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Concentrations of trace metals, phthalates, bisphenol A and flame-retardants in toys and other children's products in Israel

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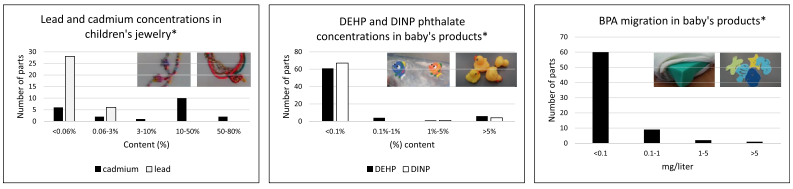
HIGHLIGHTS

- In children's jewelry, 23% exceeded the US lead standard.
- In selected childcare products, up to 45% exceeded the EU phthalates and BPA standards.
- Regulated products generally comply with standards, unregulated products are contaminated.

GRAPHICAL ABSTRACT



*In parts above limit of detection

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ABSTRACT

Trace metals and synthetic chemicals including phthalates, bisphenol A and flame retardants, are widely used in toys and childcare products, and may pose acute or chronic adverse health effects in children. In Israel, certain chemicals are regulated in childcare products, but there are still regulatory gaps. We tested regulated and unregulated contaminants in 174 item parts from 70 childcare items with potentially high oral or dermal exposure, including 22 children's jewelry items, 14 toys, 7 diaper-changing mats, 6 baby mattresses, 7 baby textiles and 14 feeding and bathing items. In children's jewelry, an unregulated product in Israel, 23% of samples exceeded the US standard for lead. In toys, a regulated product, we did not detect trace metals above the Israeli standard. In textiles, baby mattresses and diaper-changing mats, phthalates exceeded the European Union standard in 14–45% of tests with a mean of 6.74% by mass for diisononyl phthalate, and 1.32% by mass for di(2-ethylhexyl) phthalate. BPA migration exceeded the EU standard in 14–45% of tests with a mean of 1.03 ppm. The flame retardants polybrominated biphenyls, pentabromodiphenyl, octabromodiphenyl ether, tris(2,3-dibromopropyl) phosphate and tris-(aziridinyl)-phosphine oxide were not detected. For products regulated in Israel, our findings suggest general compliance with mandatory standards. However, a lack of comprehensive chemical regulation means that there are regulatory gaps, and products not regulated in Israel may contain high levels of chemical contamination, exceeding US or EU regulations. The results of this study have prompted the development of an Israeli safety standard for children's jewelry.

1. Introduction

Young children may be exposed to environmental chemicals that are released from toys and baby products. Babies and young

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children frequently mouth objects, including toys, resulting in saliva mobilization and oral exposure to toxic chemicals (Moya et al., 2004). In addition, infants may come into intimate contact with consumer products such as sleep positioners, car seats, and nursing pillows for extended periods, leading to potential exposure to chemicals in these products (Stapleton et al., 2011). Potentially toxic chemicals in consumer products include chemical elements, phthalates, bisphenol A (BPA) and flame retardants.

Trace metals have been detected in toys and baby products, in some cases causing acute poisoning in young children (Levin et al., 2008). Trace metals including lead, cadmium, arsenic, chromium, selenium, mercury, barium and zinc are frequently added to a wide variety of plastic toys, in order to provide stability, softness, brightness and flexibility to those products (Al-Qutob et al., 2014). Lead is a cumulative toxin which affects the neurological, cardiovascular and renal systems. Young children and the developing fetus are especially vulnerable to the neurotoxic effects of lead, and subtle effects on intelligence and attention occur even at very low exposure levels (Attina and Trasande, 2013). Fatal acute poisoning in a child was reported following ingestion of a charm with very high lead content (Levin et al., 2008).

Migration of trace metals from soft toys and other products is also a concern for chronic adverse health effects in children. The regulatory focus on lead has contributed to a tendency of children's jewelry manufacturers to replace lead with cadmium, a carcinogen which affects the neurological, skeletal and renal systems (Becker et al., 2010; Weidenhamer et al., 2011). In many parts of the world, toys contaminated with trace metals are sold freely on the market. In 2007 alone, nearly six million toys were recalled in the US due to excessive lead levels (Schmidt, 2008). In 2010, 12 million McDonald's cups were recalled due to cadmium content in the painted coating (CPSC, 2010a). Retailers may choose to voluntarily recall products with high levels of contamination. For example, in 2008, key chains were voluntarily recalled by Walmart due to high lead levels, even though there is no mandatory regulation on lead in key chains in the US (CPSC, 2008). In 2010, bracelets were voluntarily recalled due to high levels of cadmium, a metal not under mandatory regulation in the US (CPSC, 2010b).

Exposure to low levels of phthalates, which are used as plasticizers in PVC consumer products including toys, also poses a concern for adverse health effects in children. Di(2-ethylhexyl) phthalate (DEHP), di-*n*-butyl phthalate (DBP), benzyl butyl phthalate (BzBP) and diisononyl phthalate (DINP) have been shown to disrupt reproductive tract development in male rodents in an anti-androgenic manner (Swan, 2008). In human studies, exposure to DEHP and DBP metabolites has been associated with behavioral problems in children (Kobrosly et al., 2014), and childhood exposure to DEHP and BBzP has been associated with allergic diseases including asthma and eczema (Braun et al., 2013; Zota et al., 2014). Like trace metals, phthalate plasticizers can be extracted when young children suck and chew on toys and baby products, leading to oral exposure. In infants and toddlers, soft plastic toys account for more than 90% of exposure to DINP (Wormuth et al., 2006). Since they are not chemically bound to products, phthalates can also be released into the environment and may enter the body via inhalation and dermal absorption (Meeker et al., 2009). While the phthalate content of toys is regulated in many countries, the presence of phthalates in toys is still a widespread problem (Johnson et al., 2011).

BPA is another chemical of concern used in childcare products. It is used in polycarbonate plastics and epoxy resins and may be present, for example, in food contact materials intended for infants and children, including feeding utensils. BPA is considered to be an endocrine disrupting chemical, and young children may be particularly vulnerable (Birnbaum et al., 2012; Maragou et al., 2008).

Certain flame retardants (e.g. polybrominated biphenyls [PBB], pentabromodiphenyl ether [PentaBDE], octabromodiphenyl ether [OctaBDE], tris(2,3-dibromopropyl) phosphate [TRIS], tris-(aziridinyl)-phosphine oxide [TEPA]), which have been detected in baby products such as toys, nursing pillows and infant sleep positioners (Chen et al., 2009; Ionas et al., 2014; Stapleton et al., 2011), have been associated with a range of adverse effects including thyroid disruption, cancer and reduced fertility (Environmental Protection Agency, 2016). Flame retardants may leach to the saliva due to mouthing and hand-to-mouth behaviors, resulting in elevated exposure of infants and toddlers (Ionas et al., 2016).

Early-life exposure to PentaBDE mixtures adversely affects cognitive outcomes (Chevrier et al., 2016), sub-clinically disrupts thyroid hormone function (Jacobson et al., 2016), and alters menarche in girls and pubarche in boys (Harley et al., 2017). Exposure to OctaBDE has been associated with serum-free T4, luteinizing hormone (LH), thyroid stimulating hormone (TSH) and testosterone (Johnson et al., 2013). In addition, it has been associated with impaired motor behavior and impaired learning skills in rodents (Zuurbier et al., 2006). Exposure to PBB in pubertal girls has been associated with earlier menarche, thelarche and earlier appearance of pubic hair (Roy et al., 2009). The International Agency for Research on Cancer has classified PBB as “probably carcinogenic to humans” (Lauby-Secretan et al., 2013). Similarly, the U.S. National Toxicology Program has classified both PBB and TRIS as “reasonably anticipated to be carcinogenic to humans” (U.S. Department of Health and Human Services, 2014).

In this study, we selected a wide range of consumer products which young children are exposed to, including products shown in previous studies to contain environmental contaminants (children's jewelry, toys, baby mattresses) and products with limited information in the literature regarding the presence of environmental contaminants (diaper-changing mats, baby feeding chairs, aprons). Children's jewelry products were selected according to the definition in ASTM F2923 (ASTM International, 2014), namely products principally designed and intended to be ornaments worn by a person such as necklaces and bracelets.

The objectives and hypotheses of the study were to:

Objective 1. Measure *unregulated* contaminants in children's products.

Hypothesis 1. Due to gaps in the regulation of potentially hazardous chemicals in childcare products in Israel, we would find unregulated contaminants in childcare products.

Objective 2. Measure *regulated* contaminants in children's products.

Hypothesis 2. Due to enforcement challenges in Israel, we would find regulated contaminants in children's products.

Products were selected for the study based on an assessment of the potential for high oral (toys, jewelry) or dermal (diaper-changing mats, textiles, mattresses, etc.) chemical exposures. Several of the product categories are novel in that there are few or no reported studies about their chemical content in the literature.

2. Materials and methods

2.1. Samples

Seventy items, including 48 childcare items and 22 jewelry items, were selected and purchased, 63 from retail chains in Israel and seven from an international low-cost online retailer. The indicator for product selection was raw materials suspected to