Risks of Phthalate Exposure Among the General Population

Implications for Occupational Health Nurses

by Victoria M. Pak, BSN, RN, and Linda A. McCauley, PhD, RN, FAAN

Recently, attention to the prevalence of reproductive and developmental problems in the United States has increased. Mounting evidence demonstrates that environmental chemical exposures may play an important role in these problems. Male reproductive problems, which include undescended testicles and hypospadias, doubled from 1970 to 1993. These reproductive problems increase the risk for testicular cancer (Barret, 2005). The incidence of testicular cancer continues to increase at a rate of 2% to 4% annually in industrialized nations. In the United States, rates have stabilized after 20 years of increasing (Environmental Working Group [EWG], 2000). Recent reports highlight the presence of low-level concentrations of potential carcinogens, plasticizers called phthalates, in personal care products and cosmetics (Barret, 2005). Phthalates are known reproductive and developmental toxicants in animal studies. Swan et al. (2005) recently found a relationship between phthalates and the feminization of U.S. male infants. Colon, Caro, Bourdony, and Rosario (2000) link endocrine-disrupting chemicals like phthalates to the early onset of puberty. These investigators identified Puerto Rican girls with both premature breast development and higher levels of phthalates in their blood.

Industrial chemicals in consumer products remain unregulated in the United States. No legal requirement for health and safety testing or human exposure monitoring for any chemical in commerce exists (EWG, 2000). This article evaluates the sources, threats, extents, and potential risks of phthalate exposures, high-risk populations, and implications for occupational health nurses.

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SOURCES AND THREATS OF PHTHALATE EXPOSURE

Phthalates are recognized as toxic substances under environmental law, yet are found in common consumer products such as perfumes, medications, deodorants, nail polish, shampoos, hair sprays, food wrap, and cosmetics (EWG, 2000) (Table).

Phthalates can be ingested, inhaled, or absorbed through the skin. Individuals can be exposed to more than one phthalate, from multiple routes of exposure (David, 2000). One of the major questions among health and environmental activists is whether phthalates, ubiquitous in the environment, are safe enough for use in common products that are not tested for safety (Koo & Lee, 2004). Manufacturers may study the short-term effects of their products in laboratory animals, but rarely study long-term effects (EWG, 2000). Industry practice involves putting chemicals into widespread commercial use without testing for toxicity or monitoring individuals and the environment (EWG, 2000). High-risk populations (e.g., children and women of childbearing age) are prone to exposure and adverse effects from phthalates.

Phthalates are regulated as pollutants in air and water (Houlihan & Wiles, 2000). One phthalate, di(2-ethyhexyl) phthalate (DEHP), was removed from children's toys more than a decade ago; this same phthalate is regulated in drinking water (EWG, 2000). Empirical evidence demonstrates that phthalates such as DEHP are "gender-bending" chemicals that mimic estrogen and could disrupt the development of male infants (Swan et al., 2005). In a recent report from the Center for the Evaluation of Risks to Human Reproduction (2005), serious concern was expressed about the possibility of DEHP exposures adversely affecting male reproductive tract development and function.

Even more concerning is the fact that the Environmental Protection Agency established a "safe" daily dose of the plasticizer di-*n*-butyl phthalate (DBP), called the reference dose, based on a study published in 1953 (EWG,

Table

Phthalate Esters That Have Been Examined for Health Consequences From Environmental Exposure in Humans

Phthalate	*Uses*	*Potential Concerns*	*Urinary Metabolites*
Di(2-ethylhexyl) phthalate (DEHP)	Health care devices and tubing, building materials (e.g., floor tiles), shower curtains, food packaging, children's products (e.g., toys, baby pants)	Infant exposure during health care procedures Exposures during pregnancy might affect development of offspring	Monoethylhexyl phthalate (mEHP) Mono-(2-ethyl-5-oxohexyl) phthalate (MEOHP) Mono-(2-ethyl-5-hydroxyhexyl) (MEHHP)
Diethyl phthalate (DEP)	Personal care products (e.g., shampoos, nail polish, soaps, cosmetics, toothbrushes), toys, insecticides		Monoethyl phthalate (mEP)
Diisononyl phthalate (DINP)	Garden hoses, toys, shoes, building materials	Effects from pregnancy exposures Exposures through mouthing toys	Mono-isononyl phthalate (MINP)
Diisodecyl phthalate (DIDP)	Wiring and cables in automobiles, shoes, carpet backing, pool liners	Effects of exposure to pregnant women and children	Monocyclohexyl phthalate (mCHP)
Di-*n*-butyl phthalate (DBP)	Latex adhesives, cellulose plastics, dye solvents, varnishes, personal care products (e.g., cosmetics, nail polish)	Effects of exposure to pregnant women and children	Monobutyl phthalate (mBP)
Benzyl butyl phthalate (BzBP)	Vinyl tile, artificial leather, personal care products (e.g., perfume)	Effects of exposure to pregnant women and children	Monobenzyl phthalate (mBzP)
Di-*n*-octyl phthalate (DNOP)	Floor tiles and carpet, notebook covers	Effects of exposure to pregnant women and children	Mono-*n*-octyl phthalate (mOP)
Dimethyl phthalate (DMP)	Plastics, insect repellents, flea collars	Data too sparse	Monomethyl phthalate (mMP)

2000). At the time, the EPA classified the study as weak, and confidence in the reference dose was "low." The agency has not yet revised the safe dose (EWG, 2000). Mylchreest, Wallace, Cattley, and Foster (2000) found that DBP exposures at the level of the Environmental Protection Agency's established reference dose, which was previously thought to produce no adverse effects, actually contributed to birth defects in male neonatal rat pups, including extra nipples in one-third of the pups. This study concluded that the dose of DBP corresponding to the no observable adverse effect level was 60% lower than the current reference dose (EWG, 2000). These data suggest that phthalate exposure, and the potential for adverse effects from exposure, is greater and more common than previously anticipated.

EXTENTS AND POTENTIAL RISKS OF PHTHALATE EXPOSURE

Due to the popularity of phthalates in common products, widespread use has led to the contamination of drinking water, air, and food (Robbins, 2005). Urine samples were collected from adults as part of the Third National Health and Nutrition Examination Survey. Samples from 289 individuals were randomly selected and analyzed for phthalate monoesters. Researchers at the Centers for Disease Control and Prevention (CDC) (Blount et al., 2000) reported that all 289 individuals tested for DBP had the compound in their bodies. Scientists believe that the active toxicant of DBP is its first breakdown product, monobutyl phthalate, which has been shown to cause harm to the male system (e.g.,

birth defects in laboratory animals, particularly male offspring, including testicular atrophy, defects of the penile structure, and reduced sperm count) (EWG, 2000). Men with defects such as hypospadias, infertility, and undescended testicles experience the same symptoms found in laboratory animals exposed to DBP (Toppari et al., 1996). Twenty years of peer-reviewed animal studies confirm the ability of DBP to cause birth defects (EWG, 2006b). Although a cause-and-effect relationship has not yet been verified in humans, negative trends in the reproductive health of men and the prevalence of phthalates suggests phthalates may be directly contributing to these problems.

Current literature on the potential toxicological properties of phthalates focuses on a traditional approach to toxicology (i.e., high-level exposure for cancer endpoints, and occupational exposure leading to adult infertility) (Colborn, Dumanoski, & Myers, 1996). Recently, however, attention has focused more on low-dose toxicity of phthalates during crucial windows of fetal development; this has led to increased concern about potential health risks of phthalates (Colborn et al., 1996). In a 2004 study, researchers found phthalates in 29 maternal and 24 cord blood samples. Samples were analyzed for a variety of chemicals. Every sample tested positive for an array of phthalates. The maximum DEHP concentrations found in this study were 5,559 ng/g of serum for maternal blood and 4,004 ng/g of serum for umbilical cord blood (Greenpeace, 2004). This study highlights concern for fetuses who are exposed to these chemicals and are at risk for potential health problems, ranging from genital abnormalities to cancer, as a result.

PHTHALATES IN CONSUMER PRODUCTS

Phthalates are used in many consumer products, due in part to their multiple chemical properties. Phthalates are versatile, acting as plasticizers in nail polish and producing oily textures in lotions. They contribute to making skin feel soft and helping lotions penetrate deeper into the skin. Due to their adaptable characteristics, phthalates like DBP are important ingredients in cosmetic and beauty products. Even gum, candy, and oral medications contain DBP (EWG, 2000).

Companies can use unlimited amounts of phthalates in cosmetics, despite environmental law labeling them toxic (Houlihan & Wiles, 2000). Unfortunately, uncovering whether a product contains phthalates is not as easy as looking at its label. Companies are allowed to include phthalates as components of fragrances, flavorings, or chemical mixtures identified as trade secrets, all of which are exempt from labeling requirements (EWG, 2000).

The use of phthalates in consumer cosmetics is so pervasive that 3 major environmental health organizations contracted with a national laboratory to test 72 name-brand, off-the-shelf beauty products for phthalates. Phthalates were found in 52 of the 72 products tested (approximately 72% of the products). Only one of the products listed phthalates on its label (EWG, 2002). The EWG provides resources for identifying companies that use phthalates (EWG, 2006a) and for locating phthalate-free products (EWG, 2006c).

HIGH-RISK EXPOSURE GROUPS

In October 2000, CDC scientists announced that levels of some phthalates, including DBP and DEHP, in women of childbearing age (20 to 40 years old) exceeded government-established levels, which were set to protect against birth defects (Blount et al., 2000; Kohn et al., 2000). Estimates on DBP exposures for this age group were approximately 20 times greater than for the rest of the population (EWG, 2000). These levels are a major health concern, as both DEHP and DBP produce metabolites that are suspected to be related to teratogenic or endocrine-disrupting effects (Koo & Lee, 2004). The CDC postulates that high exposures to phthalates in women of childbearing age may arise from the use of cosmetic and beauty products.

Another high-risk population prone to adverse effects from exposure to phthalates is children. With recent changes to puberty guidelines for females, pediatricians will be less likely to prescribe hormone treatment for girls who show signs of early puberty, thus redefining what is considered normal. Development of breasts and pubic hair in 6- or 7-year-old girls is no longer considered abnormal. By 9 years old, 48% of African American girls and 15% of White girls are showing clear signs of puberty (Herman-Giddens et al., 1997; Kaplowitz & Oberfield, 1999). Many scientists believe that earlier puberty is caused by widespread exposure to chemicals that have qualities similar to estrogen (Herman-Giddens et al., 1997). In animals, chemicals that disrupt the endocrine system can affect pubertal development or sexual behavior (Colborn et al., 1996). According to the CDC, an association has been found between women of childbearing age, in whom the highest levels of phthalates in the blood have been demonstrated, and the increased incidence of early onset of puberty and reproductive problems among children (Blount et al., 2000).

According to Bornehag et al. (2004), the risks of phthalate exposure among children may go beyond reproductive problems. Asthma is the most common chronic disease among U.S. children, with rates that have more than doubled since 1980. In a 2004 study, Bornehag et al. associated exposure to phthalates found in household dust with rhinitis, eczema, and asthma in children. The dust collected from the bedrooms of children diagnosed with asthma or allergies had significantly higher levels of phthalates than did the dust from bedrooms of healthy children. Asthmatic children were more likely to live in homes with polyvinyl chloride flooring, containing phthalate compounds. A dose–response relationship between concentrations of phthalates in the dust and likelihood of being diagnosed with asthma, rhinitis, or eczema was found. The higher the concentration of phthalates in the dust, the more likely the child was to be diagnosed with one of the three diseases. This was the first epidemiological study to strongly associate phthalates with asthma and allergies.

Women who work in nail and hair salons presum-

ably have the highest exposures to phthalates like DBP because of the unregulated presence of these phthalates in the products used. Unlike consumer beauty products, labeling requirements do not apply to professional beauty products. The Fair Packaging and Labeling Act (U.S. Food and Drug Administration, 1967) requires labeling of ingredients on cosmetic products offered for sale, but not in professional salons or on products given as samples to customers (DiGangi, Schettler, Cobbing, & Rossi, 2002). According to a 1997 U.S. economic census, more than 407,000 individuals are employed in approximately 81,000 beauty salons across the country (EWG, 2000). More than 93% of U.S. nail salon workers are female (Campaign for Safe Cosmetics, 2005). Thus, a large percentage of women of childbearing age are exposed to phthalates in professional beauty products daily. These workers may have no knowledge of the problem or its prevention through the use of alternative products and safety measures.

GOVERNMENT ACTION AND HEALTH POLICY

Government approaches to phthalate regulation do not currently protect consumers or high-risk populations from aggregate phthalate exposures. No regulatory agency currently considers phthalate exposures from multiple sources when drawing safety conclusions (DiGangi et al., 2002). Exposure is unavoidable because even if a phthalate is limited or prohibited in one product, it may be present in another. For example, use of DEHP is regulated in food containers but not in health care devices (DiGangi et al., 2002). Critically ill neonates and infants in neonatal intensive care units are at greater risk for exposure to DEHP, which is used to provide the soft and flexible qualities of polyvinyl chloride equipment (e.g., intravenous tubing and blood bags) (Stewart, 1999). The majority of hospitals in the United States use polyvinyl chloride equipment, thus continually exposing vulnerable patients to hormone-disrupting agents and risking potentially adverse effects.

Europe has identified phthalates as a priority for action, emphasizing the importance of the precautionary principle to help prevent toxic exposures. In 1998, the Oslo and Paris Commission listed DBP and DEHP among substances for priority action. The 13 countries named as contracting parties agreed to stop all discharges, emissions, and losses of hazardous substances such as phthalates by the year 2020 (DiGangi et al., 2002). In Sweden, an environmental bill emphasized that all phthalates and plasticizers should be phased out on a voluntary basis (DiGangi et al., 2002). In 1999, Denmark introduced an action plan to phase out the use of phthalates in soft plastics. Denmark also resolved to regulate large uses and emissions of phthalates using bans, taxes, levies, and ecolabeling (DiGangi et al., 2002).

Despite the lack of federal regulation of the cosmetic industry in the United States, California passed the California Safe Cosmetics Act in 2005. This law protects citizens of California from harmful chemicals (e.g., phthalates) that are linked to cancer, birth defects, and other reproductive problems (EWG, 2002; Migden, 2005). The act mandates three types of regulation:

- Manufacturers are required to disclose, to the state, any harmful ingredients (e.g., phthalates) contained in their products.
- The state Department of Health Services may obtain health-related information from manufacturers about potentially harmful cosmetic ingredients.
- California's Occupational Safety and Health Administration will regulate the use of cosmetics in beauty salons, to protect workers (Migden, 2005).

The primary purpose of the California Safe Cosmetics Act is to require companies with aggregate worldwide sales of cosmetics of more than $1 million to report any cosmetic products sold in California that contain ingredients causing cancer or reproductive harm. Reports include the name of each chemical and any products containing that chemical. Under this new law, California's Occupational Safety and Health Administration will investigate whether the reported ingredient poses a safety hazard to employees who are regularly exposed to it. California's Occupational Safety and Health Administration must then propose occupational health standards to address the potential toxicity of an ingredient in the workplace (Ledger, 2005).

IMPLICATIONS FOR OCCUPATIONAL HEALTH NURSES

Phthalates have recently garnered media attention for their toxic effects at low, chronic exposure levels. Occupational health nurses will be relied on to interpret information about declining semen quality and fertility related to phthalate exposure (Robbins, 2005). Occupational health nurses must be able to educate clients and families on how to reduce exposures to phthalates and suggest alternative, phthalate-free products. Information about phthalate types, sources, and routes of exposure is available online (e.g., http://cerhr.niehs.nih.gov).

Occupational health nurses must remain cognizant of toxicities related to phthalates, particularly of the potential for adverse effects among high-risk populations. Knowledge of phthalates and their potential for toxicity will also be helpful in discerning possible exposures in both the occupational and non-occupational environments of clients. Measures to reduce exposures must be implemented through educating clients and increasing awareness of phthalate dangers. Occupational health nurses can reduce general population exposure and potential toxicities by identifying sources and routes of exposure, educating clients on alternatives to phthalates, and providing appropriate informational resources.

The widespread and increased incidence of male reproductive problems is enough to mandate further exploration of endocrine disrupters like phthalates. No study examining the impact of phthalate exposure on developing reproductive tracts in men exists (DiGangi et al., 2002). Occupational health nurses are in an ideal position to rally support for further research that will ultimately reduce phthalate exposures among the general population.

IN SUMMARY

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Implications for Occupational Health Nurses

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1. Personal care items including lotions, perfumes, deodorants, shampoos, and cosmetics are sources of phthalate exposure. Women of childbearing age, children, and beauty salon workers are at greater risk for exposure.

2. Occupational health nurses are in an ideal position to rally support for improved regulatory laws and for funding of evidence-based research that will reduce phthalate exposures and improve client health. Occupational health nurses must support the establishment and implementation of procedures for workplace safety inspections among susceptible populations.

3. Information regarding reduction of overall phthalate exposure must be available for clients. Resources like phthalate-free product lists can be valuable tools in helping clients make informed decisions about alternatives to phthalates.

As client advocates, occupational health nurses must be well informed about toxic environmental exposures and associated risks to health. Occupational health nurses are in an influential position to support improved regulatory laws that will establish and implement procedures for workplace safety inspections among susceptible populations. Occupational health nurses can recommend alternative products for clients and families and promote environmentally conscious purchasing. They can educate women of childbearing age about reducing exposure levels by promoting the use of alternative, phthalate-free products. Occupational health nurses may be able to reduce the potential for adverse effects from phthalate exposure among children. Armed with information regarding the risks of phthalates, occupational health nurses are in a pivotal position to influence policy and procedures, and to optimize the health of populations.

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