Environmental Exposure to Endocrine Disruptors: What Are the Human Health Risks?

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Summary

In 2008, Congress banned the use in children’s toys and child care articles of several chemicals known to disrupt normal development and reproduction of mice and rats. The legislation was a response to accumulating scientific evidence supporting the hypothesis that exposure to certain chemicals in consumer products and the environment might be adversely affecting human reproduction, growth, development, or metabolism by interfering with endocrine systems. This report summarizes the science underlying the environmental endocrine-disruptor hypothesis, and describes congressional actions and related programs and policy issues at the U.S. Environmental Protection Agency (EPA).

This report focuses on the potential human health effects of environmental exposure to endocrine disruptors. The potential effects on fish and wildlife also are of concern. Scientists have discovered many egg-bearing male (intersex) bass in the Potomac River, as well as intersex fish of other species in other U.S. waters. Chemicals of interest include certain pesticides (e.g., DDT), synthetic hormones administered to cattle and poultry, both prescription and over-the-counter drugs and ingredients of some personal-care products (e.g., triclocarban in antibacterial soaps), naturally occurring plant hormones (e.g., in soy beans), industrial compounds (e.g., polychlorinated biphenyls (PCBs)), some dioxins, lead, mercury, cadmium, uranium, arsenic, and organic compounds of tin. Potential sources of such chemicals include runoff from animal feedlots and agricultural fields, wastewater discharges, industrial releases, and consumer products. In the 111th Congress, H.R. 1145 would require each water resources research and technology institute to conduct technical research on prevention and removal of contaminants of emerging concern, including endocrine-disrupting compounds.

Support might be found for the hypothesis that chemicals in the environment are disrupting human endocrine systems in the apparent increases in rates of certain cancers, reported declines in sperm counts, and reported scientific evidence of increasing rates of some birth defects, thyroid disorders, attention deficit disorder, premature births, and premature puberty. There appears to be a worldwide increase in cases of testicular cancer, for which there is no clear cause. Any of these effects could be linked to hormone disruption because they are hormone dependent and have been chemically induced in experimental animals. However, scientifically demonstrating a cause-effect relationship between environmental exposure to a particular chemical and human health effects is difficult. Many scientists hypothesize that environmental levels of potential endocrine disruptors are too low to influence human endocrine systems. Others argue that significant adverse effects might result from long-term exposure to low levels of multiple endocrine disruptors.

Congress began investigating the presence and possible effects of endocrine disruptors in the environment at a hearing in 1993. In 1996, Congress directed EPA to establish and implement an endocrine-disruptor screening program for pesticides and drinking water contaminants. As of April 2009, chemical screening under that program has not begun, and funding for the program has declined, and legislators have expressed concern about the pace of program development. However, EPA this month promulgated final rules establishing the list of 67 pesticide ingredients and procedures that will be followed when the first set of testing orders is issued to manufacturers. EPA has stated that orders will be issued during the summer of 2009. Once the program is implemented, Congress might consider whether statutes and regulations provide adequate authority and direction with respect to the influence of any findings of endocrine disruption on the regulation of specific chemicals, chemical groups, uses, or products.
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*Congressional Research Service*
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Background

Scientific reports of reproductive failure among migratory birds exposed to DDT during the 1950s provided some of the earliest evidence that chemical pollutants in the environment might affect hormone-mediated processes in wildlife. In 1996, several scientists brought the endocrine disruptor hypothesis to public attention with the release of a book, Our Stolen Future. In the same year, Congress directed the U.S. Environmental Protection Agency (EPA) to develop and implement a program to screen all pesticides and suspect drinking water contaminants for endocrine-disrupting potential. Ten years later, the screening program was not yet launched, when scientists reported finding a large number of feminized male fish in the Potomac River and other U.S. waters. In response, Congress held hearings and urged federal agencies to expedite related research. In 2008, the National Toxicology Program issued a report indicating scientific concern about fetal and child exposure to several chemicals with endocrine-disrupting potential. In the same year, Congress enacted legislation banning those chemicals in children’s toys and child care articles. H.R. 1523/S. 593 and S. 753 in the 111th Congress would regulate certain uses of bisphenol A, another potential endocrine disruptor.

This report summarizes the science underlying the endocrine disruptor hypothesis, describes congressional actions, outlines EPA’s efforts to implement legislation, and discusses some policy issues that have been raised. The report is intended to support Congress as it considers legislation to control potential endocrine disruptors and as it oversees EPA’s programs. With a few exceptions, the report does not discuss in detail all of the various specific chemicals that might be endocrine disruptors and particular source categories for such chemicals that might be in the environment. Several CRS reports on specific chemicals and sources are referenced where relevant.

Endocrine Disruptors

Endocrine disruptors are chemical compounds in drugs, food, consumer products, or the ambient environment that can interfere with biological processes normally regulated by hormones within animals. Physical development, growth, reproduction, and metabolism, for example, are hormone-dependent processes that might be affected by exposure to endocrine disruptors. Some endocrine disruptors exist naturally, for example, the phytoestrogens (or plant estrogens, which are responsible for female sexual characteristics) in some plants. Others are the products of human industry—for example, some pesticides and pharmaceuticals.

3 The chemicals banned were di-(2-ethylhexyl) phthalate (DEHP), dibutyl phthalate (DBP), or benzyl butyl phthalate (BBP). The ban was enacted through Section 108 of P.L. 110-314, the Consumer Product Safety Improvement Act of 2008.
4 The endocrine system includes the glands (e.g., thyroid, pituitary gland, pancreas, ovaries, or testes) and their secretions (i.e., hormones), that are released directly into the body’s circulatory system (rather than through ducts). The endocrine system controls metabolic rates, blood pressure, growth, development, aging, blood sugar levels, and reproduction.
Some endocrine disruptors are similar in form and action to natural hormones; these are called “hormone mimics.” The terms “environmental estrogen” and “xenoestrogen” are narrower, referring only to those chemicals that mimic the action of the female sex hormones. (Similarly, environmental androgens are chemicals that mimic the action of the male sex hormones.) Other endocrine disruptors do not mimic, but block the action of hormones (for example, the anti-estrogens or anti-androgens) or otherwise modify the synthesis, secretion, transport, binding, action, or elimination of natural hormones. Some scientists prefer the more neutral but just as inclusive term “endocrine modulators” over the better known term “endocrine disruptors.”

Exposure to high levels of certain manufactured chemicals in the environment has been shown to harm insects, some vertebrate wildlife, and aquatic life by influencing the normal activities or effects of reproductive and other hormones. There also is scientific evidence that relatively low environmental levels of some chemicals may be harmful to the endocrine systems of fish and wildlife, particularly when low chemical concentrations are continuous or bioaccumulate, exposing animals higher on the food chain to greater chemical concentrations. Selected, peer-reviewed studies are described and references are cited under the next major section of this report, “Scientific Evidence.” Some scientists hypothesize that existing environmental levels of potential endocrine disruptors also may be harming human health, but other scientists believe that current levels of such chemicals in the environment are too low to exert significant adverse effects on people.

Congressional and Administrative Attention

Congress began investigating the effects of endocrine disruptors in the environment at a hearing in 1993. Among those testifying at that hearing were several researchers who later published their findings in the book, Our Stolen Future. It summarized a number of studies by wildlife biologists, epidemiologists, and other scientists, and hypothesized that endocrine disruption by environmental pollutants might be responsible for increases in deformities and population declines of amphibians, declining human fertility in various geographical regions, and reported increases in human rates of breast, testicular, and prostate cancers, as well as endometriosis. In the next few years, research produced evidence both for and against that hypothesis.
Congress continued to study the issue, and in 1996 concluded that there was a need to screen pesticide chemicals and drinking water contaminants for their potential to disrupt endocrine systems. A screening program was established by the Food Quality Protection Act (P.L. 104-170) and the 1996 Amendments to the Safe Drinking Water Act (P.L. 104-182).

The Endocrine Disruptor Screening Program

The Food Quality Protection Act (FQPA) Section 408(p)\(^{10}\) directs EPA, not later than three years after August 3, 1996, to require validated tests to determine the potential of pesticides to produce effects in humans similar to those produced by naturally occurring estrogens or, at the discretion of the Administrator, other endocrine effects in humans. The mandate covers all registered pesticide ingredients, as well as other substances identified by the Administrator which might have a cumulative effect together with pesticides and to which a substantial population may be exposed.\(^{11}\)

The 1996 Safe Drinking Water Act Amendments (P.L. 104-182) authorize screening for endocrine disruption potential of contaminants found in sources of drinking water.\(^{12}\) Under both statutes, actual screening of chemicals for toxic effects is to be conducted by manufacturers of suspect chemicals (or laboratories hired by manufacturers) following protocols approved by EPA. The laws authorize EPA to take appropriate action to protect public health under existing statutory authority if substances are found to have endocrine effects in humans.\(^{13}\)

To help implement the new provisions, EPA organized the Endocrine Disruptors Screening and Testing Advisory Committee (EDSTAC). This committee of scientists (some independent and others representing various chemical manufacturers and distributors, chemical users, public health advocates, environmentalists, and other stakeholder groups) assisted EPA in designing the chemical screening and testing program. The committee’s recommendations, released October 5, 1998, were reviewed by a special peer review panel consisting of members of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) Science Advisory Panel and the Science Advisory Board. EPA generally accepted the EDSTAC recommendations and officially “established” the Endocrine Disruptor Screening Program (EDSP) in 1998. Under this program, pesticides and other chemicals would be screened using a battery of tests known as Tier 1 assays, which are relatively inexpensive short-term tests. Chemicals that tested positive for possible endocrine disruption in one or more Tier 1 assays would be subjected to one or more Tier 2 toxicity tests, to confirm or refute Tier 1 results, and if confirmed, to determine the dose of the chemical that caused the effects. Tests would screen for effects on estrogen, androgen (hormones

\(^{11}\) The EPA Office of Science Coordination and Policy website describes the statutory authority for the Endocrine Disruptor Screening Program at http://www.epa.gov/scipoly/oscpendo/.
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responsible for male sexual characteristics), and/or thyroid systems. The thyroid hormones regulate growth and development and the rate of metabolism.

Chemical screening for potential effects on endocrine systems has not yet begun, however, because EPA has not finished selecting and validating toxicity assays. An Endocrine Disruptor Method Validation Subcommittee (EDMVS) was formed in 2001 to advise EPA on how it should select and evaluate the screens and tests to be developed. This process proved to be controversial, particularly with respect to the role of animal experimentation and the validation of tests involving live animals. Three years later, the Endocrine Disruptor Methods Validation Advisory Committee (EDMVAC) was formed to replace EDMVS. This group assisted EPA as it identified, developed, and validated the various methods for detecting potential endocrine disruptors.

In 2004 and 2005, the EDSP was reviewed and evaluated at EPA’s request by the independent Board of Scientific Counselors (BOSC) for EPA’s Office of Research and Development. A subcommittee of the BOSC prepared a final report, which is summarized in a peer-reviewed publication

• strengthen its expertise in wildlife toxicology;
• expedite validation of the tests;
• take a leadership role in applying “omics” technologies (such as proteomics or metabolomics);
• maintain funding; and
• “continue to sponsor multidisciplinary intramural research and interagency collaborations.”

The BOSC again reviewed the program in 2008. BOSC reported that the program

... exceeds expectations in progress to address concerns of the previous 2004 program review. ... The [Endocrine Disrupting Chemicals Research Program] has taken under consideration all recommendations of the previous BOSC review and those recommendations not implemented were held in abeyance because of budgetary constraints.

16 Harding, ibid.
18 Ibid., Cover letter.
The BOSC noted that

... the budget to support this program has been cut substantially. The budget has been cut 20 percent since 2003, with a 4 percent cut proposed for this year. Funds for extramural STAR grants for EDC research were completely eliminated in 2005.19

Largely as a result of the constrained budget, BOSC found that wildlife toxicology and epidemiology remain areas of weakness in EPA’s EDSP.20

EPA also worked closely with the Interagency Coordinating Committee on the Validation of Alternative Methods (to identify and validate test methods that reduce animal use or suffering) and the Organization for Economic Cooperation and Development (to ensure international acceptance of the methods.)21 EPA’s independent Science Advisory Panel (established under the Federal Insecticide, Fungicide, and Rodenticide Act) has completed peer review of validated Tier 1 assays and approved EPA’s initial test battery, but some chemical manufacturers continue to object to several of the Tier 1 assays. In July 2008, the Center for Regulatory Effectiveness (a public policy advocacy group) filed a “Request for Correction” on one of the assay validations under the Agency’s Information Quality Guidelines (IQG), and Crop Life America, a trade group for pesticide manufacturers, filed a petition to delay the EDSP orders to initiate testing. As a result, EPA delayed the issuance of orders until 2009. In April 2009, it was announced that EPA denied the Crop Life petition22 and announced that orders would be issued during the summer of 2009.

At the same time that it was developing toxicity assays, EPA established a process for prioritizing and selecting chemicals to be screened.23 In June 2007, EPA proposed a draft list of 73 chemicals for initial screening.24 The comment period for the draft list ended February 11, 2008. In April 2009, after considering comments on this list of chemicals, EPA published in the Federal Register the final list of 67 chemicals.25 The list included pesticide active ingredients, “selected based on their relatively high potential for human exposure”26 and other chemicals produced in amounts greater than one million pounds per year that also are used in pesticide products but which are categorized as inert (that is, not active) pesticide ingredients. EPA’s website “EDSP Phases” provides additional details about the process EPA used to select chemicals for screening.27

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19 Ibid., p. 5.  
20 Ibid., p. 6, 8.  
23 70 Federal Register 56449-56465, Sept. 27, 2005.  
26 70 Federal Register 56449-56465, Sept. 27, 2005.  
Late in 2007, EPA also solicited public comments about its proposed procedure for issuing orders to manufacturers to conduct initial screening and for overseeing compliance with such orders. The final version of these procedures was published in the Federal Register April 15, 2009.

The House Committee on Government Reform held a hearing October 4, 2006, to learn about the status of the EDSP and to examine the human and ecological health implications of the discovery of egg-bearing male bass in the Potomac River. One year later, some Members of that committee sent a letter to EPA Administrator Stephen L. Johnson asking him how EPA might speed up the process of screening chemicals for endocrine effects, to provide a timetable for EDSP implementation, and for explanations in response to specific questions about the process and substance of the program as designed. EPA's responses are posted on the Committee's website.

The agency indicated that the list of chemicals, procedures, and peer review of Tier 1 tests should have been completed and Tier 1 test orders should have been issued to manufacturers of the first 73 chemicals before mid-2008. An EPA website provides more information about EDSP program development.

**Research Initiatives**

The hypothesis that existing environmental levels of chemical pollutants may be harming human health by disrupting endocrine functions has been, and continues to be, hotly debated. At present, there is no conclusive evidence to support this hypothesis.

Research interest is growing, and some epidemiological studies have found statistical associations between human exposure and health effects that are consistent with the results of experiments with animals, particularly with respect to potential effects on prenatal and infant development. Research attention has focused on chemicals such as certain phthalates that are ubiquitous at low levels in the air, surface water, and food, and at higher levels in many consumer products, including medical devices and baby toys. Some other chemicals of potential concern include a number of pesticides (e.g., DDT, lindane, and vinclozolin), medicinal drugs (especially synthetic hormones), other synthetic compounds (e.g., nonylphenol, polychlorinated biphenyls (PCBs), perchlorate), and some metals (e.g., lead, mercury, arsenic, and organotins). In recent years, hundreds of studies have been conducted to determine possible health effects due to exposure to components of plastics such as bisphenol A (BPA) and phthalates. EPA has posted an inventory of endocrine research that it sponsors.

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29 74 Federal Register 17560-17579.
33 For more information about phthalates, see CRS Report RL34572, Phthalates in Plastics and Possible Human Health Effects, by (name redacted) and (name redacted).
34 For more information about BPA, see CRS Report RS22869, Bisphenol A (BPA) in Plastics and Possible Human Health Effects, by (name redacted) and (name redacted).
Many U.S. and other governmental and intergovernmental organizations are sponsoring and coordinating research efforts to clarify the scope and severity of potential endocrine disruptor effects. In the United States, work among federal public health and environmental agencies was initially coordinated by the Endocrine Disruptor Working Group, which was established by the National Science and Technology Council’s Committee on the Environment and Natural Resources. However, this working group appears to have disbanded after 1999. Internationally, the Organization for Economic Cooperation and Development (OECD) is developing harmonized international test guidelines to detect endocrine disruptors.

In the 111th Congress, H.R. 1145 would require each water resources research and technology institute, established under the Water Resources Research Act of 1984, to conduct technical research on prevention and removal of contaminants of emerging concern, including endocrine-disrupting compounds, pharmaceuticals, and personal care products. This bill also would establish a national interagency coordinating committee to plan and report to Congress on water-related research.

Scientific Evidence

Human Health Trends

Proponents of the hypothesis that environmental exposure to endocrine disruptors may be affecting human health have pointed to apparent increases in U.S. and global rates of certain cancers, reported declines in sperm counts in various nations, and scientific evidence of increasing rates of type II diabetes, obesity (especially among children), some birth defects.

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37 For more information about this group, see the EPA website for the Endocrine Disruptor Research Initiative. However, the workgroup does not appear to be active, http://www.epa.gov/endocrine/edriifact.html.
42 Centers for Disease Control and Prevention, Department of Health and Human Services. Hypospadias trends in two (continued...)
and other disorders. In some cases, these reported increases in rates of hormone-mediated diseases or conditions may reflect improvements in diagnostic tools or reporting rates rather than increased rates of disease. In other cases, disease rates may have increased in fact, but may be due to medication use, smoking, or some other reason. However, in at least a few cases, increasing exposure to chemicals in the environment seems to some a plausible hypothesis to explain an increase in disease rates. Many developmental, reproductive, and carcinogenic conditions for which increased incidences have been reported in humans are similar to effects that have been observed in wildlife and fish exposed to endocrine disruptors.

Congress has indicated its interest in several recent health trends, including: reported declines in certain nations in semen quality over the last few decades; increasing rates of deformities of male reproductive organs before 1985, after which rates stabilized; and a worldwide increase in the incidence of testicular cancer, for which there is no clear cause. Some researchers have noted the similarity of these health concerns with effects seen in rats and mice prenatally exposed to certain phthalates that act as anti-androgens. One hypothesis is that human exposure to combinations of phthalates and perhaps other ubiquitous endocrine disruptors might be interfering with the development of baby boys, resulting in what is referred to as “testicular dysgenesis syndrome.”

Human Studies of Chemical Effects on Endocrine Systems

Except for strong poisons with clear, short-term effects on health, the effects of chemical exposures on humans are difficult to demonstrate scientifically. Ethically, scientists cannot manipulate levels of human exposure to a chemical if there is a chance that harm might result. The alternative, so-called “natural experiments” (which compare the health of people with accidental exposures to the health of people with no exposure), is rare because accidental exposures of sufficient magnitude are few, and potentially contributing conditions (such as exposure to other chemicals) are inadequately controlled. In particular, study of effects of low-level exposures to environmental chemicals is problematic, because the expected effects are

(...continued)


45 Semen quality is based on ejaculate volume, sperm concentration, sperm motility, and sperm morphology.


47 Safe, ibid.


49 For more information about phthalates, see CRS Report RL34572, Phthalates in Plastics and Possible Human Health Effects, by (name redacted) and (name redacted).
subtle and potentially affected by numerous conditions. Often, virtually everyone has been exposed to the chemical being studied, and there are too few unexposed people to serve as a control group for comparison.

Scientific studies have demonstrated the potential of hormones and some other chemicals acting through hormone systems to harm human health, especially if the chemical exposure is highly concentrated and occurs during fetal or infant development. For example, the role of naturally occurring male and female sex hormones in the growth of prostate and breast cancer is well established scientifically. Moreover, research has demonstrated that administration of the drug diethylstilbestrol (DES), a strong, synthetic estrogen, to women early in their pregnancies greatly increases risk that their daughters will develop vaginal cancer and reproductive abnormalities. In addition, studies have documented a higher than normal incidence of genital tract abnormalities in male babies following in utero exposure to DES.

Some chemicals with effects on endocrine systems have therapeutic value. For example, sex hormones are used to treat some forms of cancer. There also is evidence that some plant-derived endocrine disruptors (e.g., phytoestrogens prevalent in soy beans) may protect against disease. Some scientists argue that such evidence undermines the hypothesis that endocrine disruptors in the environment are a threat to human health. Other scientists believe the evidence for therapeutic effects only underscores the potency of hormonally active chemicals.

Numerous epidemiologic studies have found associations between environmental levels of potential endocrine disruptors and effects on human development or health. For example, a

50 See the National Cancer Institute website at http://www.nci.nih.gov.
54 Perhaps in this case, the term endocrine modulator is more appropriate.
56 “Epidemiologic” studies examine groups of people to determine rates of occurrence of particular outcomes (health effects) relative to varying levels of chemical exposure. Such studies rely on statistical methods to evaluate the likelihood of hypotheses about relationships between exposures and outcomes (that is, dose-response relationships). “Associations” are regular patterns between frequencies of particular health outcomes and changes in exposure levels. Associations do not necessarily indicate a causal relationship, but there can be no causal relationship without an association.
Sharpe, Richard M., and D. Stewart Irvine. 2004. How strong is the evidence of a link between environmental (continued...)
study of newborns in Spain reported data that suggested that the combined effects of bioaccumulated estrogenic substances in the placenta played a role in the risk of male urogenital malformations. However, causality has not been (and possibly cannot be) clearly demonstrated for any adverse health effect as a result of exposure to an endocrine disruptor at levels typically present in the environment.

Most studies focus on a single chemical or closely related group of chemicals. For example, many scientists believe that the same phthalates that are toxic to rats and mice would be able to cause similar malformations in humans, because the male hormones affected by phthalates are important to the normal development of the male reproductive tract in all species of mammals. A few human studies have been conducted. Some scientists have found that relatively low levels of exposure to phthalates may be associated with health effects. A study published in 2005 provided the first evidence of subtle developmental effects in baby boys exposed prenatally to breakdown products of certain phthalates, and these effects were similar to those seen in experiments with rats and mice exposed to phthalates. A high exposure to one breakdown product of a phthalate was found to alter the development (in a laboratory culture) of human fetal testes and to reduce the number of germ cells. Nevertheless, human health effects of environmental phthalate exposure have not been conclusively demonstrated. Additional research is seen as needed to confirm or refute these findings of effects at environmental levels of human exposure.

Recently, scientists have been advising that risk assessments should consider the combined effects of chemical exposures. For example, studies with rodents suggest there may be additive effects of multiple phthalate exposures. A recent report issued by the National Research Council

(...continued)


60 Swan et al. 2005.


concluded that there is a need to explore the additive effects of exposure to phthalates.\textsuperscript{63} Dr. Andreas Kortenkamp has reviewed research on the effects of mixtures of endocrine-disrupting chemicals and has called for additional, more systematic investigations of combinations of endocrine disruptors.\textsuperscript{64}

Human hormones other than sex hormones also might be affected by environmental chemicals. A recently released study found that low-level human exposure to bisphenol A (BPA) inhibits the release of adiponectin from adipose (fat) tissue. This result indicates a possible link of BPA to diabetes, because adiponectin increases insulin sensitivity and helps regulate glucose metabolism.\textsuperscript{65} Because this study was well designed and controlled, its results are seen as particularly interesting, but until it has been replicated by an independent team of scientists, any conclusions are considered tentative.

Another chemical group that has been studied extensively is PCBs. Although the production and use of PCBs has been strictly regulated since 1976, these chemicals are ubiquitous in the air, water, soil, and many animal tissues due to their environmental persistence, tendency to bioaccumulate in animal fat, and previous widespread use. Some PCBs are known to be estrogenic.\textsuperscript{66} In addition, PCBs may affect thyroid function,\textsuperscript{67} and there is evidence that fetal exposure to PCBs affects cognitive development, but it is not known whether this toxicity is related to thyroid or any other type of hormone disruption.\textsuperscript{68} In addition, some studies have found


\textsuperscript{67} Ibid.


an association between human PCB exposure and low sperm counts, undescended testes, altered semen quality, lower age of onset of puberty, and shorter height at maturity.\(^6^9\)

In recent years, Congress has expressed concern about the possible effects on thyroid function of perchlorate, a common pollutant in drinking water and soil. Perchlorate is formed naturally but also is manufactured for various products including explosives, fireworks, road flares, and solid rocket fuel and often is associated in the environment with sites operated by the Department of Defense. Perchlorate is known to disrupt the uptake of iodine by the thyroid, and health effects associated with perchlorate exposure are expected to parallel those caused by iodine deficiency. Iodine deficiency decreases the production of thyroid hormones, which help regulate the body’s metabolism and growth. A key concern is that impairment of thyroid function in pregnant women can affect brain development in fetuses and nursing infants and can lead to attention deficit disorder, generally delayed development, and decreased learning capacity.\(^7^0\) Several studies have found that at significantly higher levels of perchlorate exposure than the amounts typically observed in the environment, thyroid changes occur in humans.\(^7^1\) However, a 2006 study by the Centers for Disease Control and Prevention (CDC) of a representative sample of the general U.S. population found that environmental exposures to perchlorate have an effect on thyroid hormone levels in women who are deficient in iodine (and on levels of the pituitary gland’s thyroid stimulating hormone in all women). (No effect was found in men.) Fully 36% of the 1,111 women in this study were found to be iodine deficient.\(^7^2\)

**Animal Studies**

The most compelling evidence for endocrine disruption due to environmental exposure to contaminants has been obtained in aquatic systems, with most of the published literature based on studies of fish.\(^7^3\)


Fish

Feminization of male fish due to exposure to endocrine-disrupting chemicals in the environment is an increasing concern. Fish appear to be useful as sentinels for the presence and possible hazard of endocrine-disrupting chemicals in the aquatic environment, since they are currently the only vertebrates for which the connection between environmental contamination and adverse effects on health has been established in both field and laboratory studies. In addition, fish are exposed to any contaminants in their aquatic habitats through skin absorption, food ingestion, and dissolved gas absorption across the gills. Aquatic food chains often are long, relative to terrestrial food chains, so bioaccumulation potential may be greater. The aquatic environment is especially well suited for these studies as it is the ultimate sink for many natural and anthropogenic compounds released into the environment.

Feminization of male fish collected from British rivers near the effluent from wastewater treatment plants alerted the scientific community to the potential hazard of endocrine-disrupting chemicals (specifically, synthetic female hormones) in the environment. Feminization of males was confirmed by the presence of eggs in the testes and vitellogenin (a protein in the yolk of eggs, usually made only by females) in the blood of male fish. (While manufacture of vitellogenin by males is clearly abnormal, it is not clear whether these males are impaired in their ability to reproduce.) More recently, marine fish populations in the English Channel and in Tokyo Bay have shown evidence of feminization.

In the United States, studies have found feminized male fish in diverse locations. For example, there is a report of complete sex reversal of male salmon in the state of Washington. Others have...

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74 However, feminization and any resulting effects on fish populations are not the only concerns. Another potential effect might be immune system changes and perhaps greater susceptibility to infections and other diseases. It was fish kills and skin lesions on a number of fish species in the South Branch of the Potomac River that prompted the Blazer et al. (2007) study of smallmouth bass which is described below.


76 Panter, Grace H., R. S. Thompson, and John P. Sumpter. 1998. Adverse reproductive effects in male fathead minnows (Pimephales promelas) exposed to environmentally relevant concentrations of the natural oestrogens, oestradiol and oestrone. Aquatic Toxicology, v. 42, n. 4, pp. 243-253.


reported intersex trout in Rocky Mountain National Park and Glacier Park, hornyhead turbot in southern California, and white sucker in Boulder, CO.

In spring of 2004, scientists found a high prevalence of feminized smallmouth bass in the South Branch of the Potomac River, which drains a rural area of West Virginia. Water samples in the area detected a number of known endocrine disruptors with estrogenic activity including several pesticides, a degradation product of industrial phenols, and two polybrominated diphenyl ethers (PBDEs), but the study authors concluded that a combination of contaminants probably was responsible for the observed effects on fish. Recent research has demonstrated that mixtures of estrogenic chemicals can act in combination, exerting adverse effects on fish even when each component is present at a level below the threshold level for producing such effects. Fish were also taken from several other rural sites in West Virginia that were characterized by low human population and low intensity agriculture. At these sites scientists found a lower prevalence of feminized bass. In contrast, in a more heavily populated and more intensely agricultural part of Virginia, 80 to 100% of male bass taken from the Shenandoah River were feminized. The cellular responses to ethynylestradiol (the bioactive component of contraceptive pills) that lead to feminization have been documented.

Androgenic substances (i.e., substances with an effect similar to that of male sex hormones) also have been detected in environmental samples, especially in pulp mill effluents, and studies have linked such effluents to masculinized female fish. Although both androgenic and estrogenic effects have been observed in fish, estrogenic activity appears to be more ubiquitous and hence

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84 Ibid., p. 250.


86 Ibid.

87 Ibid.


better studied. Moreover, the presence of estrogenic substances in some U.S. rivers and streams, especially near outfalls from wastewater treatment plants, has been well documented.

The significance of the numerous observations of feminized male fish for the sustainability of wild populations was unknown until recently. The results of a study in the Experimental Lakes Area of northwestern Ontario, Canada, demonstrated that sustainability might be adversely affected by endocrine-disrupting chemicals. Chronic exposure of fathead minnow in one lake to low concentrations of the potent synthetic estrogen 17α-ethynylestradiol (EE2) nearly extinguished this population after only two years. EE2, which is the most common component of birth control pills, is often found in wastewater plant effluent and has been found in U.S. surface water at concentrations ranging from 0.1 to 5.1 ng/l. Academic scientists working together with pharmaceutical company scientists have derived a predicted no-effect concentration for EE2 of 0.35 ng/l for aquatic life in general.

Other Wild Vertebrates

Reproductive or developmental problems potentially resulting from hormone exposure have been observed in other wild vertebrate species, especially fish-eating species, including birds (such as gulls, terns, ospreys, eagles, and pelicans), polar bears, Florida panthers, alligators, river
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In addition, there is growing evidence for effects of environmental exposure to endocrine disruptors in marine mammals.\textsuperscript{101} The accumulation of persistent chlorinated organic chemicals, such as PCBs, in seals and dolphins has been well documented,\textsuperscript{102} and research indicates that the thyroid hormone system in harbor seals is “highly sensitive to disruption by environmental contaminants,” particularly by PCBs.\textsuperscript{103} Laboratory studies of a beluga whale protein that is key in many endocrine-disrupting effects (the aryl hydrocarbon receptor) reveal that the protein binds strongly to dioxins and PCBs. This may increase the likelihood that toxic responses can be elicited by contaminants in the environment.\textsuperscript{104}

However, as is the case with humans, cause-and-effect relationships are difficult (or impossible) to show experimentally for marine mammals, because direct toxicity testing is precluded by logistical, legal, and ethical constraints.

**Invertebrates**

There is evidence of endocrine effects in some marine invertebrates. Ambiguous genitalia have been found by the EPA in Maine bivalves, allegedly due to herbicides.\textsuperscript{105} Reproductive impairment has been noted in some species of snails exposed to very low amounts of tributyltin (TBT), a constituent in anti-fouling paints used on boats. This chemical causes female snails to...
grow male reproductive organs in addition to normal female ones, a condition called “imposex.” When this condition becomes severe, affected females cannot function as females or as males; the resulting reproductive failure caused severe population declines in some species. While the use of TBT in anti-fouling paints has been severely restricted in the United States (P.L. 100-333, Organotin Antifouling Paint Control Act of 1988) and European countries, it remains in use in other parts of the world.

**Laboratory Rodents**

In laboratory experiments with rodents, there is clear evidence that exposure to some endocrine disruptors affects the development of reproductive organs and causes tumor development. For example, one study found that exposure of newborn mice to genistein (a naturally occurring plant estrogen) at a level “within the range to which humans may be exposed in soy-based infant formulas” caused effects that would impair fertility in every exposed mouse, but in no unexposed mouse. In addition, uterine cancer occurred in about one-third of the exposed mice, but not in the unexposed mice. (An expert panel of the National Toxicology Program’s Center for the Evaluation of Risks to Human Reproduction found in 2006 that the results of rodent studies were sufficient to conclude that genistein produces reproductive and developmental toxicity in offspring of rodents, but another expert panel report concluded that evidence was insufficient to demonstrate that soy formula would or would not produce such effects.)

Some on-going studies of developmental effects in rats have found effects on the reproductive organs from very low levels of exposure to DES, bisphenol-A, an ingredient in some plastic, and other substances. Other studies found no effects. The resulting controversy has prompted some scientists to note that the design of laboratory studies often has contributed to the confusion, because statistical measures were not employed to detect subtle effects. In 2001, an expert workshop to evaluate the data on low-dose effects of endocrine disruptors concluded that biological effects have been shown to occur following exposure to

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107 Ibid.
111 Ibid.
some estrogenic compounds at very low levels. The question remains whether those effects would adversely affect rodent health, however.

Environmental Exposure to Potential Endocrine Disruptors

Concern about possible human or wildlife hormone disruption has been fueled by the limited information that is available about levels of potential hormone disruptors in the environment. It is known, however, that some potential endocrine disruptors are heavily used and, in some cases, released to the environment. For example, pesticides such as DDT and dieldrin, now banned, still are found in many rivers and streams. Wastewater effluent from sewage treatment plants contains many potential endocrine disruptors, including synthetic (pharmaceutical) hormones. The U.S. Geological Survey has found synthetic hormones in U.S. streams. Concentrated animal feeding lots are another potential source of environmental contamination. Other potential endocrine disruptors are prevalent in certain foods, such as soy-based milk substitutes, because soy beans contain phytoestrogens (i.e., isoflavonoids such as genistein) at relatively high levels. Some argue that the high phytoestrogen concentrations in food far exceed concentrations of endocrine disruptors in the environment, implying that environmental exposures are likely to be relatively insignificant. Others say this conclusion is not necessarily justified, because it is based on a comparison of apples with oranges, or rather a mixture of isoflavonoids and other phytohormones with a mixture of synthetic industrial compounds, including pharmaceuticals and other chemicals, each of which may exert a different biological effect and be more or less potent at various concentrations.

Data collected during the National Health and Nutrition Examination Survey indicates that most people in the United States are exposed to various potential endocrine disruptors that are in widespread use. Bisphenol A was detected in more than 90% of the surveyed population. In

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114 That is, the effects observed are not known to be adverse. For example, at certain very low doses fetal exposure to bisphenol-A produces enlarged prostates in male rats, but it is not clear that an enlarged prostate is an adverse health impact.
119 The isoflavonoids appear to exert both estrogenic and anti-estrogenic effects which are not completely understood.
121 For more information about bisphenol A, see CRS Report RS22869, Bisphenol A (BPA) in Plastics and Possible Human Health Effects, by (name redacted) and (name redacted).
addition, the survey found almost universal American exposure to low levels of the most common phthalates, usually multiple phthalates.\textsuperscript{122} Women tend to have greater exposure than men, but children appear to be the group most exposed to di-(2-ethylhexyl) phthalate (DEHP), dibutyl phthalate (DBP), and benzyl butyl phthalate (BBP). Studies of amniotic fluid have also documented exposure to multiple phthalates for human fetuses.\textsuperscript{123} More generally, babies may be the most heavily exposed group.\textsuperscript{124} Children may be exposed to such chemicals through their mothers’ blood prenatally, through breast milk, or by eating certain foods.\textsuperscript{125}

Release of a chemical to the environment and even proof of exposure to the chemical do not necessarily lead to toxic effects, even for vulnerable populations of animals or people. Some believe that available data are reassuring, because known potential disruptors of endocrine function generally are present in the environment at very low levels.\textsuperscript{126}

On the other hand, there are no measurements at all of environmental concentrations for most chemicals in the environment, some of which might be affecting hormones. Some known hormone disruptors, such as phthalates or bisphenol A, are ubiquitous at low levels, raising the question of long-term effects and possible additive or synergistic effects with continual exposure.\textsuperscript{127} Of particular concern are chemicals designed to be biologically active in humans or in pests that are released to the environment. Synthetic hormones are an obvious example. Birth control compounds, synthetic estrogen for postmenopausal women, and synthetic thyroid hormone are three common contaminants of wastewater. Other chemicals, such as PCBs and some dioxins, are persistent in the environment and are known to bioconcentrate in the food chain.

Knowledge about the range of potential health effects in immature, as well as mature wildlife and humans, and actual exposure measurements are needed to accurately assess risks. Existing data sometimes support conflicting views, leading to controversies about the extent to which people generally are exposed to endocrine modulators, whether very low levels of exposure potentially could affect human health, and whether exposure to very low levels of chemicals in the environment currently is affecting reproduction, fetal development, or other hormone-dependent functions in animal or human populations. Nevertheless, a panel convened by the National Academy of Sciences concluded in 1999:

\textsuperscript{122} Ibid.
\textsuperscript{124} Wormuth, Matthias, Martin Scheringer, and Meret Vollenweider, et al. 2006. What are the sources of exposure to eight frequently used phthalic acid esters in Europeans? Risk Analysis, v. 26, n. 3, pp. 803-824.
\textsuperscript{125} For more information about phthalates, see CRS Report RL34572, \textit{Phthalates in Plastics and Possible Human Health Effects}, by (name redacted) and (name redacted).
\textsuperscript{126} Scientists disagree about whether it is likely that animals or people would experience adverse effects of exposure to very low doses of chemicals with the potential to disrupt endocrine function. Detailed arguments for and against the hypothesis of low-dose effects are provided in Richter, C.A., et al. 2007. In vivo effects of bisphenol A in laboratory rodent studies, Reproductive Toxicology, v. 24, n. 2, pp. 199-224; and Willhite, C.C., et al., 2008, Derivation of a bisphenol A oral reference dose (RfD) and drinking-water equivalent concentration, Journal of Toxicology and Environmental Health, Part B, Critical Reviews, v. 11, n. 2, pp. 69-146.
\textsuperscript{127} National Academy of Sciences 1999. Hormonally Active Agents in the Environment, National Academy Press, Washington, DC.

Environmental [hormonally active agents] probably have contributed to declines in some wildlife populations, including fish and birds of the Great Lakes and juvenile alligators of Lake Apopka, and possibly to diseases and deformities in mink in the United States, river otters in Europe, and marine mammals in European waters. Such contaminants, along with inbreeding, might have contributed to the poor reproductive success of the endangered Florida panther and the increased embryonic mortality of the snapping turtle in the Great Lakes.128

Policy Issues

Pace of FQPA Implementation

Environmental, consumer, and public health advocacy groups accuse EPA of “dragging its feet” in implementing many provisions of the Food Quality Protection Act (FQPA), including the mandate to establish an endocrine disruptor screening program. The Natural Resources Defense Council (NRDC) and six California-based public interest groups alleged in a lawsuit filed August 3, 1999, in the U.S. District Court for the Northern District of California that delays had caused EPA to miss FQPA deadlines.129 On January 19, 2001, EPA and NRDC agreed to settle the lawsuit. The settlement agreement states that endocrine disruptor screening would begin no later than spring 2004.130 That did not occur.

Although grower groups and the pesticide industry have echoed complaints about delays in overall FQPA implementation, they also have complained that EPA is proceeding too fast, jeopardizing the scientific basis for decisions about the screening program. Several test protocols approved for use in the screening program have been inadequately validated, according to these stakeholders. Since chemical producers would conduct the actual screening of chemicals, they want to ensure that screening requirements established by EPA would be cost-effective in identifying potentially hazardous pesticides rather than wasteful of company resources. Thus, they generally would prefer relatively quick and inexpensive screens to quickly rule out (or at least delay) the need to pursue testing of chemicals that are less likely to pose health risks. This approach would allow time for additional, and perhaps improved, test methods to be validated. Public health advocates would prefer more thorough testing of a larger number of chemicals, to ensure that all potentially hazardous substances are identified and quickly regulated.

Some scientists are concerned about adopting and implementing a program at this time to screen chemicals for endocrine effects, because the field of study is so new and developing rapidly. Almost certainly, better tests will be developed as scientists gain understanding of the endocrine systems, how they develop, how they respond to variations in hormone levels, and how they might be disrupted. On the other hand, most scientists appear optimistic about the value of screening chemicals with the methods that are being developed, as long as they are validated prior to being employed on hundreds, if not thousands, of chemicals.

A key question then is how flexible the adopted program should be: Would it be allowed to evolve quickly in response to new knowledge?

130 Ibid.
Welfare of Test Animals

Traditional methods of toxicity testing often involve administration of measured doses of chemicals to groups of laboratory animals (usually rodents), which are then observed for health effects. Test animals may be affected in a positive way (if the chemical at the administered dose improves health), unaffected, mildly adversely affected, severely adversely affected, or even killed by the administered dose. If they survive (which generally is the scientifically preferable result), they may be sacrificed (i.e., killed) at some future date to permit inspection of internal tissues, or they may be allowed to live a normal lifespan. In some cases, test animals are allowed to reproduce, so that any adverse health effects on the reproductive process or on offspring may be observed. Standard scientific protocols generally require the use of groups of animals for such tests, so as to permit statistical analysis of the results. For example, many tests require the use of 25 or 50 rats of each gender at each dose level.

Animal welfare advocates are concerned that a large number of animals might be sacrificed for the Endocrine Disruptor Screening Program, and they have questioned the value of such tests for assessing human health risks. They argue that alternatives to animal tests exist, and that others should be developed, both to improve the predictive value of the tests for human health and to protect the animals that otherwise might suffer or die. Others contend that animal models provide valuable information about the potential human health effects of chemical exposure, and animal welfare is protected by laboratory guidelines for their care. Alternative test methods for many kinds of effects have not been developed, it is argued.

For several years, federal agencies have been evaluating alternative methods for screening chemicals for toxicity, which would require the use of fewer laboratory rodents or other animals than are required using traditional toxicity tests. Alternative toxicity testing methods exist, but their results are more difficult to interpret, in terms of what they might mean for human health, and few are used routinely by federal agencies. The 103rd Congress established the Applied Toxicological Research and Testing Program within the National Institute of Environmental Health Sciences (NIEHS), in part, “to develop and validate assays and protocols, including alternative methods that can reduce or eliminate the use of animals in acute or chronic safety testing, ... to establish criteria for the validation and regulatory acceptance of alternative testing[,] and to recommend a process through which scientifically validated alternative methods can be accepted for regulatory use” (P.L. 103-43, Section 1301(a)). To implement the program, NIEHS established an ad hoc Interagency Coordinating Committee on the Validation of Alternative Methods (ICCVAM). The 106th Congress made ICCVAM a permanent interagency coordinating committee (P.L. 106-545). EPA is a member of this committee.

Regulation of Endocrine Disruptors

If EPA determines through the endocrine disruptor screening program or some other program that a chemical poses a risk to public health due to its effects on endocrine systems, the agency is authorized to act under its existing legal authorities. The authorities available to EPA that are likely to be most relevant to the protection of public health from toxic chemicals derive primarily from the Safe Drinking Water Act, the Federal Water Pollution Control Act, the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), and the Toxic Substances Control Act.

131 For brief summaries of these laws, see CRS Report RL30030, Clean Water Act: A Summary of the Law, by (name redacted); CRS Report RL31921, Pesticide Law: A Summary of the Statutes, by (name redacted); CRS Report (continued...)
Alternatively, EPA may refer a substance to another agency for action. For example, EPA might suggest that the Food and Drug Administration or the Occupational Safety and Health Administration regulate the use of particular chemicals to reduce risks.

Because many chemicals that may be endocrine disruptors have a variety of uses and may be released to the environment at several stages in their lifecycles, multiple agencies are likely to have a stake in their regulation. In such cases, any overlapping or inconsistent risk assessments, guidelines, or regulations are likely to spark controversies. For example, EPA and FDA at one time published risk assessments for mercury and guidance for consumers of fish containing mercury that appeared to be inconsistent. The resulting controversy was quelled only when the two agencies issued a joint communication. Some in Congress might be expected to urge coordination of agency efforts to avoid such controversies. Cooperation among agencies also might lead to more cost-effective regulation, an objective of President Obama and many Members of Congress.

Another concern due to multiple uses and releases of chemicals and divided authorities for regulating them might be that risks could be under-estimated and thus under-regulated if they were assessed for each source of exposure and each exposed population individually, rather than aggregated from all sources, combined with risks from chemicals with similar effects, and calculated cumulatively over time. This is a particular concern when the health effects of exposure are not immediate or not obvious, as might be the case for certain reproductive or developmental effects. This situation arguably occurred with respect to phthalates: it was the cumulative risk assessment conducted by the interagency National Toxicology Program that caused scientists to express concern about possible consequences of exposure to phthalates from multiple sources for infants and fetuses. Scientists’ concern prompted Congress to require action by regulatory agencies.

Congress might wish to evaluate whether agencies are adequately assessing cumulative and aggregate risks. Various groups of scientists have called for increased use of cumulative risk assessments. Congress has acted in the past to require cumulative and aggregate risk assessments for pesticides, when it enacted the FQPA. The Kid-Safe Chemicals Act (H.R. 6100/S. 3040) in the 110th Congress would have extended that requirement to other chemicals.

The nature of endocrine disruption may challenge would-be regulators. Disruption may consist of enhancement or inhibition of effects that vary widely within populations of humans and wildlife. Under some circumstances, disruption of a hormonally regulated process even may be beneficial. Moreover, endocrine disruption may not fit the traditional model of the relationship between increasing chemical exposure and effects, and effects may vary depending on the timing of

(...continued)


exposure and other factors. Early indicators of endocrine disruption may not be considered adverse. At what point might regulators intervene, and under what authority? Some laws might require substantial evidence of severe effects prior to agency action, while others might authorize action when risks are less certain. Congress may consider whether statutes provide agencies with appropriate authority and directives for regulating endocrine-disrupting chemicals.

Congress might also consider whether agency budgets are adequate to support appropriate levels of research and regulatory activity. Within the context of the overall federal budget, funding for research, chemical screening programs, and regulatory activity, in the view of some, should be proportionate to congressional concern about the potential risks to human or animal health posed by endocrine disruptors.

In the 111th Congress, H.R. 1145 would require each water resources research and technology institute, established under the Water Resources Research Act of 1984, to conduct technical research on prevention and removal of contaminants of emerging concern, including endocrine-disrupting compounds, pharmaceuticals, and personal care products. This bill also would establish a national interagency coordinating committee to plan and report to Congress on water-related research. In addition, H.R. 1145 would direct an interagency committee to evaluate the adequacy of funding levels and the distribution of funding across agencies. The bill would authorize to be appropriated to the National Oceanic and Atmospheric Administration for coordination and outreach activities $10 million through 2014.

Conclusion

Chemicals with the potential to disrupt endocrine systems are frequently present in the environment, particularly in rivers and streams, and in some consumer products. Exposure to high levels of some of these chemicals has been shown to harm insects, some vertebrate wildlife, and aquatic life by affecting reproductive and other hormone-dependent processes. In controlled laboratory experiments, some scientists have found that relatively low levels of certain chemicals harm the endocrine systems of fish and wildlife, particularly when exposure is continuous, chemicals bioaccumulate, or animals are exposed simultaneously to several chemicals with similar effects. Fish studies provide the most compelling evidence that endocrine disruption might be occurring due to environmental exposures to contaminants. Reproductive or developmental problems potentially resulting from hormone exposure also have been observed in birds, polar bears, Florida panthers, alligators, river otters, mink, and marine invertebrates.

Some scientists have hypothesized that existing environmental levels of chemical pollutants might be harming human health by disrupting endocrine functions. They point to increased rates of certain human health problems, demonstrated harm to human endocrine systems when people have been exposed to high levels of certain chemicals, and epidemiologic studies that have found statistical associations between exposure to environmental levels of potential endocrine disruptors and diabetes, malformations, sexual function, cognitive development, thyroid function, and other potentially hormone-mediated effects. The environmental endocrine disruptor hypothesis is disparaged by other scientists, because known potential disruptors of endocrine function generally are present in the environment at very low levels, especially compared to the levels of hormones that are naturally present in the human body, as well as in some of the plants that humans eat. Many scientists who are not convinced there is an environmental problem nonetheless are concerned about the issue, because there are no measurements at all of environmental concentrations for most chemicals, people are known to be exposed to low levels of multiple
environmental contaminants with endocrine-disrupting potential for which potential cumulative effects have not been assessed, and some studies suggest the public health consequences of exposure might be significant.

Congress might be asked to consider various issues connected to the endocrine disruptor hypothesis. In 1996, Congress mandated chemical screening for endocrine-disrupting potential. The screening program has not yet been launched, and some argue that it should not be launched until the complete test battery is validated. Others are concerned about the extent to which EPA might rely on animal experimentation in its screening program. Once the program is implemented, Congress might consider whether statutes and regulations provide adequate authority and direction with respect to the influence of any findings of endocrine disruption on the regulation of specific chemicals, chemical groups, uses, or products.

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