Examining the evidence on pesticide exposure & birth defects in farmworkers:

An annotated bibliography, with resources for lay readers

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Examining the evidence on pesticide exposure and birth defects in farmworkers

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Introduction

Recent events have drawn attention to the subject of birth defects, farmworkers and pesticide exposure, most notably the 2005 births of three babies with severe birth defects to farmworker women employed by the same Florida company, Ag-Mart Inc. Technical reports released by state agencies in Florida and North Carolina explore the possible associations between pesticides and birth defects in the cases of these three workers. A small but growing body of epidemiologic and toxicological literature informs their evaluations and provides a larger context for understanding the possible relationships between occupational pesticide exposure and birth defects. While this scientific literature may be too technical in nature for the lay reader, the material is relevant to the general public as we seek to understand and prevent harm from exposure to toxic substances like pesticides in the workplace and the broader environment.

The purpose of this bibliography is to inform the discussion of birth defects in farmworkers. The investigations into the Ag-Mart case may contribute to a perception that the tragic birth outcomes in that case are an anomaly, because the families contend that they are the direct result of egregious pesticide misuse as documented by state investigators. However, reviews of the epidemiological literature indicate that more generally, birth defects in farmworkers may not be an anomaly, but rather a real risk for families who work regularly with toxic pesticides. Rather than an issue of one bad actor causing an isolated tragedy, the possibility of increased risks of birth defects for farmworkers should be viewed as a systemic problem and an issue of social justice.

If there is growing concern in the scientific community about occupational exposure to pesticides and the risk of birth defects (and other health impacts), as we contend there is, the burden of mitigating those risks should not be placed on a vulnerable work force. Rather, regulatory agencies should improve workplace protections, and growers should accelerate efforts to replace toxic pesticides with safer alternatives or less pesticide-dependent growing practices.

Methodology

What follows is an annotated bibliography that summarizes four review articles of the epidemiological literature and nine primary epidemiology studies. All of the articles listed here were published in peer-reviewed journals within the last ten years. Taken together, they reviewed 306 articles (with some overlap) reaching as far back as 1965.

Three out of four reviews of the scientific public health literature have come to the same conclusion: while there are inconsistencies and potential biases in nearly every study, the weight of the evidence shows a potential association between workplace agricultural pesticide exposure and birth defects. The fourth review article makes no direct statement regarding such an association, but does emphasize the need for caution and parental education. The nine studies following the reviews include many different perspectives and methods of assessing the association. The findings of these studies are at times inconsistent with each other, but all of them point to this potential association between one or both parents' exposure to pesticides, and one or more birth defects.

For each study, we provide a short synopsis, summarizing the main findings, strengths and weaknesses in the data, and identifying potential sources of bias (factors that may influence the study's results). Institutional affiliation is also provided for each of the lead researchers (or the U.S. researcher, in the case of international affiliations), to facilitate identification and ease of contact if desired.

Criteria for inclusion of articles

The March of Dimes defines a birth defect as an abnormality of structure, function or metabolism (body chemistry) present at birth that results in physical or mental disability, or is fatal (1). This bibliography equates the term "birth defects" with "congenital anomalies" or "congenital malformations," the terms more often used in the scientific literature.

There are many other studies available that assess the association of pesticide exposure with other adverse reproductive health and pregnancy outcomes such as infertility, miscarriage, spontaneous abortion, stillbirth/fetal death, low birth weight, and neurodevelopmental effects found later in childhood (2). One analysis included in this bibliography did focus primarily on stillbirths, but was included because all of the stillbirth cases studied were directly caused by birth defects. While this paper is not meant to be an exhaustive review of the possible associations between occupational exposure to pesticides and birth defects, it is representative of the current epidemiology literature on the topic.

This report does not consider additional sources of pesticide exposure that are relevant to farm workers and the general public, such as exposures from food or drinking water. The studies included here do not consider possible exposures other toxics that may act synergistically or in tandem with pesticides to affect fetal development, such as lead or mercury.

Migrant Farmworkers

The exact number of farmworkers in the United States is difficult to estimate for many reasons, but the number is estimated by the 1992 Commission on Agricultural Workers to be around 2.5 million people, as cited in a 2003 study of the National Agricultural Workers Survey. The same study reports that 79% of the farmworker population in the United States is of childbearing age (between the ages of 18 and 44) (3). More than 80% of US farmworkers are foreign-born, with more than half being undocumented immigrants. (4) The average wage earned by a US farmworker is $5.94/hour, and very few farmworkers have access to health insurance or are covered by Medicaid because they are ineligible for most government social services (5). Only 12% of farmworkers in the US are native English speakers (4).

These factors combine to make health outreach and education to farmworkers quite challenging. The researchers in many of the studies cited here call for increased education of workers regarding the potential hazards of pesticides to fetuses, a task which is easier said than done. More than half of US farmworkers are migrants who travel to work sites from homes in other states or in Mexico during the growing season (4), making them difficult to reach and to track. Because so many of these workers are undocumented immigrants, they can be highly vulnerable to exploitation, and are unlikely to speak out against workplace abuses for fear of retaliation, job loss or deportation.

Even if it were possible to educate large numbers of farmworkers about the hazards that pesticide exposures may pose to them or their families, most would have little recourse. In many states, North Carolina included, workers are not protected from retaliation by their employers when they report workplace abuses to government agencies or worker advocates. While health outreach and further research are both critically important, immediate precautionary intervention is appropriate to prevent adverse birth outcomes and other occupational health hazards for farmworkers.

Introduction References

1. March of Dimes Birth Defects Foundation. Birth Defects Fact Sheet 1998. , "Quick References and Fact Sheets: Birth Defects". 2006. March of Dimes Birth Defects Foundation. 14 Apr. 2006 <http://www.marchofdimes.com/pnhec/4439_1206.asp>.

2. Medline Plus – Medical Dictionary. <http://www.nlm.nih.gov/medlineplus/mplusdictionary.html>. National Institutes of Health. Last updated: Feb. 4, 2003.

3. A. Villarejo, Don. "The Health of U.S. Hired Farm Workers". *Annual Review of Public Health*. 24 (2003): 175-193.

4. "National Agriculture Workers Survey," 2000. US Department of Labor.

5. "United States Farmworker Factsheet," 2003. Student Action with Farmworkers.

Annotated Bibliography

Review articles

1. Garcia, Anna M. **Occupational exposure to pesticides and congenital malformations: a review of mechanisms, methods, and results.** *American Journal of Industrial Medicine*. 33.3 (1998):232-40

The authors of this review systematically searched for epidemiological papers on agriculture and birth defects from 1980-1996. They identified a total of 34 such studies, and compared their respective methods and results. The majority of studies showed a positive association between worker exposure to pesticides and birth defects (congenital malformations). These studies considered workers to have been exposed to pesticides based on job title (in other words, they did not interview the workers about exposure or take measurements or samples). *Note: This is standard method of conducting studies of worker populations. It does, however, suggest the possibility that some pesticide-exposed workers could have been considered not exposed to pesticides, and vice-versa.* Many of the studies had small sample sizes. Three of the larger and most objective studies reviewed all showed evidence for positive associations between workers' pesticide exposure and birth defects.

2. Hanke W, Jurewicz J. **The risk of adverse reproductive and developmental disorders due to occupational pesticide exposure: an overview of current epidemiological evidence.** *International Journal of Occupational Medicine and Environmental Health*. 17.2 (2004): 223-43

These researchers reviewed 80 studies published since 1984, which they identified using the online EBSCO and MEDLINE databases of scientific journals. In a section of the review that was focused on 11 birth defects studies, the authors summarized that while the results of these different studies are not entirely consistent with each other, they do "indicate that parental employment in agriculture could increase the risk of congenital malformations in the offspring." In other words, parents who work in agriculture may have a higher risk of having babies with birth defects than parents who do not. The authors state that before any association between pesticides and reproductive/developmental disorders can be definitively proven, the epidemiological methods used by researchers must be improved. The authors also identify a need to increase awareness among farm workers about potential reproductive risks from working with pesticides.

3. Dolk H, Vrijheid M. **The impact of environmental pollution on congenital anomalies.** *British Medical Bulletin*. 68 (2003):25-45

This review of the epidemiologic literature selected 74 papers to discuss more generally than the Garcia and Hanke papers did, grounding the studies within the broader context of the discipline of environmental epidemiology, rather than focusing solely on occupational exposure to pesticides. Citing the long-standing debate surrounding the "possible teratogenic effects of pesticides" the authors did not make any direct statements assessing an association between pesticide exposure and birth defects. They did, however, directly identify a need for a "coherent surveillance strategy" (p 41) to measure environmental pollutants from agriculture and industry, and emphasized that "it needs to be clear to parents that mechanisms are not necessarily in place to protect them against teratogenic exposures" (p 41). In other words, parents should not assume that worker protection gear is sufficient to protect against birth defects from the toxic chemicals they are exposed to at work.

4. Chia SE, Shi LM. **Review of recent epidemiological studies on paternal occupations and birth defects.** *Occupational and Environmental Medicine*. 59.3 (2002): 149-155

This review article examined 56 epidemiological studies from 1989-1999. All 56 studies posed the same question: whether a father's workplace exposure to toxic chemicals is linked to birth defects in his children. The studies found associations between the father's exposures in farm work and birth defects. The authors echoed the recurring theme that prevention measures should be taken, and that in order to identify the most appropriate prevention measures, future studies should first verify the participants' pesticide exposures, and then use that data to identify the specific chemicals that are causing the birth defects among the study participants. Potential sources of bias were identified in most of these studies.

Non-review articles

5. Engel LS, O'Meara ES, Schwartz SM. **Maternal occupation in agriculture and risk of limb defects in Washington State, 1980-1993.** *Scandinavian Journal of Work, Environment, & Health*. 26.3 (2000):193-8.

These authors conducted a large, rigorous study in Washington state that examined whether mothers' work was related to limb defects (birth defects of the arms and legs). The researchers analyzed 14 years of birth records, and one "case" group and two "control" groups were formed. The case group consisted of 4,466 babies whose mothers worked in agriculture. The first control group consisted of 23,512 babies for whom neither parent worked in agriculture, and the second control group consisted of 5,994 babies whose father worked in agriculture. The researchers found that "maternal employment in agriculture was associated with an elevated risk of limb defects in the offspring," in other words, women who worked in agriculture were more likely to have babies born with birth defects of the arms and/or legs than women who did not work in agriculture. Three factors may have limited the significance of these findings: first, the birth defects selected for study are extremely rare (approximately 0.1% in WA); second, pesticide exposure was inferred from the job title rather than measured or reported; and finally, the authors were not able to completely rule out the possible effects of smoking and alcohol consumption during pregnancy.

6. Pierik FH, Burdorf A, Deddens JA, Juttmann RE, Weber RF. **Maternal and paternal risk factors for cryptorchidism and hypospadias: a case-control study in newborn boys.** *Environmental Health Perspectives*. 112.15 (2004):1570-1576

In this rigorous study, the authors attempted to identify risk factors for the development of two specific male birth defects, cryptorchidism and hypospadias. One of the study's strengths was its large sample size (134 cases and 313 controls, identified from 8,695 live male births, or 95% of all registered male births in Rotterdam, Netherlands over a two year period). The study further reduced bias by including only those infants who took part in a standardized birth defect screening. Parents' exposures to pesticides were determined through interview questions, and were verified using standards set by occupational hygienists. The study found that father's workplace exposure to pesticides is a risk factor for cryptorchidism, but mother's workplace exposure is not.

7. García-Rodríguez J, García-Martín M, Nogueras-Ocaña M, de Dios Luna-del-Castillo J, Espigares García M, et. al. **Exposure to pesticides and cryptorchidism: geographical evidence of a possible association.** *Environmental Health Perspectives*, 104.10 (1996):1090-1098.

Previous studies examined in this bibliography used a classic study design consisting of examining the results in a birth defects registry and comparing them with parental interviews. This study used a spatial-ecological design instead, in order to assess whether the geographic distribution of babies with cryptorchidism matched up with the areas of greatest pesticide use in Granada, Spain. It should be noted that this study considers environmental, rather than occupational, exposures to pesticides (environmental exposures are generally considered to be lower-level exposures than occupational exposures). The authors used records of a specific surgery, called orchidopexy (a procedure used to repair cryptorchidism), as a substitute measure for the defect. They found that as pesticide use in an area increased, so did the number of orchidopexies. This pattern was not observed in the "control" area (areas of low or no pesticide use included for comparison). The study had two potential sources of bias: the authors were unable to track male children who traveled to hospitals outside Granada to undergo the surgery, and standardized diagnosis procedures for the birth defect were not used. Both of these biases are likely to underrepresent the actual number of cryptorchidism cases.

8. Bell, E.M., I. Hertz-Picciotto, J.J. Beaumont. **A case-control study of pesticide and fetal death due to congenital anomalies.** *Epidemiology*. 12 (2001a): 148-156.

In another geographic study, these researchers compared California pesticide use statistics (daily application statistics accurate to within one square mile) with the addresses of 73 mothers whose fetuses died in the womb due to birth defects. Again, this is an environmental (rather than occupational) study, so the exposed population was likely to have experienced lower-level exposures than workers would. The researchers identified other risk factors in the mothers and statistically screened them out. This study had two important strengths: first, it relied on objective data on pesticide use from the Pesticide Use Report and the California State Vital Statistics Registry, specific to the class of chemical applied; and second, it included two levels of geographic range for the pesticide applications: first within nine square miles; and second, within one square mile of the mother's residence. Another strength of the study was the researchers' ability to narrow in on the period of organogenesis (the third through eighth week of pregnancy) for each of the 73 babies, when fetal development is most sensitive to birth defects from environmental factors. The authors found that "in ten agricultural counties of California, proximity to commercial pesticide applications was associated with an elevated risk of fetal death due to congenital anomalies…the largest risks for fetal death due to congenital anomalies were from pesticide exposure during the 3rd-8th weeks of pregnancy." In other words, mothers who live near agricultural spray sites are at elevated risk for birth defects, especially during the 3rd – 8th weeks of their pregnancies. Even though the pesticide application data were specific to within one mile of the home, the significance of the results were still somewhat limited by the fact that pesticide exposures were not measured in the study participants. The authors did not have information on how much time the mothers spent at home during the pregnancy, which could have also introduced bias into the results.

9. Recio R, Robbins WA, Borja-Aburto V, Moran-Martinez J, Froines JR, et. al. **Organophosphorous pesticide exposure increases the frequency of sperm sex null aneuploidy.** *Environmental Health Perspectives*. 109.12 (2001): 1237-1240.

Researchers from the National Polytechnic Institute (IPN/CINVESTAV) of Mexico, along with researchers from the Mexican National Institutes of Public Health and the University of California, Los Angeles, conducted this preliminary clinical genetic study. The object of the study was to evaluate how frequently aneuploidy ("abnormal number of sex and autosomal chromosomes in [sperm and egg] cells") occurs in male agricultural workers before and during the spray season, and any relationship with exposure to organophosphate (OP) pesticides. Exposure to OP pesticides was assessed in the workers by measuring the pesticide breakdown products in their urine. Aneuploidy is a risk factor for congenital anomalies[1] and other adverse birth outcomes. The authors note for example that 35% of spontaneous abortions are the result of aneuploidy. The authors found a "direct association between the increased frequency of sex-null [the lack of a sex chromosome: X or Y] aneuploidy and organophosphate metabolite levels." In other words, aneuploidy was more common in workers with higher exposures to OP pesticides.

Particular strengths of this study include measuring semen quality and levels of pesticide metabolites in urine using accepted standards (WHO, U.S. EPA, and Aprea et al, respectively), and taking such potential confounders as age and lifestyle into

[1] Emery BR, Carrell DT. **The effect of epigenetic sperm abnormalities on early embryogenesis.** *Asian Journal of Andrology*. 8.2 (2006): 131-42.

account. However, the study did have a very small sample size (nine individuals). The study was meant to be preliminary, and it confirmed the need for further clinical study.

10. Blatter BM, Roeleveld N, Bermejo E, Martinez-Frias ML, Siffel C, Czeizel AE. **Spina bifida and parental occupation: results from three malformation monitoring programs in Europe.** *European Journal of Epidemiology*. 16.4 (2000): 343-51

This rigorous study was based on birth defect registries in three different European countries (Spain, Sweden, and Hungary) to evaluate evidence of an association between the birth defect spina bifida and parents working in agriculture. Sample sizes were larger in comparison to some other studies in this bibliography (Sweden 482 cases/964 controls, Spain 478 cases/434 controls, Hungary 1119 cases/1489 controls). Some weaknesses of the study include the differences in the types of data recording by the different birth defects registries, and the fact that pesticide exposure was determined from job title. Data were also recorded over a number of years, and the types of pesticides in use may have changed over that period. Even with these sources of potential bias, the authors concluded that these three studies together "suggest a tendency of increased risk of spina bifida among women in agricultural occupations." In other words, the studies suggest that the babies of mothers who work in agriculture have a higher risk for spina bifida than for women in other occupations.

11. Shaw GM, Wasserman CR, O'Malley CD, Nelson V, Jackson RJ. **Maternal pesticide exposure from multiple sources and selected congenital anomalies.** *Epidemiology*. 10.1 (1999): 60-66. (from abstract)

The authors of this study used interviews to determine relationships between pesticide exposure and a specific set of birth defects (orofacial clefts, neural tube defects, conotruncal defects, and limb anomalies). The study found no evidence for an association between mothers' workplace exposures to pesticides and any of the birth defects groups examined in this study. Increased risks were shown for fathers' workplace exposures in the case of two of the orofacial defects studied here. Home use of pesticide products was not found to be a risk factor, but professional application of pesticides in and around the home did show an association with an increased risk of neural tube defects. Two of this study's strengths were its large sample size (637 "cases" and 734 "controls"), and the fact that the self-reported pesticide exposures were confirmed by an industrial hygienist. As in most of the other studies reviewed, more specific data were needed to confirm risk estimates.

12. Weidner IS, Moller H, Jensen TK, Skakkebaek NE. **Cryptorchidism and hypospadias in sons of gardeners and farmers.** *Environmental Health Perspectives*. 106.12 (1998): 793-796.

In this large and rigorous study, all of the males born in Denmark between 1983-1992 were studied to examine the association between parents' occupation in farming or gardening and the occurrence of the male birth defects cryptorchidism and hypospadias (the study examine 6,177 cases of cryptorchidism; 1,345 cases of hypospadias and 23,273 "controls"). Mothers' workplace exposure to pesticides showed an association with increased risk of cryptorchidism in this study. Neither the mothers' nor fathers' occupation in farming or gardening was shown to have a significant effect on the risk of hypospadias. Nor did farm or garden industry work for the father show an association with increased risk of cryptorchidism. The authors suggest that certain endocrine-disrupting pesticides used in Denmark during the study period could have been responsible for this increased risk.

13. Garry, V.F., M.E. Harkins, L.L. Erickson, L.K. Long-Simpson, S.E. Holland, 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.** *Environmental Health Perspectives*. 110.3 (2002): 441-449.

The authors conducted this cross-sectional study to gain more detailed reproductive health information than had been gathered on the same population in an earlier case-control study. In this study, 1,500 licensed pesticide applicators were randomly selected to be contacted, and among them 536 couples were eligible to participate. Phone interviews were conducted and followed up six months later with written surveys to verify exposures specific to the type of pesticide mixture applied. The study participants reported 76 birth defects, which were verified by confirmatory studies of medical records. Out of the 14 classes of pesticides examined in this study, two classes of pesticides, phosphines and glyphosphates, showed a significant correlation with increased birth defects and neurodevelopmental effects (such as ADD/ADHD). The authors grouped the 14 classes of pesticides into four major classes: fumigants, insecticides, herbicides, and fungicides. Comparing results within the study, the authors also showed that pesticide applicators who applied pesticides from three out of four major classes (specifically, fumigants AND insecticides AND herbicides) were more than twice as likely to have a child with a birth defect than those who applied only herbicides (15.4% vs. 6.8% respectively). Babies conceived in the spring were also significantly linked to greater prevalence of birth defects. The authors suggest that this elevated risk could be due to the greater application of herbicides during this season.

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Appendix I: Guide to technical terms

Some of the technical vocabulary found in this report includes:

- **Aneuploidy** - abnormal number of sex and autosomal chromosomes in [sperm and egg] cells.
- **Bias / Study Bias** – deviation of results or inferences from the truth, or processes leading to such systematic deviation. Any trend in the collection, analysis, interpretation, publication, or review of data that can lead to conclusions that are systematically different from the truth (source: Centers for Disease Control & Prevention, Reproductive Health Glossary). Almost all studies have bias, to varying degrees.
- **Birth Defects** (also called "congenital malformations") – an abnormality of structure, function or metabolism (body chemistry) present at birth that results in physical or mental disability, or is fatal (source: March of Dimes).
- **Birth Defects Registry** – A government-sponsored database that tracks the occurrence of birth defects among children born within a certain area. Several states in the U.S. have birth defects registries, including North Carolina.
- **Case-Control Study** – a study that compares two populations, a "case," or participants who exhibit the trait being studied, and a "control" population that does not exhibit the trait being studied.
- **Confounder / Confounding factor** – a factor that can bias the outcome of a study. In a study of workplace exposures and lung cancer, a confounding factor would be whether study participants are smokers.
- **Cross-Sectional Study:** a study conducted on a population during a specific point in time.
- **Endocrine** – the endocrine system is the body's hormone system, which functions as a messaging system during different phases of development.
- **Endocrine Disrupting** – Pollutants that can mimic hormone activity in the body disrupt the endocrine system and can harm development. This mechanism is known as "endocrine disruption."
- **Industrial Hygienist** – also known as "occupational health and safety specialist / technician," promotes workplace health and safety by assessing exposures to harmful contaminants and advising employers on preventive measures.

- **Metabolite** – breakdown products measured in the urine or other bodily fluids that indicate the presence of a pollutant in the body.
- **Occupational Exposure** – exposure to a substance that occurs on the job.
- **Organophosphate Pesticide** – a pesticide belonging to a class of chemicals known as organophosphorus compounds. Many organophosphates are highly toxic to the nervous system, functioning by inhibiting the action of an enzyme in nerve cells called acetylcholinesterase (AChE).
- **Teratogen / Teratogenic** – of, relating to, or causing developmental malformations (birth defects).

Some of the studies in this bibliography focused specifically on these relatively common birth defects:

- **Cryptorchidism** – a condition in which one or both testes fail to descend normally.
- **Hypospadias** – an abnormality of the penis in which the urethra opens on the underside.
- **Spina bifida** – defects in the spinal cord and in the vertebrae caused by the incomplete closure of the neural tube.

Appendix II:

Understanding epidemiological studies

By Dr. Jack K. Leiss, MPH, PhD

This section gives six tips for understanding the epidemiologic studies summarized in this report. First, all of the studies are based on the same basic method: dividing the workers into those who were *exposed* to pesticides and those who were *unexposed* (not exposed), and then calculating the percentage of babies with birth defects in each group. This basic method underlies all types of epidemiologic studies--longitudinal and retrospective, cohort and case-control, and others.

If the percentage of birth defects is higher in the group of exposed workers, then epidemiologists say that there is an *association* between pesticide exposure and birth defects, or that pesticide exposure is *associated with* birth defects. (Another way of saying this is that workers who were exposed to pesticides had a higher *risk* of having a baby with birth defects than unexposed workers).

If the percentage is much higher, epidemiologists say that there is a *strong* association between pesticides and birth defects, and if it is only a little higher, they say the association is *weak*. For example, if 80 out of 100 babies of pesticide-exposed workers had birth defects compared to 20 out of 100 babies of unexposed workers, epidemiologists would say that study found a *strong association*. If the numbers were 60 and 40, that would be a *weak association*. Note that a weak association does not mean that pesticides do not cause birth defects. In a weak association, there are still more babies with birth defects among the pesticide-exposed workers, but not a lot more.

Secondly, none of the studies say that pesticides *cause* birth defects. This is not because, as some say, that epidemiologic studies can never prove that something (like pesticides) causes something (like birth defects). On the contrary, most of the causes we know for different diseases (except for infectious diseases), were proven from epidemiologic studies in combination with other kinds of scientific studies. However, epidemiologists and other scientists are reluctant to use the word 'cause' until there is overwhelming evidence proving it. It takes many studies of different types – epidemiologic, toxicological (i.e., laboratory experiments with animals), *in vitro* (i.e., laboratory experiments with tissue samples), and others – to prove that a given exposure to something (like pesticides) causes a specific disease (like birth defects). Until that point is reached, epidemiologists prefer to talk of 'associations.'

The third thing to understand is how studies could show that pesticides (or any other exposure) is associated with birth defects (or any other disease) when it really isn't, or vice-versa. When this happens, it is called *bias*. This could happen if some of the workers that the epidemiologist thought were exposed to pesticides really weren't, and some of the workers s/he thought were not exposed to pesticides really were. How that would impact the study results depends on what the errors were. If the workers who were mistakenly thought be exposed to pesticides (but were really unexposed) had babies with birth defects, that could bias the study to show an association when there really wasn't one. If the workers who were mistakenly thought to be unexposed (but were really exposed) had babies with birth defects, that could bias the study to not show an association when there really was one. If there was no pattern to the errors, just a general mix-up of who was exposed and who was unexposed, that would bias the study to not show an association even if there was one.

Fourth, another way a study could show an association when there really isn't one, or vice-versa, is through what epidemiologists call *confounding*. Confounding could happen if the workers were exposed to an additional chemical that caused birth defects. For example, suppose smoking caused birth defects. If the workers who were exposed to pesticides also smoked, and the workers who were not exposed to pesticides did not smoke, the study would show that pesticides were associated with birth defects when it could have actually been from smoking. Confounding can be avoided with proper study design and statistical analysis, but the possibility that confounding is behind the results should be always be considered.

Fifth, a comment about sample size: a study with a small sample size might show an association when there really wasn't one, or vice-versa, even if all the data about which workers were exposed to pesticides were correct. However, epidemiologists and statisticians consider several different things in deciding whether a sample size is too small. Just the number by itself doesn't tell you much. Even if the sample size is considered small, that does not mean that the associations are incorrect. It means that epidemiologists are less sure about them.

Finally, it should be understood that no study is perfect, and that all studies have weaknesses that could cause them to show an association when there really wasn't one, or vice-versa. For this reason, numerous studies using different worker populations and different methods need to be considered together in asking whether pesticides cause birth defects in farmworkers. Weaknesses in a study do not mean that the study results should not be taken seriously. Unless the methods used were grossly invalid, the results should be taken seriously, but considered in light of the strengths and weaknesses of the study. Together, the various studies build up a picture of what the true situation is.

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Mission: ARC/PESTed is a non-profit organization whose mission is to advocate for alternatives to toxic pesticides in North Carolina by empowering people to make sound decisions about their health and environment.

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