JOGNN

IN FOCUS

Pesticides and Health Risks

Robyn C. Gilden, Katie Huffling, and Barbara Sattler

Correspondence
Robyn C. Gilden, RN, MS, Environmental Health Education Center, 655 W. Lombard Street, Room 665, University of Maryland School of Nursing, Baltimore, MD 21201.
rgilden@son.umaryland.edu

Keywords
pesticides
reproductive health
fertility
preconception
nursing implications
environment

ABSTRACT

Pesticides are a category of chemicals formulated to kill or repel a pest or halt its reproduction. In this article we review the toxicological and epidemiological literature; describe common potential pesticide exposures; and focus on the associated health risks to fetal development. Clinical implications are reviewed, and recommendations are made regarding the integration of this environmental health concern into nursing education, practice, research, and policy/advocacy work. Recommendations for pesticide elimination and reduction in health care settings are included.
JOGNN, 39, 103-110; 2010. DOI: 10.1111/j.1552-6909.2009.01092.x

Accepted July 2009

Robyn C. Gilden, RN, MS, is a doctoral candidate and program manager at the Environmental Health Education Center, University of Maryland School of Nursing, Baltimore, MD.

Katie Huffling, RN, MS, CNM, is the assistant director of nurse-midwifery at Dimensions OB/GYN Associates, Cheverly, MD.

Barbara Sattler, RN, DrPH, FAAN, is a professor and director of the Environmental Health Education Center, University of Maryland School of Nursing, Baltimore, MD.

Pesticides are a category of chemicals that are formulated to kill or repel a pest or halt its reproduction. Within this category, there are a range of subcategories, such as insecticides, fungicides, rodenticides, pediculocides, and biocides. In the United States, all pesticides must be registered with the U.S. Environmental Protection Agency (EPA). Registration does not require any original research into the potential human health effects that might be associated with exposure.

According to the U.S. EPA, more than 1,100 million pounds of pesticides are used in the United States annually (U.S. EPA, 2002), and approximately 90% of American households use pesticides (Adgate et al., 2000; Landrigan et al., 1999). Pesticides can be found in most of our everyday environments, including workplaces, homes, schools, in food, and in the community at large in our drinking and recreational waters, the air, soot, and soil. They are commonly used in a variety of ways including lawn sprays and household bug sprays and can be found in varying amounts in food, such as strawberries, blueberries, and apples. Children, in particular, are likely to be exposed when in their yards, on playgrounds, and on athletic fields.

Exposure to pesticides can occur via inhalation, ingestion, dermal contact, or across the placenta. Biomarkers currently exist for some pesticides in blood serum, semen, ovarian follicular fluid, amniotic fluid, umbilical cord blood, breast milk, meconium, and urine (Colborn, 2006). Biomonitoring results of the Centers for Disease Control and Prevention's (CDC) National Health and Nutrition Examination Survey (2005-2006) are published in a report titled *Third Exposure to Environmental Chemicals Report* (2005). This report stated that detectable body levels of about 50 pesticides have been found in a representative sample of the U.S. population.

Although indications of health effects from pesticides are applicable to the general population, certain subpopulations warrant particular concern and special protections. During a critical period of development, conception to puberty, exposure to pesticides can result in increased risk for health outcomes (Weselak, Arbuckle, Wigle, & Krewski, 2007). Therefore, attention to women's exposure during pregnancy is especially important.

Early Development

Fetal development is a carefully orchestrated interplay of "physical, electrical and chemical signaling among cells and organs" during which the single cell of the fertilized egg forms into the millions of cells that make up a newborn (Schettler, Solomon, Valenti, & Huddle, 1999, p. 11). Hormones play a vital role in this complex series of events, and any disruption in maternal or fetal hormone levels has the potential to negatively effect fetal development.

Depending on the timing of exposure, similar doses of chemicals can have varying effects on fetal development.

In the early stages of fetal development, cells have a flexibility that allows them to develop in numerous ways. For example, the cells in the middle mesoderm layer of the embryo have the potential to become the kidneys, skeleton, or muscle (Blackburn, 2007). As the cells develop more specialized characteristics called differentiation, their flexibility decreases. If an insult such as exposure to an environmental contaminant occurs to the embryo prior to this differentiation, normal fetal development may still occur as other cells are able to take over for those that have been injured (Schettler et al., 1999). However, if the insult occurs after differentiation or during times of increased cell proliferation, abnormal development can result in structural or functional defects, altered growth, and even fetal death. These times of sensitivity to environmental contaminants are referred to as critical windows of susceptibility (Woodruff, Carlson, Schwartz, & Giudice, 2008).

Because embryonic and fetal development is so complex and the sequencing of events so critical, similar doses of chemicals can have varying effects depending on when the fetus has been exposed. An example that illustrates the importance of the timing of exposure is the use of the pharmaceutical thalidomide, which was prescribed for women during pregnancy. The tragic birth defects that resulted from the use of thalidomide helped to promote the field of developmental toxicology. Thalidomide was never approved for use in the United States; however, the results of European use provided some extraordinary findings about the timing of toxic exposure and early human development. Researchers discovered that dramatically different birth defects resulted based on gestational age at time exposure; these defects ranged from flipper arms to lack of ear development. The field of developmental toxicology is now a critical component of the sciences that is providing evidence for nursing practice and policy work.

Pesticides and Health

When studying pesticides it is important to recognize two important characteristics: Many of them are "persistent," they do not break down into safer constituent parts but rather remain intact over prolonged periods of time, and they are readily accessible to the human body. This combination of persistence and accessibility is dramatically illustrated by the fact that human biomonitoring studies indicate that most people in the United States have detectable levels of dichloro-diphenyl-trichloroethane (DDT) in their bodies (CDC, 2005), despite the fact that DDT was banned from use in the United States in 1972. The Stockholm Convention on Persistent Organic Pollutants (POPS; 2001) identified 12 of the most dangerous and persistent chemicals and called upon the world's nations to desist from manufacturing or otherwise producing them. Ten of the 12 chemicals are pesticides.

Another concept in toxicology that applies to understanding human health effects associated with exposure is potency. Not all pesticides are equally potent or have the capacity to create the same level of health threat. For instance, acetaminophen and morphine are both analgesics, but morphine is a more potent analgesic. The same is true regarding the potential of chemicals to illicit negative effects. This concept is important when pests are being managed. Although choosing nontoxic options for pest control is the best, there is sometimes a need for pesticides in which case the least potent (least toxic) chemicals should be selected.

Health Effects

Toxicological research provides an opportunity to examine an almost infinite set of health outcomes, including molecular changes, cellular, tissue, organ, organ system, and systems-wide pathologies. The following information describes health risks that are associated with pesticide exposure.

Reproductive and Endocrine

Endocrine-disrupting chemicals (EDC) are a class of chemicals that "interfere with the production, release, transport, metabolism, action, or elimination of naturally occurring hormones in the body" that are part of the developmental regulation process (Woodruff et al., 2008, p. e2). They can affect the signaling of hormones, such as estrogens, thyroid, and androgens that are a vital component of normal embryonic development. They can also affect the neuroendocrine system, which plays a role in hemostasis and normal physiology processes (Woodruff et al.). Examples of EDCs include bisphenol A (which can be found in baby bottles), diethylstilbestrol (DES), and certain pesticides such as atrazine and vinclozolin.

Exposure to a well-known EDC, diethylstilbestrol (DES), can result in a range of potential transgenerational, reproductive effects that stem from fetal exposure. The females and males exposed to DES

in utero have exhibited reproductive tract abnormalities. The female offspring have higher rates of clear cell carcinoma of the vagina and cervix, structural abnormalities, and higher infertility rates than unexposed women (25% vs. 19%, respectively) (Kaufman et al., 2000; Newbold, 2008; Schrager & Potter, 2004). Female offspring exposed to DES also have higher rates of preterm delivery, spontaneous delivery, and ectopic pregnancy (Kaufman et al.). The male offspring may be at increased risk of testicular and prostate cancer (Schrager & Potter). Second-generational effects are now being seen, and there may be an increased incidence of ovarian cancer in the granddaughters and hypospadias in the grandsons of women exposed to DES (Blatt, Van Le, Weiner, & Sailer, 2003; Brouwers et al., 2006). Through studying health effects associated with DES exposure, scientists have also learned about some of the transgenerational mechanisms by which EDCs work, thus helping to inform current research on environmental EDCs. This research is also informing environmental regulations and other policy efforts.

In a study of boys with cryptorchidism or undescended testes, it was noted that their mothers had higher levels of organochlorine pesticide metabolites in their breastmilk (Damgaard et al., 2006). Pesticides have also been implicated in altered thyroid function and decreased testosterone and estradiol possibly leading to infertility later in life (Meeker, Ravi, Barr, & Hauser, 2008; Meeker, Ryan, Barr, & Hauser, 2006), gestational diabetes (Saldana et al., 2007), menstrual irregularities (Farr, Cooper, Cai, Savitz, & Sandler, 2004), and fetal death related to congenital birth defects (Bell, Hertz-Picciotto, & Beaumont, 2001). One study of farm workers found that couples who conceived in the spring when herbicides are typically applied had infants with elevated birth defects, and exposure to fungicides resulted in less-than-expected number of male offspring (Garry et al., 2002).

Neurodevelopmental

A main mode of action in controlling pests targets the nervous system, particularly for insecticides. For example, organophosphate insecticides like chlorpyrifos interfere with the enzyme that breaks down acetylcholase leading to a buildup of this key neurotransmitter (Colborn, 2006). Research on the effects of pesticide exposure in children and prenatal exposures indicates a link to social behavioral problems (Ribas-Fito et al., 2007), neurodevelopmental delays (Eskenazi et al., 2007; Handal, Lozoff, Breilh, & Harlow, 2007; Ribas-Fito et al., 2003; Torres-Sanchez et al., 2007), and impaired gross and fine motor skills (Guillette, Meza, Aquilar, Soto, & Garcia, 1998). A single low-dose exposure, such as with DDT, before or shortly after birth, may sensitize a child to the health effects of a later exposure to other pesticides (Colborn).

Pesticides have been implicated in altered thyroid function and decreased testosterone and estradiol, possibly leading to infertility later in life.

Immune System

Recent reviews of the literature described existing evidence that a wide variety of pesticides can affect the immune system (Caress & Steinemann, 2003; Weselak et al., 2007); however, most of the studies described high-dose exposures rather than the types of low, chronic exposures that are common. It is also difficult to capture reversible effects (Colosio, Birindelli, Corsini, Galli, & Maroni, 2005). Despite this, pesticides are suspected to lead to an increased risk for allergy and hay fever (Weselak et al.) and to be a cause or trigger for multiple chemical sensitivity (Caress & Steinemann).

Cancer

One of the most common end points investigated for health effects of any chemical is cancer. Identification of a causative mechanism for cancer is often problematic due to multiple exposures and long latency periods. Research to date implicates pesticide exposures with leukemia/lymphoma, brain, kidney, (Infante-Rivard & Weichenthal, 2007), breast (Clark & Snedeker, 2005), prostate, pancreas, liver (Dharmani & Jaga, 2005), lung, and skin cancers (Zahm & Ward, 1998). Parental occupational exposure to pesticides and/or residential pesticide use appear to be cancer risk factors. In particular, maternal exposure during pregnancy appears to be the most critical time for exposure (Infante-Rivard & Weichenthal). Exposure prior to or during pregnancy increased risk for acute lymphocytic leukemia, Wilms' tumor, and brain cancer (Daniels, Olshan, & Savitz, 1997; Zahm & Ward).

Other Health Effects

Whyatt et al. (2007) found that indoor air concentrations of pesticides correlated with umbilical cord blood levels. Prenatal exposures to pesticides have been linked with otitis media, respiratory distress, asthma, decreased fetal growth and length of gestation, and certain birth defects (Weselak et al., 2007).

Limitations to the Science and Implications

As evident by the literature review presented here, there are many studies exploring the relationship between pesticide exposure and health threats (see also the U.S. EPA's Integrated Risk Information System database, http://www.epa.gov/iris, 2009a, 2009b). It should be noted that the data defining the risk of human health effects associated with pesticide exposure are often extrapolated from animal research. This is important because almost all toxicological data are based on animal or in vitro studies because of the ethical impossibility of designing studies in which people are intentionally exposed to potential poisons. On rare occasion human data are available through occupational health research by modeling worker exposures to pesticides that they produce (manufacturing), apply (pesticide applicators/gardeners), or work in close proximity with (farmers and farm workers). Occupational health research typically focuses on adult exposure and health risks.

There are also rare human studies based on data from transportation spills; accidental releases from "point sources" meaning a smoke stack, effluent pipe, or leaking tank; or from widespread exposures such as crop spraying or community-wide use of pesticides. Nonetheless, the vast majority of estimates for human health threats are derived from animal models, which allow for the control of myriad factors that cannot necessarily be controlled in human populations. For example, diet, exercise, and air quality can all be controlled in study animals. More important, the animals under scrutiny are rarely exposed to more than one toxicant at a time, which bears little resemblance to the daily exposures of humans to potential toxicants in their everyday lives. The additive, synergistic, and potentiating effects of multiple chemicals are rarely explored in toxicological research.

Because of the uncertainty inherent in the extrapolation process from animal studies to estimates for human health threats, it is critical to insure that there is a significant margin of safety. Therefore, the American Nurses Association has adopted the Precautionary Principle to specifically guide its environmental policy work that asked that nurses heed and act on early warnings for potential dangers.

> When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established. The principle includes taking action in the face of uncertainty; shifting burdens of proof to those who create risks; analysis of alternatives to potentially harmful activities; and participatory, decision-making methods. The precautionary principle takes the life cycle of products or chemicals into account and adds the proactive steps of pre-market analysis of environmental harm. (ANA, 2003, p. 2)

This tenet is especially important in pesticide policy initiatives. It helps us to understand that nurses cannot wait until the "perfect" study has been implemented but must act on data that suggest potential for harm.

Implications for Clinical Practice

Pesticides in the Health Care Setting

Maryland hospitals were surveyed about their pesticide use as part of the Integrated Pest Management in Health Care Facilities Project sponsored by the Maryland Pesticide Network and Beyond Pesticides (2008), of which the Maryland Nurses Association is a member. The survey results showed that 80% of Maryland's hospitals and health care facilities use toxic pesticides in their buildings. The biggest pest problems were ants, cockroaches, and rodents (mice and rats). The biggest problem areas were the kitchens, cafeterias, and food services areas.

Facilities identified 25 specific pesticides used inside and outside the facility. Of these, 19 were used inside only and of these 19

- 11 linked to cancer
- 12 associated with neurological effects
- 10 associated with reproductive effects
- 5 cause birth defects or developmental defects
- 12 are sensitizers or irritants
- 10 cause liver or kidney damage
- 6 are suspected endocrine disruptors (Maryland Pesticide Network and Beyond Pesticides, 2008)

Although there is a need to use antimicrobials and sterilizers/disinfectants to control bacteria, viruses, and other pathogenic microbes in many locations within health care settings, it is almost never necessary to use pesticides for insects and rodents. For these pests, other options exist. As part of the Integrated Pest Management in Health Care Facilities Project (Maryland Pesticide Network and

Beyond Pesticides, 2008), hospitals were invited to participate in a pilot program in which integrated pest management (IPM) techniques were introduced to address the insect and rodent problems. The preliminary data from these pilots indicate that using IPM approaches can maintain pest-free health care facilities without adding health risks from the use of pesticides. In hospitals, schools, and other settings in which nurses are employed, nurses can work with facilities managers and advocate for the use of IPM as a mode of pest management (Table 1).

One of the key components of IPM is the prevention of pest infestation. Nurses can play an instrumental role in this prevention by ensuring that food is not left out in staff and patient areas and crumbs and spills are promptly disposed of. They can also advocate for timely waste removal in staff and patient areas. If a pest is identified, nurses should promptly notify the facilities staff so that interventions can be targeted to that area. These interventions may include identifying and sealing sources of entry into the facility and the use of physical and mechanical controls such as traps and vacuuming. Nurses can also be advocates for the rights of staff and patients to be informed when pesticides are used so that they may take precautions to avoid or minimize exposures.

Health Care Without Harm, a nonprofit organization dedicated to environmental health and sustainability in hospitals, has created a number of helpful guidance materials for the implementation of IPM in hospitals. For more information see http://www.noharm.org/us/pesticidesCleaners/pesticides.

Implications for Nursing

The 1995 Institute of Medicine report, *Nursing, Health and the Environment*, recommended that environmental health should be integrated into nursing education, practice, research, and policy/advocacy. The following are suggested implications for nursing in light of the evidence regarding pesticides and their potential health effects.

Table 1: Steps for Integrated Pest Management

Set action thresholds for each specific pest that would trigger action
Monitor and identify pests to ensure no unnecessary use of pesticides
Prevention control habitat including access to water, and food and shelter (for insects)
Control using the least risky and toxic option first and then increasing to more potent chemicals if needed

Education

Given the ubiquitous use of pesticides and the growing evidence of health risks, it is imperative that this information be included in basic, advanced, and professional development education for all nurses. In addition, the basic concepts of toxicology and how these relate to pesticide-related health risks to humans need to be integrated within the basic curriculum. Integrating a lecture on toxicology into a pharmacology course helps students to understand the similarities that toxic chemicals have to pharmaceuticals in terms of the importance of dose/response, host factors, potency/toxicity, and other parallel concepts.

When teaching assessment skills, introducing the peer-reviewed science about pesticides and their associated health risks can help students to incorporate appropriate questions about their patients' potential exposures. An excellent and credible source of information is the National Library of Medicine's (NLM) databases and informational sources, see http://sis.nlm.nih.gov/enviro.html.

Practice

Due to the widespread use of pesticides it is important for nurses to assess the potential for pesticide exposures in their patients and environmental exposure questions should be included in comprehensive patient health histories. Questions that may illicit sources of pesticide exposures include the following: Do you use pesticides in your home, lawn, or workplace? Do you use pesticides on your pets (this includes flea collars, dips, and once-a-month products)? If you do use pesticides, what do you use?

Nurses should include pesticide poisoning in their differential diagnosis when appropriate and be able to provide anticipatory guidance to decrease exposures. If pesticides are used in the home, instructions on how to keep insects and rodents out of the home is key, thus preventing the need for pesticides. Reducing/eliminating pests' access to food and water includes storing food in tightly closed containers, cleaning up food spills and crumbs, and removing standing water from leaking faucets and other faulty plumbing. Also, entry to the building may be eliminated by sealing cracks and repairing holes where pests can enter from out-

Knowledge about pesticide exposures and associated fetal health risks compels nurses to take action in our daily practice and advocacy efforts.

doors. For pest-specific alternatives to pesticides see http://www.pesticide.org/factsheets.html#alternatives.

If a workplace exposure is found, employers are required by law to provide information on hazardous substances through the Material Safety Data Sheets (MSDS). Although the health information can be lacking on these informational documents, there should be a telephone number to call for specific information on safe handling. If working with pesticides is essential, it should be noted that these chemicals can persist on clothing and can be tracked into the home on shoes. Changing out of contaminated clothes at the worksite, taking the clothing home in a plastic bag, and then laundering them separately can offer some protection from contaminating the household. Taking shoes off before entering the home is also helpful. If at all possible, women should not be working around pesticides when they are pregnant.

The risks imposed in utero makes assessment of pesticide exposure critical during the prenatal period. Huffling (2008) developed a prenatal assessment tool that can be found at http://e-commons.org/files/2009/04/prenatal-exposure-questionnaire-ehec.pdf. This assessment tool can help guide nurses through their assessment and their anticipatory guidance. It can be used in a variety of settings, such as in the office, home, and hospital, and is useful not only during the prenatal period but also for any time during a woman's reproductive years.

Research

Although much of the knowledge that we have about health effects associated with pesticides are gleaned from the field of toxicology, there are a number of other research disciplines that can be applied to pesticide research. Nurses have many opportunities to research questions about the relationship between pesticide exposures and human health. The National Health and Nutrition Exam Studies (NHANES) is a national survey of a representative body of the American population (CDC, 2009). In addition to providing data on demographics, nutrition, and health status, NHANES now includes body-burden information about several hundred chemicals that may be found in the human body. Nurse epidemiologists have an opportunity to use this large data source to explore the relationship between people's body burdens of one or more pesticides and a wide array of health outcomes.

The prospective National Children's Study (2009) will be recruiting pregnant women in 2009 into a 20-year prospective study that will follow the children for the first 20 years of life. The study will record a broad range of environmental health exposures, including estimates of pesticide residues in foods and pesticide exposures in homes/yards/farms and will track the children's health status. This will provide another ideal set of data for nurse researchers to explore.

In addition, nurse researchers can consider ways to research pesticides by including pesticide exposures among variables for consideration in epidemiologic studies, utilizing community-based research to determine best ways in which to decrease human pesticide exposures, and assessing the effectiveness of local/state/federal policies to eliminate/decrease pesticide exposures.

Advocacy and Policy

Guided by the Precautionary Principle nurses can engage in policy and advocacy. Individually and through their professional organizations nurses can advocate for policies that address pesticide use in hospitals, schools, agriculture, and communities; increased funding for pesticide research; and human health effects during the process by which the EPA allows pesticides to be registered for use.

The types of policies that can help to reduce exposures are quite varied. Some hospitals and school systems in the United States have explicit policies calling for a preference for organic foods that decreases the likelihood of pesticide residue exposures. In Canada, local laws prohibit the use of pesticides and herbicides from use on lawns solely for cosmetic purposes. In many states, there is a requirement that school systems implement IPM as the required approach to pest management. These represent several different policies that all help to reduce exposure to potentially toxic chemicals and thus promote disease prevention.

Conclusion

Pesticides are found in homes, workplaces, schools, and the community. The evidence regarding pesticide exposure and health threats com-

bined with nurses' knowledge of special vulnerabilities during fetal development compels nurses to incorporate this knowledge into all levels of our professional practice.

Pesticide assessments and the associated anticipatory guidance and intervention strategies to reduce exposures are tools for disease prevention. Just as the HPV vaccine is a tool for prevention and only works if we administer it, the same is true of environmental health assessment and intervention strategies; they must be administered for the risk for disease to be decreased. There are many reproductive health outcomes that can be affected by exposures to pesticides. Every time nurses help to eliminate these exposures through our practice and policy efforts, we decrease a health risk and thereby promote healthy people and healthy environments.

REFERENCES

Adgate, J. L., Clayton, C. A., Quackenboss, J. J., Thomas, K. W., Whitmore, R. W., Pellizzari, E. D., et al. (2000). Measurement of multi-pollutant and multi-pathway exposures in a probability-based sample of children: Practical strategies for effective field studies. *Journal of Exposure Analysis and Environmental Epidemiology, 10*(6, Pt 2), 650-661.

American Nurses Association. (2003). *American Nurses Association adopts precautionary principle.* Retrieved from http://www.nursingworld.org/MainMenuCategories/OccupationalandEnvironmental/PrecautionaryApproach.aspx

Bell, E. M., Hertz-Picciotto, I., & Beaumont, J. J. (2001). A case-control study of pesticides and fetal death due to congenital anomalies. *Epidemiology, 12*(2), 148-156.

Blackburn, S. T. (2007). *Maternal, fetal, & neonatal physiology: A clinical perspective* (3rd ed.). St. Louis, MO: Saunders.

Blatt, J., Van Le, L., Weiner, T., & Sailer, S. (2003). Ovarian carcinoma in an adolescent with transgenerational exposure to diethylstilbestrol. *Journal of Pediatric Hematology Oncology, 25*, 635-636.

Brouwers, M. M., Feitz, W. F., Roelofs, L. A., Kiemeney, L. A., de Gier, R. P., & Roeleveld, N. (2006). Hypospadias: A transgenerational effect of diethylstilbestrol? *Human Reproduction, 21*, 666-669.

Caress, S. M., & Steinemann, A. C. (2003). A review of a two-phase population study of multiple chemical sensitivities. *Environmental Health Perspectives, 111*(12), 1490-1497.

Centers for Disease Control and Prevention. (2005). *Third national report on human exposure to environmental chemicals.* Atlanta, GA. Department of Health and Human Services.

Centers for Disease Control and Prevention. (2009). *National health and nutrition examination survey.* Retrieved March 30, 2009, from http://www.cdc.gov/nchs/nhanes.htm

Clark, H. A., & Snedeker, S. M. (2005). Critical evaluation of the cancer risk of dibromochloropropane (DBCP). *Journal of Environmental Science and Health. Part C, Environmental Carcinogenesis and Ecotoxicology Reviews, 23*(2), 215-260.

Colborn, T. (2006). A case for revisiting the safety of pesticides: A closer look at neurodevelopment. *Environmental Health Perspectives, 114*(1), 10-17.

Colosio, C., Birindelli, S., Corsini, E., Galli, C. L., & Maroni, M. (2005). Low level exposure to chemicals and immune system. *Toxicology and Applied Pharmacology, 207*(2, Suppl.), 320-328.

Damgaard, I. N., Skakkebaek, N. E., Toppari, J., Virtanen, H. E., Shen, H.the Nordic Cryptorchidism Study Group. et al. (2006). Persistent pesticides in human breast milk and cryptorchidism. *Environmental Health Perspectives, 114*(7), 1133-1138.

Daniels, J. L., Olshan, A. F., & Savitz, D. A. (1997). Pesticides and childhood cancers. *Environmental Health Perspectives, 105*(10), 1068-1077.

Dharmani, C., & Jaga, K. (2005). Epidemiology of acute organophosphate poisoning in hospital emergency room patients. *Reviews on Environmental Health, 20*(3), 215-232.

Eskenazi, B., Marks, A. R., Bradman, A., Harley, K., Barr, D. B., Johnson, C., et al. (2007). Organophosphate pesticide exposure and neurodevelopment in young Mexican-American children. *Environmental Health Perspectives, 115*(5), 792-798.

Farr, S. L., Cooper, G. S., Cai, J., Savitz, D. A., & Sandler, D. P. (2004). Pesticide use and menstrual cycle characteristics among premenopausal women in the Agricultural Health Study. *American Journal of Epidemiology, 160*(12), 1194-1204.

Garry, V., Harkins, M., Erickson, L., Long-Simpson, L., Holland, S., & Burroughs, B. (2002). Birth defects, season of conception and sex of children born to pesticide applicators living the Red River Valley of Minnesota, USA. *Environmental Health Perspectives, 110*(Suppl. 3), 441-449.

Guillette, E. A., Meza, M. M., Aquilar, M. G., Soto, A. D., & Garcia, I. E. (1998). An anthropological approach to the evaluation of preschool children exposed to pesticides in Mexico. *Environmental Health Perspectives, 106*(6), 347-353.

Handal, A. J., Lozoff, B., Breilh, J., & Harlow, S. D. (2007). Effect of community of residence on neurobehavioral development in infants and young children in a flower-growing region of Ecuador. *Environmental Health Perspectives, 115*(1), 128-133.

Huffling, K. (2008). *Prenatal environmental health questionnaire.* Retrieved from http://e-commons.org/files/2009/04/prenatal-exposure-questionnaire-ehec.pdf

Infante-Rivard, C., & Weichenthal, S. (2007). Pesticides and childhood cancer: An update of Zahm and Ward's 1998 review. *Journal of Toxicological and Environmental Health B Critical Review, 10*(1/2), 81-99.

Kaufman, R. H., Adam, E., Hatch, E. E., Noller, K., Herbst, A. L., Palmer, J. R., et al. (2000). Continued follow-up of pregnancy outcomes in diethylstilbestrol-exposed offspring. *Obstetrics and Gynecology, 98*(4), 483-489.

Landrigan, P. J., Claudio, L., Markowitz, S. B., Berkowitz, G. S., Brenner, B. L., Romero, H., et al. (1999). Pesticides and inner-city children: Exposures, risks, and prevention. *Environmental Health Perspectives, 107*(Suppl. 3), 431-437.

Maryland Pesticide Network and Beyond Pesticides. (2008). *Integrated pest management in health care facilities project, taking toxics out of Maryland's health care sector: Transitioning to green pest management practices to protect health and the environment.* Baltimore: Author. Retrieved from http://www.mdpestnet.org/publications/IPM.in.HCF.pdf

Meeker, J. D., Ravi, S. R., Barr, D. B., & Hauser, R. (2008). Circulating estradiol in men is inversely related to urinary metabolites of nonpersistent insecticides. *Reproductive Toxicology, 25*(2), 184-191.

Meeker, J. D., Ryan, L., Barr, D. B., & Hauser, R. (2006). Exposure to nonpersistent insecticides and male reproductive hormones. *Epidemiology, 17*(1), 61-68.

National Children's Study. (2009). Retrieved from http://www.nationalchildrensstudy.gov/Pages/default.aspx

National Library of Medicine. (2009). *Environmental health and toxicology specialized information system*. Retrieved from http://sis.nlm.nih.gov/enviro.html

Newbold, R. (2008). Prenatal exposure to diethylstilbestrol (DES). *Fertility and Sterility, 89*(Suppl. 1), e55-56.

Ribas-Fito, N., Cardo, E., Sala, M., Eulalia de Muga, M., Mazon, C., Verdu, A., et al. (2003). Breastfeeding, exposure to organochlorine compounds, and neurodevelopment in infants. *Pediatrics, 111*(5, Pt 1), e580-e585.

Ribas-Fito, N., Torrent, M., Carrizo, D., Julvez, J., Grimalt, J. O., & Sunyer, J. (2007). Exposure to hexachlorobenzene during pregnancy and children's social behavior at 4 years of age. *Environmental Health Perspectives, 115*(3), 447-450.

Saldana, T. M., Basso, O., Hoppin, J. A., Baird, D. D., Knott, C., Blair, A., et al. (2007). Pesticide exposure and self-reported gestational diabetes mellitus in the Agricultural Health Study. *Diabetes Care, 30*(3), 529-534.

Schettler, T., Solomon, G., Valenti, M., & Huddle, A. (1999). *Generations at risk*. Boston: Massachusetts Institute of Technology.

Schrager, S., & Potter, B. E. (2004). Diethylstibestrol exposure. *American Family Physician, 69*, 2395-2400.

Stockholm Convention on Persistent Organic Pollutants. (2001). *Stockholm convention on persistent organic pollutants*. Retrieved from http://chm.pops.int/Portals/0/Repository/convention.text/UNEP-POPS-COP-CONVTEXT-FULL.English.PDF

Torres-Sanchez, L., Rothenberg, S. J., Schnaas, L., Cebrian, M. E., Osorio, E., Del Carmen Hernandez, M., et al. (2007). In utero p,p′-DDE exposure and infant neurodevelopment: A perinatal cohort in Mexico. *Environmental Health Perspectives, 115*(3), 435-439.

United States Environmental Protection Agency. (2002). *2000-2001 pesticide market estimates: Historical data*. Retrieved from http://www.epa.gov/oppbead1/pestsales/01pestsales/historical.data2001.3.htm

United States Environmental Protection Agency. (2009a). *Integrated pest management (IPM) principles*. Retrieved from http://www.epa.gov/opp00001/factsheets/ipm.htm

United States Environmental Protection Agency. (2009b). *Integrated risk information system*. Retrieved from http://www.epa.gov/iris

Weselak, M., Arbuckle, T. E., Wigle, D. T., & Krewski, D. (2007). In utero pesticide exposure and childhood morbidity. *Environmental Research, 103*(1), 79-86.

Whyatt, R. M., Garfinkel, R., Hoepner, L. A., Holmes, D., Borjas, M., Williams, M. K., et al. (2007). Within- and between-home variability in indoor-air insecticide levels during pregnancy among an inner-city cohort from New York City. *Environmental Health Perspectives, 115*(3), 383-389.

Woodruff, T., Carlson, A., Schwartz, J., & Giudice, L. (2008). Proceedings of the summit on environmental challenges to reproductive health and fertility: Executive summary. *Fertility and Sterility, 89*(Suppl. 1), e1-e20.

Zahm, S. H., & Ward, M. H. (1998). Pesticides and childhood cancer. *Environmental Health Perspectives, 106*(Suppl. 3), 893-908.