Reducing Exposure to Environmental Toxicants Before Birth: Moving from Risk Perception to Risk Reduction

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SYNOPSIS

In this study, we considered approaches to reducing maternal exposure to hazardous environmental toxicants, focusing on risk communication to pregnant women and providers, but also considering identification of environmental toxicants in the community and reduction of environmental toxicants. We addressed the following questions: (1) What do pregnant women and their providers know about environmental toxicants and perinatal health? and (2) What policy strategies are needed (should be considered) to move forward in risk reduction in this area? We reviewed the literature on knowledge of pregnant women and providers regarding these issues.

While there is limited research on what pregnant women and their providers know about environmental toxicants and perinatal health, there is evidence of reproductive and perinatal toxicity. This article describes a wide range of policy strategies that could be implemented to address environmental toxicants in the context of perinatal health. Effective leadership in this area will likely require collaboration of both environmental health and maternal and child health leaders and organizations.

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Evidence of the negative impact of environmental toxicants on human health is on the rise. While early work largely considered the effects of pollutants on cardiovascular, pulmonary, and cancer disorders among adults, it is now clear that exposures in utero and during childhood may be even more hazardous, with wider-ranging effects. 1,2 First, fetuses, infants, and children undergo rapid growth and development as compared with adults. The higher rate of cell division and differentiation may increase susceptibility to adverse effects of exposures and experiences with exposures during critical development periods, leading to permanent structural and/or organ system deficits.^{3,4} Second, the fetus may be exposed even when the mother appears to be unexposed. For example, environmental toxicant exposures, such as polychlorinated biphenyls and lead, persist in body tissues and thereby expose a fetus even after maternal exposure is eliminated.^{5,6} Finally, exposures during early life could permanently affect reproductive tract structures and harm the next generation (e.g., mechanism of action for diethylstilbestrol).

A wide range of environmental toxicants has been implicated as hazards across the reproductive continuum, from conception to birth. The study of reproductive and perinatal environmental hazards is rapidly evolving and apparently conflicting results have been reported. This requires us to not only evaluate the evidence of what is hazardous, but also to examine what can and should be done about it. Effectively addressing environmental toxicants in the context of perinatal health will likely require ongoing collaborative scholarship, leadership, and advocacy from both the fields of environmental health (EH) and maternal and child health (MCH).

Three general approaches can be taken to reduce exposure to environmental toxicants. First, the toxicant source could be targeted. This would include, for example, strengthening regulatory components of the Clean Air Act or developing new technologies to further improve water quality so that exposures are diminished or eliminated. A second approach involves the up-to-date identification of environmental toxicants present in our communities. Primarily, this relates to methods of reporting chronic exposures, with the intent that exposure will be reduced either by avoiding the exposure, through community clean-up activities, or both. A third approach is risk communication to women and their providers. This is necessarily intertwined with risk identification, as women's and provider's knowledge of the link between exposure and outcomes may not lead to a reduction in exposure if the presence of the exposure is not publicized.

In this article, we address the following questions: (1) What do pregnant women and their providers know about environmental toxicants and perinatal health? and (2) What policy strategies are needed to move forward in risk reduction in this area?

BACKGROUND

Impact of environmental toxicants on reproductive and perinatal outcomes

Environmental toxicants with the potential for harming reproductive or perinatal health are numerous. For many toxicants, there is as yet little empirical human data to demonstrate adverse effects, and risk communication on those factors is either minimal or absent. The literature on health outcomes categorizes the most studied toxicants in the arena of human reproductive/ perinatal health as: air pollution, 7-17 heavy metals (e.g., lead), 18-22 mercury, 23-27 arsenic, 28,29 and pesticides. 30-40 While there are a number of methodologic challenges to studying these exposures and birth outcomes, and results have been somewhat mixed, there is evidence that these toxicants may increase risks of low birthweight, intrauterine growth restriction, preterm birth, and birth defects. A growing literature on emerging chemicals of concern indicates that the toxicants most frequently investigated, both due to concerns of toxicity and their seemingly ubiquitous nature, are endocrine disruptors, including bisphenyl A, phalates, and perchlorates.41,42

While debate persists regarding the existence and/or magnitude of exposure thresholds at which individual environmental toxicants may cause harm to reproductive and perinatal health, we argue that it is necessary to investigate what consumers (primarily pregnant women, but also women generally) and providers believe and do about exposure to these toxicants. In many cases, there may be no individual-level benefit against which to balance exposure (e.g., air pollutant), leading to advocacy for reducing exposures regardless of the level of scientific proof of causation. There may be benefits associated with other toxicants, however, necessitating a risk analysis. This is clearly an issue with regard to fish consumption. Eating fish may expose women to mercury, a toxicant potentially hazardous at any level to the developing fetus,²³ and at the same time provide fatty acids that may promote healthy brain development in the fetus. We argue that leadership is critical when knowledge is uncertain.

WHAT DO PREGNANT WOMEN KNOW AND DO ABOUT ENVIRONMENTAL TOXICANTS?

Overview

Little empirical data on knowledge about environmental toxicants have been reported with regard to either women or their providers. Data collected by the Organization of Teratology Information Services (OTIS) hint at the interest and knowledge level in this regard. OTIS is a private nonprofit organization with specialized teratology information centers covering 24 states, a regionalized telephone consulting service via a toll-free number (866-626-OTIS), and a website with fact sheets (www.otispregnancy.org). One can glean from OTIS caller data that a nascent level of awareness exists among the general public. For example, OTIS 2003–2004 survey data reveal the types of exposures queried from more than 70,000 annual inquiries: 4% maternal illness, 8% environmental agents, 3% radiation, 17% occupational agents, 4% herbal products, 6% drugs of abuse, and 58% medications. In addition, they show that 74% of calls were related specifically to pregnant women, 9% to preconceptional concerns, and 8% to breastfeeding.43

Few published studies reveal where women seek health information generally, 44-47 and none address concerns regarding reproductive and/or perinatal environmental or occupational toxic exposures. There is broad variation in information-seeking behavior, presumably by gender, age, and other sociodemographic factors, with respect to the full range of sources-broadcast media, organized health events, billboards, print news media, magazines, computer-based resources, friends, families, and clinicians. Figure 1 highlights information sources identified in a systematic search of online materials conducted between June and August 2007, using the search terms "pregnancy," "pregnant women," "reproductive health," "environmental exposures," "environmental hazards," and "environmental toxins."48

Information sources also exist that women (and their providers) might use to learn about potential environmental hazards at work and at home. The federal government hosts a number of technical websites. However, two federally funded websites operated by nonprofit organizations are particularly accessible. Community Right to Know (www.crtk.org/index.cfm) provides links for accessing information about local environmental hazards/conditions, environmental legislation, and toolboxes for community organizing. SCORECARD (www.scorecard.org) allows a zip codebased search of local environmental conditions, air and water quality, and location of pollution sites. The

website also includes fact sheets on a wide variety of chemicals and exposures—indexed by type of health risk posed (including developmental and reproductive toxicants)—and links to federal regulations regarding health and environmental exposures.

Environmental toxicants

Despite a rigorous and broad search of Medline and the Internet (using broad search terms and iterative combinations, e.g., environment, environmental, toxicants, pollutants, pollution with pregnancy, perinatal, prenatal, maternal, and reproductive), we did not identify any peer-reviewed articles on pregnant women's knowledge and behaviors regarding multiple environmental toxicants and childbearing. This was in contrast to a substantial literature on exposure to toxicants and reproductive/perinatal health. The few published studies that have examined knowledge of hazardous environmental toxicants and childbearing considered only the issue of mercury exposure from fish. First, an article by Frey et al. examined women's knowledge prior to conception for a wide range of topics, but the only environmental topic considered was consumption of certain fish. Slightly more than half of women reported knowledge of the risks associated with such consumption. This was in marked contrast to women's knowledge of factors such as smoking and alcohol use, for which ≥95% of women were aware of the potential dangers. 49 However, this study did not test the accuracy of women's knowledge (e.g., which fish and what amounts pose a hazard).

A recent 12-state study of women of childbearing age focused on fish consumption generally (not within the context of pregnancy), understanding of mercury toxicity, and awareness of advisories regarding fish consumption. Only 20% of women reported being aware of state advisories on sport fish consumption. The majority (71%) of women were aware that mercury harms the developing fetus, with knowledge more likely among women who reported being aware of the advisories (87% vs. 67%).⁵⁰ Second, in the only published study with data presented that were specific, pregnant, low-income pregnant, and breastfeeding women in a California Women, Infants and Children clinic were surveyed regarding knowledge of fish advisories and mercury. Approximately 45% of women were aware that health warnings had been issued for consumption of fish and shellfish in women of childbearing age, and only 31% of all women (more than two-thirds of those with any awareness) had specific awareness of the advisory content. Levels of awareness were slightly higher for pregnant women.⁵¹

Figure 1. Information resources for reproductive-age women and their health-care providers

Source	Available information
Organization of Teratology Information Specialists (OTIS)	www.otispregnancy.org Fact sheets in English and Spanish on a variety of common exposures Links to OTIS information centers for both health professionals and individuals
March of Dimes Birth Defects Foundation	www.marchofdimes.com/pnhec/159.asp Fact sheets, brochures, and a screening checklist
Motherisk	www.motherisk.org Telephone helplines to answer women's questions about pregnancy, including exposures Links to peer-reviewed articles about environmental exposures and child health E-Learning Center for health-care professionals with video tutorials on teratology
American College of Obstetricians and Gynecologists	www.acog.org/publications/patient_education Brochure on good health before pregnancy, including environmental exposures
What to Expect	www.whattoexpect.com/pregnancy/work-issues/health-and-safety.aspx Basic information about common exposures, particularly in the workplace Includes message boards and blogs for women to post and respond to questions
Women's Voices for the Earth	www.womenandenvironment.org Grassroots environmental health and justice organization Reports and fact sheets with specific information on risks of household cleaning products and exposures (e.g., mercury during pregnancy) Awareness campaigns and community events
Office of Women's Health, U.S. Department of Health and Human Services (HHS)	www.4woman.gov Fact sheets on mercury and medications, "Fish Facts Print and Go Guide," and "Food Don'ts Print and Go Guide" General information on the environment and women's health General information about preconception, pregnancy, and overall health
Agency for Toxic Substances and Disease Registry, Centers for Disease Control and Prevention (CDC), HHS	www.atsdr.cdc.gov Complex and comprehensive information about toxic substances; little specific information is oriented to reproductive health
Food and Drug Administration, HHS	www.fda.gov/womens/healthinformation/pregnancy.html Fact sheets on pregnancy and medicines, infections, and food safety, including mercury and fish. Site allows users to research the safety and effectiveness of various medications that might be used during pregnancy.
National Institute of Environmental Health Sciences (NIEHS), HHS	www.niehs.nih.gov Links to NIEHS studies regarding reproductive health Specific information can be found at http://www.niehs.nih.gov/oc/factsheets/pregnant/ home.htm Offers comprehensive information about environmental influences on the development and progression of human disease; limited information about reproductive health is available
National Institute of Occupational Safety and Health (NIOSH), National Occupational Research Agenda, Fertility and Pregnancy Abnormalities Team, CDC, HHS	www.cdc.gov/niosh NIOSH conducts research and makes recommendations about the prevention of work-related injury and illness; geared toward professionals and employers. Specific information about reproductive health includes general safety and health issues at work for pregnant women.

continued on p. 633

Source	Available information
Occupational Safety and Health Administration (OSHA)	www.osha.gov Offers complex, comprehensive information about workplace safety and health; geared toward employers. Website includes a link to information specifically about OSHA's standards regarding reproductive hazards.
National Library of Medicine	www.toxtown.nlm.nih.gov ToxTown website includes interactive tool for the general public to learn about toxic chemical and environmental health risks. Some information included about risks to pregnant women. More technically oriented sites include: National Library of Medicine: Household Product Database: www.hpd.nlm.nih.gov National Library of Medicine: MedlinePlus: www.nlm.nih.gov/medlineplus/ poisoningtoxicologyenvironmentalhealth.html National Library of Medicine: TOXNET: www.toxnet.nlm.nih.gov

Broadly expanding our Internet search with regard to any environmental toxicants, we identified a few unpublished reports relevant to this topic focusing on risk communication interventions. However, these studies were limited to fish contamination. The Adult Food Stamp Nutrition Education Fish Connection program in California targeted women who could become or were pregnant, as well as mothers. Participants demonstrated increased knowledge and changes in consumption with regard to mercury-containing fish after four classes. Some broad-based efforts do not specifically target pregnant women or women of childbearing age. One example is the Fish Contamination Education Collaborative, an outreach and education project supported by the Environmental Protection Agency (EPA). While the activities were broad, they assessed knowledge, attitudes, and beliefs among women of childbearing age of different ethnicities, comparing baseline to follow-up.52 The study found an increase in awareness of fish advisories and in beliefs about the importance of fish advisories related to health issues generally (not specific to pregnancy).

Occupational toxicants

As many of the environmental toxicants are also prevalent in occupational settings, we searched for literature on occupational exposures and pregnancy with regard to women's knowledge and actions, but found no reported or published journal articles providing empirical data. We then specifically investigated whether occupational health regulations had been evaluated with regard to reproductive and perinatal health. The Occupational Safety and Health Act promulgated the Hazard Communication Standard in 1983, with mandated evaluation of health hazards, labeling of containers, use of material safety data sheets (MSDSs),

and employee training to ensure information uptake. In 1991, the Government Accounting Office conducted a study of regulatory action in this arena, finding current federal efforts inadequate.⁵³ Recommendations included more comprehensive and specific review of toxicity data, separate analyses for reproductive and developmental outcomes in risk assessment, and more data and information for decision-makers and the media. We found no evaluations of the Hazard Communication Standard in the published literature prior to 1990, and few since. Regarding hazards to reproductive health, in the late 1980s, only 53% of the MSDSs in Massachusetts noted the potential effects of lead and ethylene glycol ethers on reproductive health.⁵⁴

Beyond processes to meet federal information and safety training mandates, employers may offer occupational health services that are of potential use to women who may be concerned about toxic exposures. Frazier and colleagues reported on the experiences of women presenting to an occupational health service's reproductive hazards consultation service.⁵⁵ Eighty percent of the women using the service were already pregnant and working, with a mean of 15.5 chemical exposures classified as reproductive hazards.

WHAT DO PROVIDERS KNOW AND DO ABOUT ENVIRONMENTAL TOXICANTS?

Overview

Data on provider knowledge and behavior are as scarce as that for women. In a recent article on preconceptional factors and occupational/environmental factors, McDiarmid and Gehle speculated that women may have more interest and knowledge than providers.⁵⁶ The lack of current baseline information on provider knowledge and behavior means that efforts to address these issues

with providers are difficult to evaluate. While directly targeting women may have effects on their exposure, knowledgeable providers who disseminate information to patients may have an even greater alternative or complementary effect. Educated providers could initiate conversations about environmental toxicants or act to reinforce women's own knowledge. For example, drawing on literature relating to maternal smoking, studies suggest that educating providers may be more effective in changing women's behavior than directly targeting women to quit. ^{57,58}

Dissemination of knowledge, however, is not the only role providers can play, and it may not even be the primary role that is needed regarding environmental toxicants and reproductive/perinatal health. Education of clinicians could lead to increased assessment and identification of women with regard to hazardous environmental toxicants, more accurate estimation of the risk associated with such exposures, communication of risk estimates to women, and appropriate referral of women to specialty care and resources.

There appears to be general consensus that clinicians are not well-versed on the subject of environmental exposures. In 1988, the Institute of Medicine examined the role of primary care physicians in occupational and environmental medicine and called for enhanced physician training and education, stating, ". . . as a minimum, all primary care physicians should be able

to identify possible occupationally or environmentally induced conditions and make the appropriate referrals for follow-up."⁵⁹ We found only one study examining environmental medicine content in medical school curricula. With nearly all of the accredited U.S. medical schools responding to the survey, 76% indicated inclusion of environmental content, with a mean of seven hours of instruction on this content.⁶⁰

Clearly, education for clinicians occurs along a continuum, undertaken in the context of residency training and continuing education. The materials described in Figure 2 are those found in our searches.

Considerations concerning risk reduction strategies

Our exploration of risk communication regarding environmental hazard risks to reproductive/perinatal health uncovered a set of policy and practice initiatives that were germane and potentially instructive of future directions. We observed that policy tools and practice knowledge are available in the broadest sense, but nearly all lack a concerted focus on the populations and health concerns at hand. Moreover, those focused efforts that do exist are relatively recent and understudied. These strategies can be conceptualized as being along a continuum from risk perception to risk reduction, and along a continuum from the individual level to the population level. Figure 3 shows a brief synopsis of this set of strategies.

Figure 2. Sources of provider education specific to pregnancy and environmental hazards

- Pope AM, Rall DA, editors. Environmental medicine: integrating a missing element into medical education. Washington: National Academy Press; 1995.
 - This text can be used to integrate material into medical school curriculum; it has four appendices with 55 case studies, and also educational resources and teaching aids. The topic of Case Study #53 is reproductive and developmental hazards.
- Frazier LM. Workplace reproductive problems. Primary Care: Clinics in Office Practice 2000;27:1039-55.
 Written for practicing primary care physicians, this article includes an overview of hazards and specific advice about screening, assessment, counseling, and possible actions that the physician can take to assist his/her patient.
- Hoskins IA. Environmental and occupational hazards to pregnancy. Primary Care Update for OB/GYNS 2003;10:253-7.
 This article offers a brief synthesis of new science.
- Agency for Toxic Substances and Disease Registry. Case studies in environmental medicine [cited 2009 Mar 24]. Available from: URL: http://www.atsdr.cdc.gov/csem/csem.html
 - This Web-based series of self-instructional publications is designed to increase primary care providers' knowledge of hazardous substances in the environment. The continuing education course, "Taking an Exposure History," was updated in 2000 and is the most relevant of the set to perinatal health.
- Association of Occupational and Environmental Clinics (AOEC). Peer-reviewed modules [cited 2009 Mar 25]. Available from: URL: http://www.aoec.org/resources.htm
 - Educational resources are posted on the AOEC website.
- Journal of Midwifery and Women's Health 2006, Volume 51, Number 1
 - This supplemental issue includes an editorial, feature articles on toxins, a case study of screening for pesticide exposure, and an article on information sources. The issue also includes a tear-out fact sheet to give to patients. The supplement is part of the self-study continuing medical education series of the American College of Nurse-Midwives (ACNM) and is accessible on the ACNM website (http://www.midwife.org).

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Figure 3. Environm	Figure 3. Environmental toxins risk reduction strateg	strategies for perinatal health	
Strategies	What exists	Strengths	Limitations
Public notification	News releases, information posting on governmental and nonprofit organization websites, posting of notices in public places	Required in legislation for many known hazardous substances; structures and resources in place Potentially broad reach, particularly with regard to the Internet	Most often general in nature, without translation to issues of reproductive risks Questions regarding whether notification laws incorporate sufficient range of chemicals, industries, and sites [®] Emphasis on specific areas related less to science than to context of individual behavior change Content of information not easily controlled; varies widely with respect to accessibility, the nature and scope of content, differing and unspecified audiences, and technical complexity May be inaccessible to some with limited reading ability and language barriers
Mass media	Print, television, and radio news features produced nationally, regionally, and locally	Some documented effectiveness in knowledge improvement ^b Potential to reach a broad and diverse audience	Can be general in nature without translation to issues related to reproductive health Selection of topics covered not systematic Quality control is absent; potential for "unscientific" sensationalism
Product labeling	Laws requiring labeling of risks of toxic exposure for a wide assortment of specific chemicals, including pesticides	Content of information can be controlled, consistent Some documentation of effectiveness of labeling with respect to alcohol and smoking in pregnancy ^{c,d}	Can be difficult to craft appropriate messages when substance may have both risks and benefits (e.g., fish) May be inaccessible to some with limited reading ability and language barriers
Legislation/regulation	Bans on smoking in public places, such as worksites and restaurants	Substantial reduction in environmental tobacco smoke exposure®	Political process of legislation and regulation can be complex and protracted
Health provider counseling	American College of Obstetricians and Gynecologists standard environmental history form includes smoking, alcohol, and drug use. More recently, clinician querying about fish consumption and/ or residential proximity to known pollution sources encouraged by professional groups ⁶	Women known to seek and trust information from their health-care providers ^{9,h}	Limited education of women's health clinicians in specific regard to environmental exposures ¹ Practice constraints; limited time for counseling Some exposures are difficult for women to self-identify Timing of information vs. timing of exposure; can be too late to make a preventative difference

Figure 3 (continued). Environmental toxins risk reduction strategies for perinatal health

Strategies	What exists	Strengths	Limitations
Specialized resource centers	10 Environmental Protection Agency (EPA)-sponsored pediatric environmental health specialty units 17 Organization of Teratology Information Services programs	Information provided by scientific experts; assume high degree of accuracy. Appropriate translation of specific risks likely. With sufficient outreach, can be broadly recognizable and wellused!	Can be expensive; requires public funding Currently not coordinated efforts with respect to lifespan approach; address pediatric and reproductive/perinatal foci independently Uneven geographic coverage
Surveillance	Systematic surveillance available for many reproductive and perinatal outcomes, such as low birthweight and birth defects EPA report, "America's Children and the Environment," includes quantitative information for trends related to levels of environmental contaminants in air, water, food, and soil, and concentrations of contaminants measured in children and women Some local health agency efforts to monitor, for example, blood mercury levels among specific population subgroups!	Number of toxicants examined and frequency of measurement for the maternal and child health population increased in recent years National Children's Study (longitudinal) launched	Limited and uneven quality monitoring of spontaneous and induced abortions as well as infertility Uneven monitoring of exposures and outcomes at the local level hampers pinpointing of potential hot spots

O'Neil SG. Superfund: evaluating the impact of executive order 12898. Environ Health Perspect 2007;115:1087-93.

Food Safety and Inspection Service, Department of Agriculture (US). PR/HACCP rule evaluation report. Changes in consumer knowledge, behavior, and confidence since the 1996 PR/

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Hankin JR. Fetal alcohol syndrome prevention research. Alcohol Res Health 2002;26:58-65.

Repace JL, Hyde JN, Brugge D. Air pollution in Boston bars before and after a smoking ban. BMC Public Health 2006;6:266.

McDiarmid MA, Gehle K. Preconception brief: occupational/environmental exposures. Matern Child Health J 2006;10(5 Suppl):S123-8.

*Lumley J, Oliver S, Chamberlain C, Oakley L. Interventions for promoting smoking cessation during pregnancy. Cochrane Database Syst Rev 2004;4:CD001055.

Melvin C, Gaffney C. Treating nicotine use and dependence of pregnant and parenting smokers: an update. Nicotine Tob Res 2004;6 Suppl 2:S107-24.

Schenk M, Popp SM, Neale AV, Demers RY. Environmental medicine content in medical school curricula. Acad Med 1996,71:499-501.

Woodruff TJ, Axelrad DA, Kyle AD, Nweke O, Miller GG. America's children and the environment: measures of contaminants, body burdens, and illnesses. Washington: Environmental Institute of Medicine, Board on Health Promotion and Disease Prevention. Forging a poison prevention and control system. Washington: National Academies Press; 2004. Protection Agency (US); 2003. Also available from: URL: http://www.epa.gov/envirohealth/children/index.htm [cited 2009 Mar 31].

McKelvey W, Gwynn RC, Jeffery N, Kass D, Thorpe LE, Garg RK, et al. A biomonitoring study of lead, cadmium, and mercury in the blood of New York City adults. Environ Health Perspect 2007;115:1435-41.

POTENTIAL FUTURE POLICY DIRECTIONS

Exposure of reproductive-age women to environmental toxins is an issue of national leadership and commitment. As an initial step, better management of information, including information vehicles, is needed. While perhaps not satisfying all constituencies, the current efforts of federal agencies and national nonprofit groups focused on environmental and occupational toxic exposures are noteworthy. Environmental science is slowly coming to the attention of public and private sector professionals concerned with MCH, but there is room for improvement. Organizational, as well as communication and behavior change aspects will clearly be important components, but effectiveness in these arenas remains uncertain with respect to a wide range of interventions.

While prenatal influences are important to consider, the earliest time periods—the periods prior to conception (preconceptional), not just prior to birth (prenatal)—demand greater attention. First, exposure during the preconceptional period may persist in body tissues (e.g., lead). Second, exposures in early life could permanently affect reproductive tract structures (e.g., diethylbestrol). Third, women may be unaware of pregnancy during the early period, when the fetus is most vulnerable to malformations and loss. Furthermore, this knowledge is likely influenced by demographic and psychosocial risk factors, so that women with the highest risk are the least likely to learn of their pregnancy early. Finally, even if women know they are pregnant, they may not be able to initiate prenatal care during this early period and receive information, as clinicians may not see women until 10-12 weeks gestation.

Therefore, we suggest adoption of a life course approach to this problem, which should lead to an expansion of education efforts and presumably not to a dilution of the message. For example, risk communication efforts need to target providers beyond obstetricians/gynecologists and midwives. Ways to reach nonpregnant women with these messages need to be developed. We must ensure that a one-size-fits-all strategy does not evolve as a result of shifting to a life course approach.

To date, more focus (and action) has been given to child health, with a concomitant lack of attention and resources given to environmental toxicant exposures during the preconceptional and pregnancy periods. Even if the goal remained to improve children's health, it is clear that exposures to children's mothers (and fathers) prenatally and even prior to conception may have a lifelong impact on the child. To truly protect children from environmental toxicants, we need to expand beyond a narrow conceptualiza-

tion of children's EH and consider exposures during these earliest time periods. The recent investment in the National Children's Study affirms the interest of researchers and policy makers in investigating the potential lifelong effects of prenatal exposures on childhood and adult health.

Another foundational area is in the field of risk communication. Risk perception plays a central role in risk communication strategies. Bennett compiled a list of "fright factors" that may lead to perception of risks as "more worrying and less acceptable." Nearly all of these factors apply to the issue of environmental toxicants and reproductive/perinatal health, suggesting that risks might be perceived as more alarming for this topic than for others. What little is known specifically about risk perception by women regarding pregnancy suggests that there are factors resulting in overestimation of risk. 61-64 The findings of these studies highlight the very charged context of pregnancy with regard to risk communication, a factor we must consider as we seek to inform women of risks of exposures that may be difficult to prevent. It is clear that we are far from a complete understanding of how women perceive risk during pregnancy—an important domain to master to develop effective risk communication about potential hazards, such as environmental toxicants.

Our review of environmental risk communication in relation to perinatal outcomes suggests, then, a number of potential next steps for concerned professionals and government agencies. We believe that there are several straightforward and low-cost actions that can be taken in the short term. In addition, our analysis points to both a need and an opportunity to reduce environmental hazard exposures preconceptionally and in the pregnancy period over the longer term.

Feasible short-term actions

Capitalize on public notification requirements that stem from environmental legislation. Government agencies can work together and with their nonprofit partners to further enhance their websites and print materials by organizing available information. Technological tools, such as links to local environmental data on existing websites, could serve as a model and means for making perinatal health-related information more accessible to women and health-care providers. This would further require some translation of the scientific data and related information for general public audiences, as well as efforts to address culture and language-specific targeting concerns.

Continue and enhance use of the news media. As noted, mass media can be influential and already has

demonstrated an interest and commitment to report on environmental issues. Partnerships exist in other arenas of health care wherein journalists convene for education on selected topics (e.g., Journalism Fellowships in Child and Family Policy and the Knight Center for Specialized Journalism) so that the information they provide is clear, accurate, and systematically presented (e.g., foundation-supported projects that focus on health-care reform and expansions of publicly supported health insurance for low-income children). A parallel effort could be undertaken to focus on EH exposure risks to women and children.

Product labeling. For some toxicants, product labeling has tremendous potential to change exposure; however, the knowledge base in this area is minimal (Figure 3). To explore how labeling can be effectively implemented in this arena will likely require a systematic set of research and demonstration projects.

Reexamine potential workplace interventions. An opportunity also exists for exploring with labor unions, the Occupational Safety and Health Administration, and occupational health professionals how improvements might be made in relation to reproductive and perinatal health concerns in the workplace systems of toxic risk notification and safety education. In addition, such efforts could serve as a vehicle for promoting initiatives to further reduce or eliminate environmental tobacco smoke in the workplace.

Promote improved health-care provider counseling for women and couples. Given the greater likelihood of exposure in impoverished and/or isolated geographic communities, the EH professional community might consider establishing and/or strengthening partnerships with the Health Resources and Services Administration to implement targeted and vigorous outreach to health-care providers working in area health education centers, community health centers (including those for migrant workers), and MCH programs in states and communities. These education and service programs address the needs of the most vulnerable groups (e.g., low-income, minority, immigrant, and geographically isolated populations). They also have strong relationships with provider organizations and training programs, such as the National Health Service Corps, which interface with medical professionals serving such groups.

To make up-to-date information on relevant environmental science more accessible to women's health providers, the organizations' online strategies could be replicated in the MCH professional community. American College of Obstetricians and Gynecologists, other MCH professional organizations (e.g., American

College of Nurse-Midwives, Association of Women's Health, Obstetric and Neonatal Nurses, American Academy of Pediatrics, and American Academy of Family Practice), and MCH-related government agencies (e.g., Maternal and Child Health Bureau, and the Office of Women's Health, Centers for Disease Control and Prevention [CDC] Divisions of Perinatal Health and Birth Defects) can feature information on EH hazards more expansively and prominently in their communications, including websites.

Efforts also might be made to capitalize on CDC's preconception health and health-care initiative and advocate for greater attention to EH concerns. While this initiative has acknowledged these issues, to date relatively few EH professionals or agencies have gotten involved in the initiative, and the issue of hazardous environmental exposures (acute and/or chronic) has not been a high priority.

McDiarmid and Gehle recommend that the environmental history be expanded to (1) include assessment of environmental exposures that occur in a woman's home, community, or workplace and (2) present an occupational/environmental history checklist, adapted from work by Grajewski, 65 for use by providers at the preconception visit. Faucher echoes this notion. Information technology tools developed initially in the pharmacy industry to assist medical care providers in examining and calculating risk in relation to contraindications in medication might be designed to assist in calculating environmental exposure risks, thereby enhancing capabilities in counseling women and their partners.

Tailoring of risk messages has moved to the forefront in other areas of risk communication, with a number of investigations indicating that tailoring improves communication. Tailoring was initially applied to print communications, but has been used more recently in online materials, where information is gathered from the individual and used to create tailored messages dynamically. Information about a woman's residential and occupational environments could be ascertained and combined with various databases to create a uniquely tailored risk assessment and risk communication message.

Surveillance. While systematic surveillance is available for many reproductive and perinatal outcomes, routine monitoring of spontaneous and induced abortions as well as infertility faces limitations due to data availability and quality. Birth defect registry data are available but are not routinely monitored with regard to potential environmental impact, nor are the levels of toxicants monitored in correlation with birth defects or other reproductive and perinatal outcomes.

The limitations of national and local data impede our ability to track environmental impact over time. Further, as we seek to implement population-based interventions to reduce maternal exposures, impact on reproductive and perinatal health outcomes will be difficult to ascertain without increased surveillance of outcome indicators. In some cases (e.g., spontaneous abortions), data collection will need to expand. Other outcomes (e.g., birth defects) may only require increased use and monitoring of existing data.

Increased measurement and monitoring of both toxicant biomarkers (e.g., blood levels) and self-reported exposures for pregnant women and women of childbearing age is needed. This might be accomplished by additions to existing national surveys and examinations, including the Pregnancy and Risk Assessment Monitoring System, the Behavioral Risk Factor Surveillance System, the National Survey of Family Growth, the National Survey of Children's Health, and the National Health and Nutrition Examination Survey. Federal agencies could also collaborate with OTIS and pediatric environmental health specialty units (PEHSUs) to systematically track data on knowledge and actions of pregnant women.

Longer-term initiatives

Create an organized system of information and care specific to hazardous environmental exposures related to perinatal health. Consideration should be given to creating a more organized approach to information compilation, dissemination, expert technical advice, and guidance for medical education that is similar to the system used by U.S. poison control centers (PCCs). In its recent review of PCCs nationwide, the Institute of Medicine noted that while there are aspects of the PCC system that need to be strengthened, they represent a critical set of services.⁷⁰ Resources that might be used and enhanced to replicate this model in the arena of perinatal environmental risk exist, but potential impact is hampered by (1) limited geographic coverage of the Toxicology Information System (TIS), (2) absent or weak linkages between the PEHSUs and TIS, and (3) absent or weak connections with MCH programs and with the Center for the Evaluation of Risks to Human Reproduction health research. To be effective, such a system needs to be very publicly visible (to assure universal access for the population and for professionals) and should be a joint private and public health/MCH and EH science effort. Consideration might be given to ways in which OTIS and the PEHSU collaboration could play a role in design and implementation.

Undertake a nationally visible and scientifically and politically credible initiative that brings together health and environment, with a focus on preconceptional and prenatal toxic environmental exposures. The current state of governmental complexity and fragmentation with respect to research, public information, regulation, and health services likely thwarts the natural evolution of collaborative action in this arena. The EPA's Prenatal Partnership on Environmental Health has made some progress in this regard, but certain key players have not been present at the table; most notably, the Health Resources and Services Administration (both the MCH Bureau and the Bureau of Primary Care) and public sector professionals with a major focus on MCH. Moreover, community and state government agency representatives should be key participants.

A report by the U.S. Surgeon General or the Institute of Medicine may provide unifying structure and public policy visibility. Deliberation undertaken to develop such a report would need to include a discussion of the role federal, state, and local agencies in MCH and EH play with regard to protecting pregnant women from environmentally hazardous exposures. This initiative would work toward:

- 1. National shared goals;
- A rational organization of complementary program components for knowledge development (research), information dissemination, consultation, and service, as well as research that includes community-state-national linkages;
- 3. A prevention model that incorporates a lifespan perspective through primary (information and education), secondary (risk identification), and tertiary (counseling) prevention services that would serve as the underpinning; and
- 4. Communication mechanisms that link all components and strengthen accountability (including use of data/surveillance and other feedback systems) for improved outcomes for women and children consistent with the shared goals articulated.

CONCLUSIONS

While the body of research informing us what pregnant women and their providers know about environmental toxicants and perinatal health is limited, evidence of reproductive and perinatal toxicity has accumulated to a point where leadership and action are necessary. We have described a wide range of policy strategies that could be implemented to address environmental

toxicants in the context of perinatal health. Effective leadership in this area will likely require collaboration of both EH and MCH leaders and organizations.

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