticides in surface water—and Centers for Disease Control data detailing monthly pregnancy and birth outcomes. The data reveal that between 1996 and 2002, women in the US were significantly more likely to give birth to a child with birth defects if conception had occurred in the months of April through July. NAWQA surface water samples indicate that concentrations of atrazine, nitrates, and other pesticides were also higher in the months of April through July. This correlation was statistically significant, demonstrating elevated concentrations of agrichemicals in surface water coincided with a higher risk of birth defects among live births for children conceived between April and July.

Brain & nervous system harms

European Food Safety Authority. "Scientific Opinion on the Developmental Neurotoxicity Potential of Acetamiprid and Imidacloprid." *EFSA Journal* 11, no. 12 (2013): 3471.

A scientific opinion paper issued in 2013 (and updated in 2014) by the European Food Safety Authority on the potential for developmental neurotoxicity of two neonicotinoid insecticides, acetamiprid and imidacloprid. The panel cited concerns over toxicity to developing mammalian nervous systems, similar to effects that occur with nicotine, which acts via the nicotinic acetylcholine receptors. Given evidence that these two neonicotinoids could act on the same receptors to excite and/or desensitize them, these chemicals could affect developing mammalian nervous systems similar to nicotine. The panel concluded that both compounds may affect neuronal development and function, and that current acute reference doses may not be protective enough for the possible developmental neurotoxicity of these neonicotinoids. In addition, the Panel concluded that "no reliable conclusion" could be drawn for the acceptable daily intake for acetamiprid, but the current acceptable daily intake for imidacloprid was considered to be appropriately protective.

Eskenazi B., K. Huen, A. Marks, K.G.Harley, A. Bradman, D.B. Barr, et al. "PON1 and Neurodevelopment in Children from the CHAMACOS Study Exposed to Organophosphate Pesticides in Utero." *Environ Health Persp* Aug 2010 118: 1775-1781. See http://dx.doi.org/10.1289/ehp.1002234.

The enzyme paraoxonase 1 (PON1) detoxifies metabolites of some OP pesticides, and PON1 genetic variations among individuals influence enzyme activity and quantity. The study authors investigated whether PON1 genotypes and enzyme activity levels in mothers and their children were linked to neurodevelopmental changes and/or prenatal exposure to OP pesticides (as assessed by maternal urinary concentrations of dialkyl phosphate metabolites). The researchers found that of the 353 two-year-olds assessed, children with a certain variation of PON1 (the PON1-108T allele) scored more poorly on the Mental Development Index and somewhat lower on the Psychomotor Development Index. The authors concluded that while the variations of PON1 were clearly associated with outcomes in child neurobehavioral development, additional research is needed to confirm the relationship between PON1 genotype, enzyme activity and exposure to OP pesticides.

Richardson, Jason R., Michele M. Taylor, Stuart L. Shalat, Thomas S. Guillot, W. Michael Caudle, Muhammad M. Hossain, Tiffany A. Mathews, Sara R. Jones, Deborah A. Cory-Slechta, and Gary W. Miller. "Developmental Pesticide Exposure Reproduces Features of Attention Deficit Hyperactivity Disorder." *FASEB Journal: Official Publication of the Federation of American Societies for Experimental Biology* 29, no. 5 (May 2015): 1960–72. doi:10.1096/fj.14-260901.

This cross-sectional study examined developing mice and exposure to deltamethrin, a pyrethroid insecticide. Pregnant female mice were given oral doses of deltamethrin every three days. The doses were lower than the "no observable adverse effect level" or NOAEL, which is used to set an allowable range for human exposure by EPA, to mimic common exposure levels in the population. The offspring of the mice, which were exposed in utero, were then assessed using a number of markers of behavior and neurochemistry that are associated with attention deficit hyperactivity disorder (ADHD). Exposure to deltamethrin during development resulted in increased dopamine transporter (DAT) levels in the brain, deficits in working memory and attention, and impulsive-like behaviors. The researchers observed features reminiscent of ADHD as a result of prenatal exposure to deltamethrin in mice. The authors hypothesized that conflicting results from other studies may be due to variation in DAT expression in different regions of the brain, depending on animal models used. The researchers also analyzed data from the National Health and Nutrition Examination Survey (NHANES), and found that children with elevated metabolites of pyrethroid pesticides in their urine were more likely to be diagnosed with ADHD.

Rohlman, Diane S., T.A. Arcury, S.A. Quandt, M. Lasarev, J. Rothlein, R. Travers, et al. "Neurobehavioral Performance in Preschool Children from Agricultural and Non-Agricultural Communities in Oregon and North Carolina." *NeuroToxicology* 26, no. 4 (August 2005): 589–98. doi:10.1016/j.neuro.2004.12.002.

This study focused on low-level chronic exposures to OP pesticides in Latino children of agricultural workers. Neurobehavioral performance in preschool children from agricultural communities were compared to non-agricultural communities in Oregon and North Carolina. Modest differences were found in agricultural community children compared to non-agricultural community children that were consistent with effects in adults exposed to low concentrations of OP pesticides, based on previous findings by the same investigators on adults and adolescents. Multiple regression analysis revealed that the agricultural children performed less well on measures of response speed (Finger Tapping) and latency (Match-to-Sample).

Sagiv, Sharon K., Sally W. Thurston, David C. Bellinger, Larisa M. Altshul, and Susan A. Korrick. "Neuropsychological Measures of Attention and Impulse Control among 8-Year-Old Children Exposed Prenatally to Organochlorines." *Environ Health Persp* 120, no. 6 (February 22, 2012): 904–9. doi:10.1289/ehp.1104372.

This study was on a birth cohort in New Bedford, MA born between 1993-1998. They examined PCBs and p,p'-DDE cord serum, and used a teacher's rating scale to examine attention and impulse control (Continuous Performance Test) and components of the Wechsler Intelligence Scale for Children, 3rd edition. Children with p,p'-DDE (a breakdown product of the organochlorine insecticide DDT) in cord serum had significantly lower test scores; those with PCBs showed an even greater effect. The authors pointed out sex-specific effects that have been identified in other studies. The results support an association between organochlorines and neuropsychological measures of attention among boys in Massachusetts, where eight-year-old boys had associations for higher exposure to both p,p-DDE and PCBs with neuropsychological deficits.

Shelton, Janie F., E.M. Geraghty, D.J. Tancredi, L.D. Delwiche, R.J. Schmidt, B. Ritz, et al."Neurodevelopmental Disorders and Prenatal Residential Proximity to Agricultural Pesticides: The CHARGE Study." *Environ Health Persp*, June 23, 2014. doi:10.1289/ehp.1307044.

The CHARGE study is an ongoing California population-based case-control study of >1,600 participants that aims to uncover a broad array of factors contributing to autism and developmental delay. This study focused on autism spectrum disorder (ASD) and developmental delays (DD) in relation to residential proximity to agricultural pesticide applications during pregnancy. For exposure (any vs. none) during pregnancy, children with ASD were 60% more likely to have OPs applied near the home than mothers of DD children. Children with DD were nearly 150% more likely to have carbamate pesticides applied near the home. The study reported positive associations between ASD and prenatal residential proximity to OP pesticides in the second (for chlorpyrifos) and third trimesters (OPs overall), and pyrethroids in the three months before conception and in the third trimester.

Wagner-Schuman, Melissa, Jason R. Richardson, Peggy Auinger, Joseph M. Braun, Bruce P. Lanphear, Jeffery N. Epstein, Kimberly Yolton, and Tanya E. Froehlich. "Association of Pyrethroid Pesticide Exposure with Attention-Deficit/hyperactivity Disorder in a Nationally Representative Sample of U.S. Children." *Environmental Health: A Global Access Science Source* 14 (2015): 44. doi:10.1186/s12940-015-0030-y.

Pyrethroid insecticides produce an ADHD phenotype in animal models with the effects more pronounced in males. Exposure to pyrethroids can come from multiple sources—via agricultural use, food residues and use in the home. A national sample was used for this cross-sectional study, examining 8–15 year old participants (N = 687) in the 2001–2002 National Health and Nutrition Examination Survey. Exposure was assessed using concurrent urinary levels of the pyrethroid metabolite 3-phenoxybenzoic acid (3-PBA). ADHD was defined by either meeting Diagnostic and Statistical Manual of Mental Disorders-Fourth Edition criteria on the Diagnostic Interview Schedule for Children (DISC) or caregiver report of a prior diagnosis. Children with urinary 3-PBA above the limit of detection were twice as likely to have ADHD compared with those below the limit of detection. Hyperactive-impulsive symptoms increased by 50% for every 10-fold increase in 3-PBA levels, while effects on inattention were not significant. In addition, the authors found that prevalence of ADHD was higher in those with detectable urinary pyrethroid pesticide levels than those with non-detectable levels.

Childhood cancers

Booth, Benjamin J., M.H. Ward, M.E. Turyk, and L.T. Stayner. "Agricultural Crop Density and Risk of Childhood Cancer in the Midwestern United States: An Ecologic Study." *Environmental Health* 14, no. 1 (December 2015). doi:10.1186/s12940-015-0070-3.

This "ecologic" study was used to help generate hypotheses about relationships between environmental exposures and health outcomes. County-level crop production data was used as a proxy for pesticide exposure. Cancer registries in six Midwest states (Iowa, Illinois, Indiana, Michigan, Ohio, and Missouri) provided incidence data for leukemia; specifically acute lymphoid leukemia (ALL) and acute myeloid leukemia (AML) among children ages 0-4 years. Significant associations were found, including higher levels of total leukemias in areas of dry bean production; oat production and increased incidence of AML; and sugarbeets and total leukemias. State-level analyses showed additional positive associations between several crops and total leukemia and central nervous system tumors.

Flower, Kori B., Jane A. Hoppin, Charles F. Lynch, Aaron Blair, Charles Knott, David L. Shore, and Dale P. Sandler. "Cancer Risk and Parental Pesticide Application in Children of Agricultural Health Study Participants." *Environ Health Persp* 112, no. 5 (April 2004): 631–35.

A follow-up Agricultural Health Study of 17,357 children of pesticide applicators in Iowa showed an increased risk of childhood cancers, including all lymphomas. Stronger associations were found between cancer risk and fathers' exposure, which was assessed via questionnaire on work practices and exposure. An increased risk of cancer was detected among children whose fathers did not use chemically-resistant gloves compared with fathers who did use gloves. Risk was increased when fathers were exposed prenatally to aldrin, dichlorvos and ethyl dipropylthiocarbamate. The results from this analysis suggest that on-farm parental exposures to pesticides may play a role in the etiology of childhood lymphoma.

Kunkle, Brian, S. Bae, K. P. Singh, and D. Roy. "Increased risk of childhood brain tumors among children whose parents had farm-related pesticide exposures during pregnancy." *JP Journal of Biostatistics* 11, no. 2 (November 2014): 89–101.

Malignant brain tumors are the leading cause of cancer death in children. Meta-analyses of 15 published epidemiology studies indicated that preconception and prenatal pesticide exposure increase brain tumor risk. This effect was found in children whose mothers had farm-related exposure in pregnancy or whose fathers were exposed before conception. The researchers also conducted a search of a comparative toxicogenomics database, and identified an association between herbicide and astrocytoma with more than 300 genes altered by exposure to herbicides, fungicides, insecticides or all pesticides.

Van Maele-Fabry, Geneviève, Perrine Hoet, and Dominique Lison. "Parental Occupational Exposure to Pesticides as Risk Factor for Brain Tumors in Children and Young Adults: A Systematic Review and Meta-Analysis." *Environment International* 56 (June 2013): 19–31. doi:10.1016/j.envint.2013.02.011.

This systematic review and meta-analysis of 20 studies published between 1974-2013 examined parental occupational pesticide exposure and occurrence of childhood brain tumors. The authors found statistically significant associations for parents potentially exposed to pesticides in occupational settings and occurrence of brain tumors in their offspring. Significantly increased risk of astroglial brain tumors was observed for prenatal and preconception exposures. Although the analysis supports an association between brain tumors and occupational pesticide exposures, results should be interpreted with caution due to potentially confounding effects of work-related factors other than pesticide exposure.

Vinson, F., M. Merhi, I. Baldi, H. Raynal, and L. Gamet-Payrastre. "Exposure to Pesticides and Risk of Childhood Cancer: A Meta-Analysis of Recent Epidemiological Studies." *Occupational and Environmental Medicine* 68, no. 9 (September 1, 2011): 694–702. doi:10.1136/oemed-2011-100082.

A meta-analysis of 40 studies analyzing odds ratio data showed an increased odds ratio of lymphoma and leukemia in children whose mothers were exposed to pesticides prenatally. Brain cancer risk was correlated with paternal prenatal and postnatal exposures. The leukemia odds ratio (a statistical calculation of odds that can indicate whether the effect is statistically significant)was associated with prenatal exposure of both the mother and father. The authors also did a meta-analysis of three cohort studies that reported relative risk values and found no link between parental pesticide exposure and childhood cancer incidence.

Diabetes & obesity

Janesick, A. and B. Blumberg. "Endocrine Disrupting Chemicals and the Developmental Programming of Adipogenesis and Obesity." *Birth Defects Research Part C: Embryo Today:* Reviews 2011. 93, no. 1: 34–50.

This review article explores possible explanations for the variation in individual propensity to gain weight and accrue body mass, even at identical levels of caloric input. The authors review evidence from clinical, epidemiological, and biological studies showing that obesity is largely programmed early in life, including prenatally. They examine the environmental obesogen hypothesis, which holds that "prenatal or early life exposure to certain endocrine disrupting chemicals can predispose exposed individuals to increased fat mass and obesity. Obesogen exposure can alter the epigenome of multipotent stromal stem cells, biasing them toward the adipocyte lineage at the expense of bone." The authors concluded that individuals exposed to obesogens early in life or prenatally might thus experience changes in their stem cell compartment, which in turn influences the generation of fat cells from stem cells.

Lee, Duk-Hee, Miquel Porta, David R. Jacobs, and Laura N. Vandenberg. "Chlorinated Persistent Organic Pollutants, Obesity, and Type 2 Diabetes." *Endocrine Reviews* 35, no. 4 (August 2014): 557–601. doi:10.1210/er.2013-1084.

The authors reviewed evidence on persistent organic pollutants (POPs) and Type 2 diabetes. From the evidence they evaluated, it appears that background exposure to mixtures of POPs (organochlorines and polychlorobiphenyls, or PCBs) can increase Type 2 diabetes risk in humans. Authors suggested that inconsistencies in results from different studies may be due to differences in distribution of exposure among study subjects. Furthermore, there may be differences in the observed shape of the dose-response curve (e.g., an inverted U-shaped association) in human studies which can result in inconsistencies, depending on the levels and associations.

Warner, M., A. Wesselink, K. G. Harley, A. Bradman, K. Kogut, and B. Eskenazi. "Prenatal Exposure to Dichlorodiphenyltrichloroethane and Obesity at 9 Years of Age in the CHAMACOS Study Cohort." *American Journal of Epidemiology* 179, no. 11 (June 1, 2014): 1312–22. doi:10.1093/aje/kwu046.

This CHAMACOS study (Salinas, California) examined prenatal exposure to DDT and DDE in nine-year-old children, and found that prenatal exposures in boys were associated with increased odds of becoming overweight or obese, while associations for girls were not significant. The sex differences persisted after considering pubertal status. Obesity was based on BMI, obesity, waist circumference, and percent body fat among the 261 children studied. The results of this study support the hypothesis that DDT and DDE may act as "obesogens." Interestingly, an earlier study by Warner et al. (2013) on the same group of children at age seven did not find significant correlations between obesity and DDT exposure [Warner, Marcella, et al. "In Utero DDT and DDE Exposure and Obesity Status of 7-Year-Old Mexican-American Children in the CHAMACOS Cohort." *Environmental Health Perspectives* 121, no. 5 (March 19, 2013): 631–36. doi:10.1289/ehp.1205656].

Reproductive harms

Aksglaede L., K. Sorensen, J.H. Petersen, N.E. Skakkebaek and A. Juul. "Recent decline in age at breast development: The Copenhagen puberty study." Pediatrics 2009. 123(5): e932-939.

Researchers from Denmark collected data from 2095 females aged 5.6 to 20 years in two Copenhagen cohorts (1991–1993 and 2006–2008) to examine differences in breast development. Using the most accurate method of palpation, the authors found the onset of puberty—defined as the mean estimated age at the attainment of glandular breast tissue—occurred significantly earlier in the 2006 cohort. The ages at which menarche and pubic hair development occurred also slightly decreased in the 2006 cohort. As a result of these timing changes in early and later markers of puberty, the length of puberty appears to have increased. The authors interpreted these observations as indicative of gonadotropin-independent estrogenic actions at the level of breast development, rather than an earlier activation of the pituitary-gonadal axis. These changes in timing could not be explained by alterations in reproductive hormones and BMI, suggesting other factors involved need to be explored.

Wohlfahrt-Veje, C., H. R. Andersen, T. K. Jensen, P. Grandjean, N. E. Skakkebaek, and K. M. Main. "Smaller Genitals at School Age in Boys Whose Mothers Were Exposed to Non-Persistent Pesticides in Early Pregnancy: Prenatal Pesticide Exposure and Reproductive Health in Boys." *International Journal of Andrology* 35, no. 3 (June 2012): 265–72 doi:10.1111/j.1365-2605.2012.01252.x.

This study addressed genital size at school age in Danish boys age six to 11 who were either sons of occupationally exposed greenhouse workers or unexposed mothers. Examinations of 86 to 94 boys at ages six to 11 years of age included genital examination (eight boys declined this) and gynecomastia. Eighty-four of the boys had blood samples taken, with serum concentration of several hormones that play a role in reproductive development, including anti-Mullerian hormone, follicle-stimulating hormone, luteinizing hormone, sex hormone binding globulin, estradiol, testosterone and inhibin B. Fifty-nine boys were in the exposed group, 35 were in the group whose mothers were unexposed. Sons of women in the high exposure group had smaller genital size compared to sons of women who had medium exposure; both groups had smaller genitals compared to unexposed mothers. After excluding the boys with genital malformations, boys in the high exposure group still had significantly reduced testis volume.

Wohlfahrt-Veje, C., H. R. Andersen, I. M. Schmidt, L. Aksglaede, K. Sørensen, A. Juul, T. K. Jensen, P. Grandjean, N. E. Skakkebaek, and K. M. Main. "Early Breast Development in Girls after Prenatal Exposure to Non-Persistent Pesticides: Prenatal Pesticide Exposure and Reproductive Health in Girls." *International Journal of Andrology* 35, no. 3 (June 2012): 273–82. doi:10.1111/j.1365-2605.2011.01244.x.

Pregnant women working in greenhouses in Funen, Denmark, were recruited for this prospective study from July 1996 to October 2000. The main exposure for most women were growth regulators and fungicides. Their offspring, eighty-three girls between ages 6 and 11, were examined between 2007-2008. Fifty-three girls were in the exposed group, 30 were in the unexposed group. Breast development occurred about 1-1.5 years earlier in the exposed girls compared to the unexposed.

Zawatski, W., and M. M. Lee. "Male Pubertal Development: Are Endocrine-Disrupting Compounds Shifting the Norms?" *Journal of Endocrinology* 218, no. 2 (July 11, 2013): R1–12. doi:10.1530/JOE-12-0449.

This review examines evidence for a shift in pubertal timing in males associated with exposure to polychlorobiphenyls and discussed evidence supporting the subtle effects of lead, dioxins and the organochlorine pesticide endosulfan on delaying pubertal onset and progression in boys. Exposure to endocrine-disrupting compounds may also affect pubertal testosterone production without having a noticeable effect on sexual maturity rating. Several of the reports reviewed demonstrate plausible associations of exposures to EDCs with altered pubertal onset humans, which are consistent with animal data. The authors conclude that these findings, in parallel with the observed secular trends in pubertal timing, support a role for environmental chemicals in shifting pubertal development. It is not known whether changes in pubertal development pose future health risks for infertility or other detrimental reproductive or metabolic outcomes.

Appendix B: Glossary of Key Terms

Active ingredient – The ingredient or ingredients in a pesticide that prevents, destroys or controls pests. All other ingredients are inert, meaning that they do not contribute directly to mitigating pests but add to product performance. For example, inerts may act to help the active ingredient penetrate a plant's surface, shield the pesticide from degradation due to exposure to sunlight, or extend a product's shelf-life.

Cumulative exposure – The aggregate effect of exposure to multiple chemicals/pesticides that an organism/person may experience over time.

Cumulative impacts – The aggregate effect of exposures to environmental contaminants and other determinants of health that may compound or otherwise add to the overall effect. Cumulative impacts is a newer way for public health scientists to assess the effects of exposure to multiple environmental contaminants as well as non-chemical stressors such as poverty or race.

Endocrine disruptors – The endocrine system is a collection of glands that produce hormones that regulate metabolism, growth and development, tissue function, reproduction, sleep and mood, among other things. Endocrine disruption refers to interference with any aspect of hormone function by an exogenous (e.g., not originating from an organism) chemical or mixture of chemicals. Such interference can, for instance, occur when environmental contaminants mimic or block hormones or hormonal action.

Epigenetics – The study of mechanisms that regulate gene expression. These mechanisms do not alter the DNA itself, however, they do turn genes on and off in ways that can either promote or interfere with health. Epigenetic changes can arise in response to the environment, for example, from diet, stress, smoking or exposure to chemicals. Some epigenetic changes may be passed from parents to offspring.

Field trials – The testing of different seed varieties, pesticides, fertilizers and other variables to compare the resulting yields.

Food tolerance – The maximum amount of a pesticide allowed to remain in or on food as determined by EPA.

Fumigants – Pesticides used to manage insects, weeds and disease-causing fungi and nematodes. A standard pre-planting treatment, often fumigants are sprayed or spread over an area before cultivation with the intention of managing pests in the soil. Designed to vaporize, fumigants are highly volatile and prone to drift.

Genetically engineered (GE) – Organisms that have had the genes of another organism inserted into their genetic code for perceived advantage. For the purposes of this report, GE is used mainly in reference to crops that have been engineered to be resistant to herbicides.

Herbicide – A pesticide designed to prevent, destroy or control plants, weeds or grasses.

Insecticide – A pesticide designed to prevent, destroy or control insects.

Incidence – A measure of the number of new cases of a characteristic (e.g., a disease or a risk factor) of a population arising over a given period of time.

Inhalation exposure – Exposure to a chemical by breathing it.

Neurotoxicity – Any poisonous effect produced specifically on nervous tissue, the primary tissue of the central nervous system (brain and spinal cord), which regulates sensory input, muscle control and mental activity. Neurotoxicity may also affect the peripheral nervous system, which comprises the motor and sensory nerves that connect the central nervous system to the rest of the body.

Obesogen – An endocrine disruptor that interferes with normal development and control over fat cell proliferation and energy balance, often resulting in weight gain.

Pesticide – Any substance intended for preventing, destroying or controlling pests, including vectors of human or animal disease, plant and animal species that cause harm to or interfere with agricultural production, processing and storage, wood and wood products and animal feed. Pesticides may also be administered to animals to control pests in or on their bodies or used as a plant growth regulator, defoliant or desiccant. Pesticides contain at least one active ingredient and any number of inert ingredients.

Pesticide drift – The off-target movement of agricultural pesticides into residential areas, schools and other private and public spaces. There are two primary types of drift, spray and volatilization. Pesticides can also move around in the environment when they land on soil and stick to dust. Wind can then blow contaminated dust particles up and off the site.

Physical properties – The physical properties of a chemical compound such as a pesticide influence its mode of action (how it works), dosage and mode of application, and include such characteristics as molecular weight and form (appearance and odor), vapor pressure (how easily it can volatilize), solubility (how easily it can dissolve in a given solvent) and soil adsorption (how easily it "sticks" to soil and sediment). These qualities also help determine how long a pesticide might persist in the environment and whether it gets broken down or bioaccumulates in an organism.

Prevalence – The proportion of a population that has (or had) a certain characteristic, such as a disease or a risk factor.

Reference value – A value derived using risk assessment of an individual pesticide that can be used as a basis for determining what a "safe" level of exposure is. Government agencies can derive different reference values based on their different risk assessment approaches. For instance, different assumptions might be made with regards to inhalation toxicity of a specific pesticide, by accounting for the different breathing rates of adults and infants.

Risk – In the study of public health, the size of an effect can be calculated statistically by determining risk, which can be expressed as a proportion or a percentage. Risk is the proportion of people with a disease divided by the number of people who are at risk for that disease. Another way of calculating the size of an effect is known as an "odds ratio," which is a different calculation that sometimes gets confused with relative risk because at times, the values obtained can be close numerically. The odds are the number of people who experience the event divided by the number of those who do not.

Spray drift – The uncontrolled movement of pesticides when wind blows these in the form of liquid droplets during spraying.

Synergistic effect – When different chemicals/pesticides interact in a way that produces effects greater than the sum of their individual parts.

Systematic review – A method for answering research questions using a predefined, multistep process to identify, select, critically assess, and synthesize evidence from scientific studies to reach a conclusion. Systematic review allows for transparency in the process of reviewing disparate lines of scientific evidence to document the basis of scientific judgments.

Take-home pathway – An exposure pathway by which contaminants are transported from the workplace to the residence by a worker's clothing, skin, hair or other means. Children and other family members may be exposed to higher levels of environmental contaminants by this pathway.

Toxic – Any substance that contains poisons or is itself poisonous.

Toxicity – Any poisonous effect produced by exposure to a chemical.

Toxin – Any poison or venom produced by an organism that may cause disease when introduced into the body.

Volatilization drift – The uncontrolled movement of pesticides as they "volatilize" or turn into gas and rise into the air, which can occur hours or sometimes days after application. Fumigants are an example of a type of pesticide that can volatilize very readily.

Appendix C: Top Pesticides Used

Key
? – Insufficient data
ND – No data available
I – Insecticide
H – Herbicide
F – Fungicide
PGR – Plant growth regulator
FUM – Fumigant

Table C-1: Most Commonly Used Pesticide Active Ingredients - Agriculture Listed by volume of use[1]

Pesticide & use level range (millions of lbs active ingredient)	**PAN HHP[2]**	**Type**	**High[3] acute toxicity**	**Carcin-ogen**	**Acute neuro-toxicant (ChE inhibitor)**	**Devel. or reprod. toxicant**	**Endocrine disruptor**	**Primary crops**	**Food residues[4]**
Glyphosate (180-185)		H				?	?	Hay/pasture, soybeans, corn	ND
Atrazine (73-78)	Y	H		Y		?	suspected	Corn, sugarcane	Spinach, wheat, onions, lettuce, water
Metam-sodium (50-55)	Y	FUM	Y	Y		Y	suspected	Potatoes, carrots, tomatoes, onions, peanuts	ND
Metolachlor, (S) (30-35)	Y	H		possible		?	suspected	Tomatoes, beans, corn, cotton	Oats, celery, water, corn
Acetochlor (28-33)	Y	H		Y		?	suspected	Corn, popcorn	Water
Dichlorpropene (27-32)		FUM	Y	Y		?	?	Strawberries, sweet potatoes, tree nuts	
2,4-D (25-29)	Y	H		possible		?	suspected	Grasses, wheat, citrus fruits, tree nuts	Potatoes, water
Methyl bromide (11-15)	Y	FUM	Y			Y	suspected	Tomatoes, strawberries, almonds, peppers, watermelon, cucumbers	ND
Chloropicrin (9-11)	Y	FUM	Y	?		?	?	Tobacco, tomatoes, strawberries, bell peppers	ND
Pendimethalin (7-9)	Y	H		possible		?	suspected	Soybeans, corn, cotton, peanuts	Carrots, collard greens, kale
Ethephon (7-9)		PGR			Y	?	?	Cotton, walnuts, grapes, tomatoes	ND
Chlorothalonil (7-9)	Y	F	Y	Y		?	?	Tomatoes, watermelons, onions	Cranberries, celery, green beans
Metam Potassium (7-9)		FUM	Y	Y		Y	?	Lettuce, potatoes	ND
Chlorpyrifos (7-9)	Y	I			Y	?	suspected	Tree nuts, apples, alfalfa, broccoli, citrus, grapes, sweet corn	Apples, bell peppers, cranberries, kale, grapes, peaches
Copper Hydroxide (6-8)		F				?	?	Tree nuts, grapes, peaches	ND
Simazine (5-7)	Y	H				Y	suspected	Corn, citrus, grapes, tree nuts	Blueberries, kale, water, oranges
Trifluralin (5-7)	Y	H		possible		?	suspected	Soybeans, cotton, green beans, broccoli, tomatoes	Carrots, spinach, wheat, soybeans, broccoli
Propanil (4-6)	Y	H		possible		?	suspected	Rice, oats, barley, wheat	Wheat
Mancozeb (4-6)	Y	F		Y		Y	suspected	Apples, tomatoes, onions, watermelon	ND
Acephate (2-4)	Y	I		possible	Y	?	suspected	Cotton, tobacco, cranberries, mint	Green beans, bell peppers
Diuron[5] (2-4)	Y	H		Y		Y	suspected	Oranges	Asparagus, oranges, water, potatoes
MCPA (2-4)	Y	H	Y	possible		?	?	Flax, barley, wheat, rice	water
Paraquat (2-4)	Y	H	Y			?	suspected	Corn, soybeans, cotton, apples	ND
Dimethenamid (2-4)	Y	H		possible		?	?	Corn, soybeans, sugarbeets	Soybeans, water

Table C-2: Most Commonly Used Pesticide Active Ingredients – Home & Garden
Listed by volume of use

Pesticide & use level range (millions of lbs active ingredient)	**PAN HHP**	**Type**	**High acute toxicity**	**Carcinogen**	**Acute neurotoxicant (ChE inhibitor)**	**Devel. or reprod. toxicant**	**Endocrine disruptor**
2,4-D (8-11)	Y	H		possible		?	suspected
Glyphosate (5-8)		H				?	?
Carbaryl (4-6)	Y	I		Y	Y	Y	suspected
Mecoprop-P (MCPP) (4-6)	Y	H		possible		?	?
Pendimethalin (3-5)	Y	H		possible		?	suspected
Pyrethroids[6] (2-4)	Y	I	Y	Y		Y	suspected
Malathion (2-4)	Y	I	Y	possible	Y	Y	suspected
Dicamba (1-3)		H				Y	?
Malathion (2-4)	Y	I	Y	possible	Y	Y	suspected
Trifluralin (1-3)	Y	H		possible		?	suspected
Pelargonic Acid (< 1)		H/F		?		?	?

Notes

1 See Table 3.6 and 3.7 in *Pesticide Industry Sales & Usage, 2006 and 2007 Market Estimates,* U.S. EPA, Washington, DC Feb 2011. See www.epa.gov/opp00001/pestsales/07pestsales/market_estimates2007.pdf. Aldicarb was removed from the list as registration was withdrawn in 2010.

2 PAN International has compiled and published a list of Highly Hazardous Pesticides (HHPs) that are harmful to human health and the environment, and targeted for global reduction and elimination. See www.panna.org/issues/publication/pan-international-list-highly-hazardous-pesticides.

3 PAN's online pesticide database provides an explanation of these categories and additional toxicity, use and regulatory information for these and other pesticides. See www.pesticideinfo.org.

4 Based on USDA's Pesticide Data Program, as listed on www.whatsonmyfood.org.

5 Noted health effects not applicable for products with < 7% diuron, and applied to foliage.

6 Health hazards of specific pyrethroids vary, the effects indicated here represent those with most hazardous potential effects.

Appendix D

Online Resources

This compilation of online resources highlights a number of key resources made available by government agencies and public interest groups. It is not intended to be comprehensive.

Pesticide use data

California Pesticide Use Reporting
calpip.cdpr.ca.gov

EPA Pesticide Industry Sales & Usage
www.epa.gov/pesticides/pesticides-industry-sales-and-usage-2006-and-2007-market-estimates

USDA National Agricultural Statistics Service
www.nass.usda.gov

Pesticide health harms

Agency for Toxic Substances and Disease Registry, ToxFAQ
www.atsdr.cdc.gov/toxfaqs/index.asp

Collaborative on Health and the Environment, Toxicant & Disease Database
www.healthandenvironment.org/tddb

EPA Pesticides & Human Health Issues
www.epa.gov/pesticide-science-and-assessing-pesticide-risks/human-health-issues-related-pesticides

EPA Recognition & Management of Pesticide Poisonings
www.epa.gov/pesticide-worker-safety/recognition-and-management-pesticide-poisonings

Ontario College of Family Physicians, Systematic Review of Pesticide Human Health Effects
ocfp.on.ca/docs/pesticides-paper/2012-systematic-review-of-pesticide.pdf

PAN International Highly Hazardous Pesticides
www.panna.org/issues/publication/pan-international-list-highly-hazardous-pesticides

PAN's pesticide database
www.pesticideinfo.org

Physicians for Social Responsibility, Pesticides & Human Health: A Resource For Healthcare Professionals
www.psr-la.org/media/resources/reports-training-materials/#Pesticides

The Endocrine Disruption Exchange
endocrinedisruption.com/pesticides/introductionf

Pesticides & children's health

Beyond Pesticides, Learning/ Developmental Disorders Resource Page
beyondpesticides.org/resources/pesticide-induced-diseases-database/learningdevelopmental

Center for Environmental Resource & Children's Health
cerch.org/research-programs/chamacos

EPA Pesticides & Children
www.epa.gov/children/what-you-can-do-protect-children-environmental-risks

National Academy of Sciences: Report on "Pesticides in the Diets of Infants and Children"
www.nap.edu/catalog/2126/pesticides-in-the-diets-of-infants-and-children

PAN's Children's Health Page
www.panna.org/children

Pesticide food residues

FDA Total Diet Study
www.fda.gov/Food/FoodScienceResearch/TotalDietStudy/

Whats On My Food? Database (also includes health effect data)
www.whatsonmyfood.org

USDA Pesticide Data Program
www.ams.usda.gov/datasets/pdp

Childhood health trends

American Academy of Pediatrics
www.aap.org

CDC Child Health Statistics
www.cdc.gov/nchs/fastats/children.htm

Health and Wellbeing of Children in Rural Areas
mchb.hrsa.gov/nsch/2011-12/index.html

State Cancer Profiles
statecancerprofiles.cancer.gov

Children's environmental health

Children's Environmental Health Network
www.cehn.org

Children's Environmental Health Project
www.cape.ca/children

Healthy Babies, Bright Futures
hbbf.org

Healthy Child, Healthy World
healthychild.org

Learning & Developmental Disabilities Initiative
www.healthandenvironment.org/initiatives/learning

Pediatric Environmental Health Specialty Units
www.aoec.org/PEHSU.htm

Physicians for Social Responsibility
www.psr.org/resources/pediatric-toolkit.html

The Children's Environmental Health Institute
cehi.org

Safer alternatives for agricultural pest control

University of California Statewide Integrated Pest Management
www.ipm.ucdavis.edu

Regional IPM Centers
www.ipmcenters.org

Organic Farming Research Foundation
www.ofrf.org

Bio-Integral Resource Center (BIRC)
www.birc.org

Rodale Institute
rodaleinstitute.org

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