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Reproductive Health and the Industrialized Food System: A Point of Intervention for Health Policy

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Abstract

How and what food is produced impacts nutrition and the environment, two key drivers of healthy human reproduction and development. Our industrialized food system yields a large volume of food that is relatively low in cost for consumers. At the same time, it produces food that tends to be high in calories and low in nutritional value, and involves the intensive use of pesticides, chemical fertilizers, hormones, antibiotics, fossil fuel, and chemicals in food packaging. These characteristics are potentially harmful to reproductive and developmental health. Policies to advance a healthy food system are an opportunity to prevent adverse reproductive health impacts and avoid associated health costs among current and future generations.

Keywords

Public Health; Children's Health; Environmental Health; Special Populations; Maternal And Child Health

Introduction

Public policies that have informed food production in the U.S. since the end of World War II have supported the growth of a highly concentrated and productive food system. (1) Our “industrialized” food system is also characterized by intensive application of petroleum-based pesticides and chemical fertilizers in place of crop rotation, manure, and diversification to manage pests and maintain fertility; and by distant distribution of processed food over local and fresh food. (2) While successful at producing high-yields of certain foods offered at a low price in the marketplace, our industrialized food system also comes with potential adverse health consequences that have yet to be scrutinized by government regulators in a manner comparable to other polluting industries. (1)

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Recognition of the need for a more complete accounting of the human and environmental health impacts of our industrialized food system is growing among the public, regulatory agencies, scientists, and health professionals. (1,3–5) To help inform that knowledge gap, we describe: [1] the relationship of the industrialized food system to reproductive health, defined as encompassing all aspects of reproductive and developmental health throughout the life course, including conception, fertility, pregnancy, child and adolescent development, and adult health; and [2] opportunities for health professionals to advance food system-related policies in order to accelerate improvements in reproductive health.

Reproductive Health, Nutrition and the Environment

Our food system is inextricably linked to two key drivers of reproductive health: nutrition and the environment (Figure 1). Humans are more susceptible to the benefits and harms of nutrition and the environment during periods extending from around the time of conception through pregnancy, infancy, childhood, and puberty. This susceptibility can be attributed to the dynamic growth, high metabolic rate, immature liver detoxifying mechanisms, and under-developed nervous, respiratory, reproductive and immune systems that characterize these developmental periods. (6)

A woman's nutrition before and during pregnancy can impact her child's health, including pregnancy outcomes and conditions that manifest later in life such as cardiovascular and metabolic disease. (7,8) The environment can also contribute to negative health outcomes over short and long-term time frames. For example, the potential health consequences of prenatal exposure to toxic environmental contaminants include immediate effects, such as birth defects, pre-term birth, and low birth-weight; short-term effects, such as learning disabilities and childhood cancers; and long-term health impacts, such as diabetes, cardiovascular disease, and cancers later in life. (6,9–11)

Every pregnant woman in the U.S. has measurable levels of multiple environmental chemicals in her body that can harm human reproduction and development; many of these chemicals are at levels associated with adverse health outcomes in human studies (Figure 2). (11) In general, toxic environmental chemicals end up in pregnant women primarily due to human activities, and the food system is an important pathway of exposure.

Food system-related and other environmental chemicals are then able to cross the placenta and enter the fetus. In 2010, the *President's Cancer Panel Report*, an annual report to the President of the United States, sponsored by the National Cancer Institute, and written by members appointed by President George W. Bush, concluded that, "to a disturbing extent, babies are born "pre-polluted." (12)

Some environmental chemicals in our food like bisphenol A (BPA) break down quickly, but exposure is constant so they are always present in our bodies. Other chemicals like the pesticide DDT, dioxins and polychlorinated biphenyls (PCBs) do not break down but rather accumulate over time in the food system, and thus are able to appear in our bodies long after the chemicals have been banned (Appendix). While the impact of our daily exposure to individual chemicals has sometimes been studied, the cumulative health impact of

concurrent exposure to many such chemicals has not, primarily due to limitations in the current regulatory structure.(13) Our limited understanding of the potential harm is recognized by the National Academy of Sciences as a gap in current scientific methodologies that inform public policy. (14)

How Key Reproductive Health Impacts Manifest Through the Stages of the Food System

1. Production

Pesticides—Millions of pounds of synthetic pesticides are applied annually in U.S. conventional (i.e., non-organic, resource-intensive) agriculture to prevent, destroy, repel, or mitigate pests. (15) Pesticide residues applied in agriculture do not all stay on food crops or even the farm but can move into the wider environment where they can contaminate air, water and soil. (16,17) Pregnant women are exposed to agricultural pesticides primarily from contaminated food, water, air and soil, and this exposure is ubiquitous among pregnant women in the U.S. (Figure 2).

Pesticide exposure during pregnancy and early childhood can harm the developing brain and adversely impact child mental and behavioral development. (18) It is estimated that 40 percent of U.S. children have enough cumulative exposure to pesticides to potentially impact their brains and nervous systems. (19) Pesticide residues in the types and amounts of foods and beverages typically consumed by the U.S. population can lead over time to exposures that are high enough to increase the chance of children developing cancer and other chronic diseases. (20) Pesticide exposure can interfere with all developmental stages of reproductive function in adult females, (21) and is associated with adverse reproductive health outcomes across the life span of men and women, including birth defects, (22) sterility in males, (23) spontaneous abortion, diminished fetal growth and survival, (21) childhood leukemia and adult breast and testicular cancer. (24–27)

Chemical Fertilizers—Farms today are very large and increasingly likely to “monocrop” - that is, grow just one crop intensively, year after year with the use of chemical fertilizers to maintain yield. In 2007, the majority (58%) of the nearly 23 million tons of chemical fertilizers used in U.S. agriculture were nitrogen based and the nitrogen was derived from natural gas. (28) Nitrogen-based chemical fertilizers contribute to groundwater contamination and impaired aquatic systems, (29,30) and ---because they are fossil fuel-derived--to climate change. Groundwater is the source of drinking water for many Americans, especially those using wells. Nitrates in drinking water can cause “blue baby syndrome” (methemoglobinemia) in infants and have been associated with higher risks of reproductive health impacts and cancer. (31,32) Even when fertilizers derived from animal waste or treated sewage sludge are employed in industrialized farming operations, the upstream use of antimicrobials, heavy metals and additives to animal feeds may leave these fertilizers contaminated with pollutants that can find their way into drinking water. (33,34).

Hormones in Beef Cattle—Three natural steroid hormones (estradiol, testosterone, and progesterone), and three synthetic surrogates (zeranol, trenbolone and melengestrol) are

currently in widespread use by U.S. and Canadian beef cattle producers to increase meat production or yield. (35) Policy in the U.S. is inconsistent in regards to hormone use in livestock, as no steroid hormones are approved for growth purposes in dairy cattle, veal calves, pigs, or poultry. (36) In Europe, the use of natural and synthetic steroid hormones in cattle production has been illegal for over 20 years.

The use of hormone growth promoters results in residues that can be measured in meat and in drinking water as a result of manure contamination and runoff from cattle feedlots. (37) Livestock also excrete naturally occurring steroidal estrogens. (38) It is estimated that 90% of the total estrogen in the environment is contributed by livestock manure. (39)

The safety of consuming hormones in beef is unclear, as definitive data are lacking on this question. However, there is strong evidence that environmental exposure to hormonally-active compounds can interfere with normal human hormone function and cause adverse reproductive and other health outcomes. (6,40)

Antimicrobials in Beef Cattle, Swine and Poultry—As much as 80% of all antimicrobials used in the U.S. are used in food animal production. (41) Antibiotic use for treating sick animals constitutes only a small fraction of the total. Up to 70% of total antimicrobial use is given at non-therapeutic doses to otherwise healthy beef cattle, swine, and poultry to promote more rapid growth, or to offset the risk of infection among animals raised in confined animal feeding operations (CAFOs); most of these antimicrobials are from drug classes important to human medicine. (42) This practice is recognized as a significant contributor to the epidemic of antibiotic resistance among human pathogens; (42,43) a concern that extends to the care of pregnant women, for example, after cesarean section. (44)

The routine use of antimicrobials in animal feed given to healthy animals is prohibited in many industrialized countries including the European Union. No such legislation exists in the U.S., although a bill to reduce the use of antimicrobials in healthy animals was re-introduced in the U.S. House of Representatives in March 2011 (41).

Arsenic compounds are also used extensively in the U.S. in feed consumed by conventionally raised poultry and swine for disease prevention, meat pigmentation and growth promotion. (34) This practice results in arsenic residues in food and the introduction of large volumes of arsenic-bearing wastes into the environment, including via the common use of this manure as cropland fertilizer. (34,45) Emerging data suggest that early-life exposure to arsenic in drinking water is linked to liver, lung, and kidney cancer in adult humans. (46) Arsenic has also been linked to spontaneous abortion in animal studies. (47)

In February 2011, two Maryland state senators introduced a bill to the state legislature that would ban the sale and use of chicken feed containing arsenic in Maryland. (48) On the same day, Food and Water Watch launched a “Hold the Arsenic” campaign with over 120 organizations and businesses to help garner public support for the bill. Arsenical feed additives have not been approved as safe in the European Union, and are not allowed in USDA-certified organic meat production.

Fossil Fuel Consumption and Climate Change—The average U.S. farm relies heavily on fossil fuels and is not energy efficient. (49) Fossil fuels are consumed by the production of natural gas-derived fertilizers and petroleum-based pesticides, by farm machinery and by transporting food to distant markets.

Overall, agricultural emissions are important contributors to reduced air quality. (1) Agricultural use of fossil fuels produces a number of air pollutants associated with adverse pregnancy and child health outcomes including carbon dioxide, particulates, and nitrogen and sulfur oxides. (1,50,51)

Food animal production is also a major source of greenhouse gas-emissions in the form of carbon dioxide, nitrous oxide, and methane. The relative contribution of industrialized livestock production has been estimated to be 18% of all global anthropogenic greenhouse gas emissions. (52) The climate impacts of industrialized livestock production are largely due to the use of fossil-fuel intensive grain to feed the animals, and to deforestation for feed production and pasture.

It is anticipated that climate change will impact nutrition and the environment, and thus reproductive health. For example, climate change may produce malnutrition and disruption of the global ecosystem that is central to food production and human health. (53) Climate change may also lead to social disruption, (54) which, based on the experience of women living in areas affected by Hurricane Katrina, can lead to increased infant mortality rates, and increased likelihood of giving birth to low birth weight or very low birth weight infants. (55) Similarly, pre-term births in California between 1999 and 2006 were positively associated with high ambient temperatures, (56) a condition expected to increase in some areas of the U.S. under predicted climate change scenarios.

2. Packaging

Packaging and cookware widely used to store, heat and serve food and beverages are sources of exposure to chemicals that can disrupt the normal functioning of hormones critical to human reproduction and development. Exemplary of these “endocrine disrupting” chemicals are BPA (bisphenol a), found in many everyday products, including polycarbonate plastic containers and the linings of canned foods and beverages; phthalates, which migrate from food packaging materials and from the ambient environment into food; and perfluorochemicals (PFCs) used in the manufacture of non-stick cookware, i.e. Teflon coatings, and to make food-contact packaging oil and water resistant. These chemicals represent a reproductive health concern because widespread exposure is documented among pregnant women in the U.S, (11) (Figure 2); the placenta does not protect the fetus from exposure; and exposure to each of these chemicals is associated with adverse female and/or male reproductive and developmental and health impacts. (14,57–59) The widespread use of plastic packaging also creates large volumes of waste, and disposal in landfills or by incineration (which produces dioxin, described in the Appendix) transfers environmental contaminants back into our air, water, soil and ultimately, our food system.

3. The Product

Policies, practices and marketing all drive what ends up on our dinner plate, (60) and all heavily favor foods that are unhealthy for pregnant women, children and adolescents. Our industrialized food system delivers large volumes of processed food that is cheap, convenient, attractively packaged, and tasty, but high in calories and low in nutritional quality. On average, Americans today consume about 600 more calories each day than they did in 1970, (61) and eat excessive amounts of animal protein, on average, nearly twice the global average. (62)

Widespread exposure to processed, prepared and sugar-sweetened foods and beverages contribute to our obesity epidemic and the concomitant increased risk for many diseases, including diabetes, heart disease, some forms of arthritis, and several cancers. (63) The prevalence of diets that are relatively high in fructose and low fiber may also factor into the obesity epidemic by adversely influencing children's metabolism and the related capacity to regulate their weight. (64)

High consumption of animal fats and processed meats also contributes to an increased risk of obesity, cardiovascular disease, diabetes, metabolic syndrome, dementia, and some kinds of cancer. (65) Consuming animal fat is also an important pathway of exposure to reproductive toxicants such as dioxin that persist in the environment and the food chain (Appendix).

Approximately one in three women in the U.S. ages 20–49 are overweight or obese. (66). Being overweight and obesity during pregnancy are linked to adverse maternal and child health consequences that can span generations, (67) and to increased utilization of healthcare services. (68)

Environmental chemicals may exacerbate the influence of inactivity and dietary contributors to obesity and related disorders. It is hypothesized that environmental endocrine disrupting chemicals can permanently derange developing regulatory systems required for maintaining a normal body weight. (69) Paradoxically, our industrialized food system contributes to virtually all of the fetal and developmental chemical exposures linked to obesity that were cited in the May 2010 White House Task Force on Childhood Obesity Report to the President, (63) including BPA, perfluorooctanate (PFOA), phthalates, fructose, and certain organophosphate pesticides.

The Role of Health Professionals in Advancing a Healthy Food System

“Farm policy is health policy” and the healthcare sector is uniquely poised to advance policies in support of a healthy food system as a primary prevention strategy to ensure healthy pregnancies, children and future generations. (3)

Society-wide policy actions are essential to creating a healthy food system because: [1] many of the environmental impacts of the industrialized food system are not controllable at the individual level (e.g. food, air and water pollution); [2] public research to help steer the

food system of the future is determined mainly via federal policy; and [3] food system-related environmental justice issues cannot be sufficiently redressed by individual action.

According to the U.S. Environmental Protection Agency (USEPA), environmental justice means no group of people, including racial, ethnic, or socioeconomic groups, should bear a disproportionate share of negative environmental consequences. Food system-related environmental justice issues are exemplified by disparities in access to healthy foods, where societal actions are needed to create opportunities to increase fruit and vegetable consumption in underserved areas. (70,71) There are also disparities in exposure to food system-related environmental pollution, for example, women and men exposed to pesticides at work and in agricultural communities incur substantively higher exposures than the U.S. population overall. (72,73)

National Policy Opportunities

The federal Farm Bill, a complex piece of legislation that Congress passes every five to seven years, and is responsible for some \$60 billion in annual spending, is a key driver of the U.S. food system. As such, the Farm Bill presents a relevant point of policy intervention for healthcare professionals and institutions.

While the purpose of the Farm Bill is to supplement and secure farm incomes, ensure a stable food supply, support the American farm economy, and help ensure that the poor have enough food to eat -- more than two-thirds of the Farm Bill is food stamps -- it has also resulted in adverse impacts on human and environmental health. (3)

For example, the Farm Bill encourages high production and lower prices for certain commodities like corn, soybeans and wheat that then become the principal feed stocks for low-priced sugars, hydrogenated oils and highly refined starches that are so prominent in America's processed food supply and linked to the obesity epidemic. Public investments in the resource-intensive production of a very narrow range of commodity crops has been further encouraged by the research agenda propagated in past Farm Bills, which have supported these trends.

The Farm Bill also impacts the environment by encouraging the kind of concentrated, resource-intensive production that predominates in conventional agriculture. This results in highly centralized practices that degrade our air, water, and other resources with pesticides, chemical fertilizers, arsenic, hormones and other contaminants.

In anticipation of the renewal of the Farm Bill in 2012, leading physicians and other health professionals and practitioners have signed a Charter for a Healthy Farm Bill (www.healthyfoodaction.org). A collaboration of health professional and other organizations recently launched a set of Principles for a Healthy, Sustainable Food System to accelerate these efforts. When children's diets change from conventional to organic food, their pesticide levels go down, indicating that the food supply is a primary source of exposure, and thus amenable to policy interventions to reduce harm. (74)

The health of our food system is also impacted by federal policy decisions that may not at first glance appear to be germane to the food we eat. Examples include the regulation of

toxic releases from non-agricultural processes under the Clean Air Act -- such as mercury-emissions from coal-fired power plants that ultimately end up in the fish consumed by pregnant women and children (Appendix)--- and the regulation of chemicals in commerce under the Toxic Substances Control Act (TSCA).

Under TSCA, the vast majority of the over 80,000 chemicals in commerce, including chemicals that enter the food system directly via packaging, cookware and/or indirectly from the ambient environment, have entered the marketplace without comprehensive and standardized information on their reproductive, developmental and other toxicities. As a consequence, just because a consumer product is readily available on the shelf at the store is no assurance that it is non-toxic. The inadequacies of the U.S. regulatory framework for chemicals in commerce are receiving increased attention by the USEPA, (13) the American Medical Association, (75) broad coalitions of non-governmental organizations, e.g., the Safer Chemical Healthy Families Coalition, and industry, e.g., the American Chemistry Council. In an attempt to address their own regulatory shortcomings, the European Union adopted “REACH”, a policy to reform the regulation of environmental chemicals, in 2007.

Healthcare Institutional Policy Interventions

Healthcare institutions can support the development of urban agriculture programs, farmer’s markets and local food sourcing outlets to increase accessibility to healthier foods. Community-based obesity prevention interventions implemented by Kaiser Permanente and others are currently being evaluated, and these results will help inform environmental-based approaches more broadly. (5,76)

Healthcare systems have also undertaken procurement policies to create a sustainable and healthy food service model, and nearly 350 hospitals have taken the Healthy Food in Healthcare Pledge in support of these efforts. (77) For example, data from four institutions demonstrate that implementation of “Balanced Menus” which reduce meat purchasing in hospitals can yield substantial savings in costs and greenhouse gas emissions. (78) Because the food system purchasing power of the healthcare system is so large---about \$12 billion annually---changing hospital food system procurement patterns can leverage food system change more broadly.

Clinician education is a key gap. Healthcare institutions and societies of reproductive health and other professionals can organize and participate in continuing medical educational activities such as Grand Rounds and in other forums to increase clinician understanding of the links between reproductive health and the industrialized food system.

Patient-Level Policy Interventions

To the extent that we can choose what we eat, the ease, ready availability, and intensive marketing of highly processed foods of low nutritional value --- in excess of \$4.2 billion in 2009 --- can make it difficult to choose wisely. (64,79,80) Compared to the output of the dominant industrialized food system, healthier foods are more difficult to get, less convenient, and frequently more expensive to purchase. (60) While individuals’ decisions about what to eat are influenced in these myriad structural ways, people do make choices

about what to eat. Improving those decisions can make a difference to an individual's health, and by sending a signal to the market, influence the food system more broadly.

Recently, it was suggested that any comprehensive approach to address the obesity epidemic must consider the contribution of both public policy and individual behavior. (81) Borrowing from an environmental justice lens, the proposed "behavioral justice" framework holds that individual responsibility for behavior is inextricably wedded to societal responsibility to provide equal opportunities to make healthier choices regarding diet and exercise. (81)

Behavioral justice provides a useful way to contextualize and shape healthcare interventions on the patient level. For example, to combine behavioral and societal responsibility clinicians can advise a new mother about eating more fruits and vegetables, provide her with information about how the food system impacts health and what she can do to make change, and offer her a coupon to the hospital hosted farmer's market. This policy supports individuals in making healthier food choices, educates consumers about the policies that underlie their food options and how they can participate in society-wide decision-making, and encourages the development of a local, sustainable food system.

Conclusion

How and what food is produced impacts nutrition and the environment. Pregnant women and children are highly susceptible to the benefits and harms of nutrition and the environment, and these influences can impact reproductive health outcomes in the short and long term. Our industrialized food system is highly productive and yields large volumes of food that is relatively low in cost for consumers, but it also engenders substantive environmental impacts, and the food produced tends to be high in calories and low in nutritional value. Policy interventions by the healthcare sector at national, institutional and patient levels offer mutually reinforcing opportunities for advancing a healthy food system as a strategy for preventing adverse reproductive health impacts among current and future generations.

Appendix

Table 1.

Full names of chemical analytes as illustrated in Figure 2.

BPA	Bisphenol-A	
DMP	Dimethylphosphate	Organophosphorus Pesticides
DEP	Diethylphosphate	
DMPT	Dimethylthiophosphate	
DEPT	Diethiophosphate	
DMDTP	Dimethyldiophosphate	
DDE	Dichlorodiphenyldichloroethylene	Organochlorine Pesticides
HCB	Hexachlorobenzene	
DDT	Dichlorodiphenyltrichloroethane	
PFOA	Perfluorooctanoic acid	Perfluorinated Compounds (PFCs)

PFOS	Perfluorooctane sulfonate	
PCBs	Polychlorinated biphenyls	

Appendix: Food System Pollutants of Non-Agricultural Origins

The food consumed by pregnant women and children is directly impacted by releases of toxic chemicals into the environment by non-agricultural industrial practices. For example, mercury is a toxic metal that enters our food system when it is released into air and water from industrial sources. Coal-fired power plants are the largest current sources of mercury emissions in the country. (1) When mercury enters the environment it is converted into methylmercury by bacteria living in sediments in fresh and salt water, and is absorbed by fish when they feed in contaminated streams and oceans. Fish consumption is the primary source of mercury exposure in the U.S., and women of childbearing age and children can incur exposures of health consequence if they consume excessive amounts of fish. (2)

Methylmercury is toxic to the brain and nervous system of the fetus, infant and developing child.(3, 4) Developmental and cognitive effects of exposure such as diminished IQ can occur in children exposed prenatally to low doses that do not result in effects in the mother. (5–7) About three percent of U.S. women of child-bearing age have a blood level of mercury that places their child at some increased risk of adverse health effects.(8) The neurotoxic effects of *in utero* and childhood exposures to methylmercury may be delayed and manifest later in life. (3, 4)

Historical widespread use of polychlorinated biphenyls (PCBs) prior to 1978 is reflected in the presence of these endocrine disrupting chemicals in our food supply in 2010.

Endocrine disrupting chemicals are broadly defined as chemicals that can interfere with normal hormonal regulation. PCBs persist in the environment, accumulate in animal fat, and thus contaminate today's meat, dairy products and breast milk.(9–11) Current exposure levels to PCBs and chlorinated pesticides have been shown to affect thyroid function during pregnancy,(12) a time when a woman's thyroid hormones play a vital role in fetal neurodevelopment.(13, 14) Prenatal exposure to PCBs has been linked to long-term impact on children's intellectual function, (15) prenatal exposure to PCBs and organochlorine pesticides has been linked to attention deficit hyperactivity disorder-like behaviors in childhood. (16)

Dioxins and dioxin-like compounds (DLCs) are endocrine disrupting chemicals released by human activities that have largely but not completely been regulated. (17) Their persistence in the food chain is exacerbated by the current industrial practice of rendering fats and animal protein from recently dead animals and offal not acceptable for human consumption and adding these fats to animal feed given to animals raised for human consumption. (18) Diets high in animal fat are the main source of human exposure to DLCs. Health effects have been shown to occur at the highend of the background range for the general population and the developing individual is extensively sensitive to exposure. (17) Health effects of exposure are many and varied (i.e., cardiovascular disease, diabetes, cancer, altered thyroid

and immune status, altered neurobehavior, cognition, and development of reproductive organs, etc.) and may cross generations. (17, 19)

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Figure 1.
Environmental Influences of Reproductive and Developmental Health

Figure 2.

These data show the results of chemical analytes measured in a sub-samples of 268 pregnant women from the National Health and Nutritional Examination Survey (NHANES) 2003–2004, a nationally representative sample of the U.S. population. Because NHANES data are collected to be “typical” of the U.S. population, highly exposed subpopulations may be underrepresented. For each of the chemicals presented in Figure 2, the industrialized food system is an important pathway of exposure and the chemical has been linked to adverse reproductive and developmental health outcomes. The cumulative health impact of all of these chemicals has not been studied. Full names of the chemicals in this analysis are provided in the Appendix.

Source: Woodruff TJ, Zota AR, Schwartz JM. Environmental chemicals in pregnant women in the US: NHANES 2003–2004. *Environ Health Perspect.* Epub 2011 Jan 14.