Report to the
U.S. Consumer Product Safety Commission
by the
CHRONIC HAZARD ADVISORY PANEL ON PHTHALATES
AND PHTHALATE ALTERNATIVES

July 2014

APPENDIX E2

CHILDREN'S ORAL EXPOSURE TO PHTHALATE ALTERNATIVES FROM MOUTHING SOFT PLASTIC CHILDREN'S ARTICLES

UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
4330 EAST WEST HIGHWAY
BETHESDA, MD 20814

Memorandum

Date: July 14, 2014

TO : Mary Ann Danello, Ph.D., Associate Executive Director for Health Sciences

FROM : Michael A. Babich, Ph.D., Chemist, Division of Health Sciences MAB

SUBJECT : Children's oral exposure to phthalate alternatives from mouthing soft plastic children's articles*

The attached report provides the U.S. Consumer Product Safety Commission's (CPSC's) Health Sciences' staff assessment of children's oral exposures to phthalate alternatives from mouthing soft plastic articles made from polyvinyl chloride (PVC). This work was performed at the request of the Chronic Hazard Advisory Panel (CHAP) on phthalates and phthalate alternatives.

* These comments are those of the CPSC staff, have not been reviewed or approved by, and may not necessarily reflect the views of, the Commission.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS*

3β-HSD	3β-hydroxysteroid dehydrogenase
AA	antiandrogenicity; antiandrogenic
ADHD	attention deficit hyperactivity disorder
ADI	acceptable daily intake
AGD	anogenital distance
AGI	anogenital index
ASD	Autistic Spectrum Disorders
ASTDR	Agency for Toxic Substances and Disease Registry
ATBC	acetyl tributyl citrate
BASC-PRS	Behavior Assessment System for Children-Parent Rating Scales
BBP	butylbenzyl phthalate
BIBRA	British Industrial Biological Research Association
BMD	benchmark dose
BMDL	benchmark dose (lower confidence limit)
BNBA	Brazelton Neonatal Behavioral Assessment
BRIEF	Behavior Rating Inventory of Executive Function
BSI	behavioral symptoms index
CBCL	Child Behavior Check List
CDC	Centers for Disease Control and Prevention, U.S.
CERHR	Center for the Evaluation of Risks to Human Reproduction
CF	consumption factor
CHAP	Chronic Hazard Advisory Panel
CHO	Chinese hamster ovary
CNS	central nervous system
CPSC	Consumer Product Safety Commission, U.S.
CPSIA	Consumer Product Safety Improvement Act of 2008
CRA	cumulative risk assessment
CSL	cranial suspensory ligament
cx-MIDP	mono(carboxy-isononyl) phthalate (also, CNP, MCNP)
cx-MINP	mono(carboxy-isooctyl) phthalate (also COP, MCOP)
DAP	diallyl phthalate
DBP	dibutyl phthalate
DCHP	dicyclohexyl phthalate
DDP	di-*n*-decyl phthalate
DEHA	di(2-ethylhexyl) adipate
DEHP	di(2-ethylhexyl) phthalate
DEHT	di(2-ethylhexyl) terephthalate
DEP	diethyl phthalate
DHEPP	di-*n*-heptyl phthalate
DHEXP	di-*n*-hexyl phthalate
DHT	dihydrotestosterone

* List applies to main report and all appendices.

DI	daily intake
DIBP	diisobutyl phthalate
DIDP	diisodecyl phthalate
DIHEPP	diisoheptyl phthalate
DIHEXP	diisohexyl phthalate
DINP	diisononyl phthalate
DINCH®	1,2-cyclohexanedicarboxylic acid, diisononyl ester
DINX	1,2-cyclohexanedicarboxylic acid, diisononyl ester
DIOP	diisooctyl phthalate
DIPP	diisopropyl phthalate
DMP	dimethyl phthalate
DNHEXP	di-*n*-hexyl phthalate
DNOP	di-*n*-octyl phthalate
DOTP	di(2-ethylhexyl) terephthalate
DPENP	di-*n*-pentyl phthalate
DPHP	di(2-propylheptyl) phthalate
DPS	delayed preputial separation
DSP	decrease spermatocytes and spermatids
DVO	delayed vaginal opening
ECHA	European Chemicals Agency
ECMO	extracorporeal membrane oxygenation
ED_{50}	median effective dose
EPA	Environmental Protection Agency, U.S.
EPW	epididymal weight
FDA	Food and Drug Administration, U.S.
f_{ue}	urinary excretion factor
GD	gestational day
GGT	gamma-glutamyl transferase
GLP	good laboratory practices
grn	granulin
HBM	human biomonitoring
hCG	human chorionic gonadotrophin
HI	hazard index
HMW	high molecular weight
HPV	high production volume
HQ	hazard quotient
IARC	International Agency for Research on Cancer
ICH	International Conference on Harmonisation
insl3	insulin-like factor 3
IP	intraperitoneally
JRC	Joint Research Centre
LD	lactation day
LH	luteinizing hormone
LMW	low molecular weight
LOAEL	lowest observed adverse effect level
LOD	level/limit of detection

LOQ	level/limit of quantitation
MBP	monobutyl phthalate
MBZP	monobenzyl phthalate
MCPP	mono(3-carboxypropyl) phthalate
MDI	mental development index
MECPP	mono(2-ethyl-5-carboxypentyl) phthalate
MEHP	mono(2-ethylhexyl) phthalate
MEHHP	mono(2-ethyl-5-hydroxyhexyl) phthalate
MEOHP	mono(2-ethyl-5-oxohexyl) phthalate
MEP	monoethyl phthalate
MIBP	monoisobutyl phthalate
MINP	mono(isononyl) phthalate
MIS	Mullerian inhibiting substance
MMP	monomethyl phthalate
MNG	multinucleated gonocyte
MNOP	mono-*n*-octyl phthalate
MOE	margin of exposure
MSSM	Mount Sinai School of Medicine
MW	molecular weight
NA	not available
NAE	no antiandrogenic effects observed
NCEA	National Center for Environmental Assessment
NHANES	National Health and Nutritional Examination Survey
NNNS	NICU Network Neurobehavioral Scale
NOAEL	no observed adverse effect level
NOEL	no observed effect level
NR	nipple retention
NRC	National Research Council, U.S.
NTP	National Toxicology Program, U.S.
OECD	Organisation for Economic Cooperation and Development
OH-MIDP	mono(hydroxy-isodecyl) phthalate
OH-MINP	mono(hydroxy-isononyl) phthalate
OR	odds ratio
oxo-MIDP	mono(oxo-isodecyl) phthalate
oxo-MINP	mono(oxo-isononyl) phthalate
PBR	peripheral benzodiazepine receptor
PDI	psychomotor developmental index
PE	phthalate ester
PEAA	potency estimates for antiandrogenicity
PND	postnatal day
PNW	postnatal week
POD	point of departure
PODI	point of departure index
PPARα	peroxisome proliferator-activated receptor alpha
PPS	probability proportional to a measure of size
PSU	primary sampling unit

PVC	polyvinyl chloride
RfD	reference dose
RTM	reproductive tract malformation
SD	Sprague-Dawley
SDN-POA	sexually dimorphic nucleus of the preoptic area
SFF	Study for Future Families
SR-B1	scavenger receptor class B1
SRS	social responsiveness scale
StAR	steroidogenic acute regulatory protein
SVW	seminal vesicle weight
TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
TDI	tolerable daily intake
TDS	testicular dysgenesis syndrome
TEF	toxicity equivalency factors
TOTM	tris(2-ethylhexyl) trimellitate
TPIB	2,2,4-trimethyl-1,3 pentanediol diisobutyrate
T PROD	testosterone production
TXIB®	2,2,4-trimethyl-1,3 pentanediol diisobutyrate
UF	uncertainty factor

1 Introduction

The Consumer Product Safety Improvement Act (CPSIA)[*] of 2008 (CPSIA, 2008) was enacted on August 14, 2008. Section 108 of the CPSIA permanently prohibits the sale of any "children's toy or child care article" individually containing concentrations of more than 0.1% of dibutyl phthalate (DBP), butylbenzyl phthalate (BBP), or di(2-ethylhexyl) phthalate (DEHP). Section 108 prohibits on an interim basis the sale of "any children's toy that can be placed in a child's mouth" or "child care article" containing concentrations of more than 0.1% of di-*n*-octyl phthalate (DNOP), diisononyl phthalate (DINP), or diisodecyl phthalate (DIDP). These restrictions became effective in February 2009. In addition, Section 108 of the CPSIA directs the Consumer Product Safety Commission (CPSC) to convene a Chronic Hazard Advisory Panel (CHAP) "to study the effects on children's health of all phthalates and phthalate alternatives as used in children's toys and child care articles." The CHAP will recommend to the U.S. CPSC whether any phthalates or phthalate alternatives other than those permanently banned should be declared banned hazardous substances.

The number of possible phthalate alternatives is potentially very large. CPSC staff identified five compounds as the most likely to be used in children's products (Versar/SRC, 2010) (Table E2-1; Figure E2-1). A sixth alternative (2,2,4-trimethyl-1,3 pentanediol diisobutyrate, TXIB®, TPIB)[†] was added when it was found in toys (see below). TPIB is an additive that is typically used in combination with other plasticizers. CPSC staff prepared toxicity reviews for the six phthalate alternatives to support the CHAP's analysis (Versar/SRC, 2010; Patton, 2011).

CPSC staff also performed laboratory studies of children's toys and child care articles to assist the CHAP. In December 2008, two months prior to the effective date of the new phthalate restrictions, CPSC staff purchased 63 children's toys and child care articles to:

1. Identify the plastic used in all component parts;
2. Identify the plasticizer(s), if present;
3. Determine the concentration (mass percent) of plasticizer where present; and
4. Measure the migration of plasticizers into simulated saliva to estimate oral exposure.

The results of the laboratory study have been reported (Dreyfus, 2010; Dreyfus and Babich, 2011). This memorandum uses the information obtained in the laboratory study to estimate children's oral exposure to phthalate alternatives from mouthing soft plastic articles.

---

[*] Public Law 110-314.

[†] TXIB® is a registered trademark of Eastman Chemical Company. Although "TXIB" is the commonly used abbreviation for 2,2,4-trimethyl-1,3 pentanediol diisobutyrate, the alternate abbreviation TPIB is used here to represent the generic chemical.

Table E2-1 Possible phthalate alternatives for use in children's toys and child care articles (Versar/SRC, 2010).

Common Name[a]	Systematic Name	Abbr.[b]	CAS	MF	MW (range)[c]
TXIB®	2,2,4-trimethyl-1,3 pentanediol diisobutyrate	TPIB	6846-50-0	$C_{16}H_{30}O_4$	286.4
di(2-ethylhexyl) adipate	hexanedioc acid, 1,6-bis(2-ethylhexyl) ester	DEHA	103-23-1	$C_{22}H_{42}O_4$	370.6
acetyl tributyl citrate	1,2,3-propanetricarboxylic acid, 2-(acetyloxy)-, tributyl ester	ATBC	77-90-7	$C_{20}H_{34}O_8$	402.5
diisononyl hexahydrophthalate	1,2-cyclohexanedicarboxylic acid, diisononyl ester	DINX	166412-78-8 474919-59-0	$C_{26}H_{48}O_4$	424.7 (396.6—452.7)
di(2-ethylhexyl) terephthalate	1,4-benzenedicarboxylic acid, 1,4-bis(2-ethylhexyl) ester	DEHT[d]	6422-86-2	$C_{24}H_{38}O_4$	542.6
tris(2-ethylhexyl) trimellitate	1,2,4-benzenetricarboxylic acid, tris(2-ethylhexyl) ester	TOTM	3319-31-1	$C_{33}H_{54}O_6$	546.8

[a] National Library of Medicine (NLM, 2011). Chem ID database.
[b] Abbr., abbreviation; CAS, Chemical Abstracts Service number, MF, molecular formula; MW, molecular weight.
[c] DINX includes isomers with C8–C10 ester groups.
[d] Di(2-ethylhexyl) terephthalate is also commonly abbreviated as "DOTP."

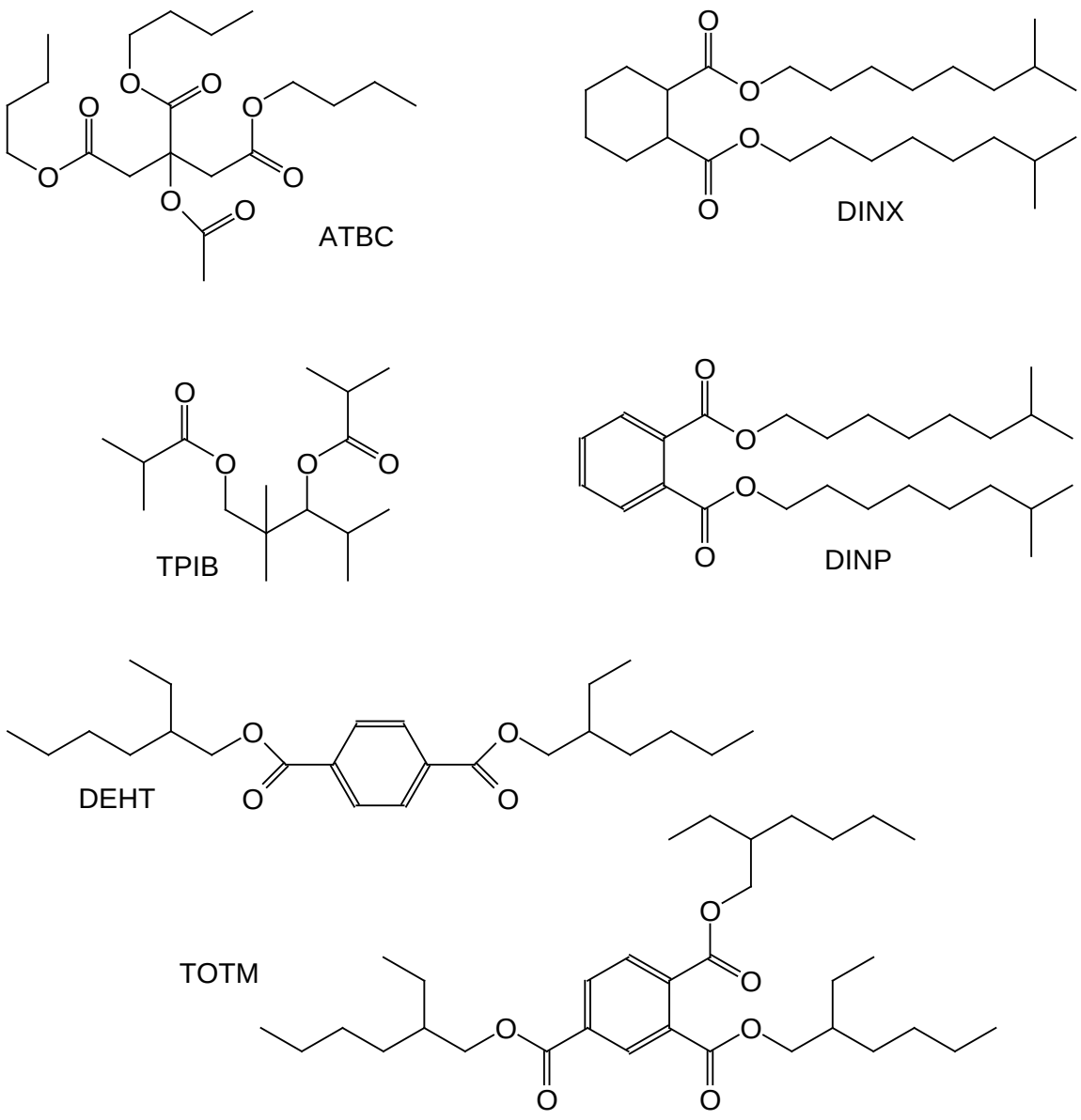

Figure E2-1 Chemical structures of phthalate alternatives.

2 Methodology

2.1 Migration

The methods for measuring plasticizer migration have been described in detail previously (Dreyfus, 2010; Dreyfus and Babich, 2011). Briefly, plasticizer migration into simulated saliva was measured by a variation (Chen, 2002) of the Joint Research Centre (JRC) method (Simoneau *et al.*, 2001). A punch press was used to cut three 10 cm^2 test disks from each sample. The three disks from each sample were extracted two times each in 50 ml of simulated saliva (JRC formulation) in a 250 ml Schott Duran bottle for 30 minutes. The two volumes of simulated saliva were combined and then extracted with 50 mL of cyclohexane. The cyclohexane extract was analyzed by gas chromatography/mass spectrometry (GC-MS).

2.2 Calculations

Exposure from mouthing soft plastic teethers and toys was estimated by:

$$E = R \times T/W \quad (1)$$

where: E, estimated daily exposure, µg/kg-d; R, migration rate, µg/h; A, area of the article in the child's mouth, cm^2; T, exposure duration, minutes/d; W, body weight, kg.

Mouthing durations for various objects and age groups are from a CPSC study of children between 3 months and less than 36 months old (CPSC, 2002) (Table E2-2). The mouthing duration depends on the child's age and the type of object mouthed (Greene, 2002). Generally, children up to 3 years old mouth fingers most, followed by pacifiers, and teethers and toys. The mouthing duration was for the object category "all soft plastic articles except pacifiers." Pacifiers are made from either natural rubber or silicone, not PVC. The mean migration rate and mouthing duration were used to estimate the mean oral exposure. The 95^{th} percentile exposure was estimated in two ways, using either the 95^{th} percentile migration rate or 95^{th} percentile mouthing duration.

Body weights were as follows: 3 to <12 months, 8.6 kg; 12 to <24 months, 11.4 kg; 24 to <36 months; 13.8 kg (EPA, 2011, Table 8-1). The body weight for 3 to <12 months is a weighted average of the 3 to <6 month and 6 to <12 month values. The migration rate (R) is for a 10 cm^2 disk. A standard surface area of 10 cm^2 was assumed for the surface area of the article in the child's mouth (Simoneau *et al.*, 2001; CPSC, 2002).

Table E2-2 Mouthing duration (minutes per day) for various objects by age group (Greene, 2002).

Age	N[a]	Object mouthed	Duration (minutes/day)		
			Mean	*Median*	*0.95*
3–12 months	54	soft plastic toys	1.3	0	7.1
		soft plastic teethers & rattles	1.8	0	12.2
		all soft plastic, except pacifiers	4.4	1.2	17.5
		non-soft plastic teethers, toys, & rattles	17.4	12.6	58
		pacifiers	33	0	187.4
		nonpacifiers	70.1	65.6	134.4
12–24 months	66	soft plastic toys	1.9	0.1	8.8
		soft plastic teethers, rattles	0.2	0	0.9
		all soft plastic except pacifiers	3.8	2.2	13
		nonsoft plastic teethers, toys, & rattles	5.7	3.2	18.6
		pacifiers	26.6	0	188.5
		nonpacifiers	47.4	37	121.5
24–36 months	49	soft plastic toys	0.8	0	3.3
		soft plastic teethers & rattles	0.2	0	0.8
		all soft plastic except pacifiers	4.2	1.5	18.5
		nonsoft plastic teethers, toys, & rattles	2.2	0.8	10.7
		pacifiers	18.7	0	136.5
		nonpacifiers	37	23.8	124.3

[a] N, number of children observed; 0.95, 95th percentile.

3 Results

3.1 Composition of Toys and Child Care Articles

CPSC staff purchased 63 children's products, including 43 toys, 12 child care articles, and 8 art or school supplies (Table E2-3). These products comprised 128 component parts, of which 37 (28.9 %) were made from polyvinyl chloride (PVC). One child care article (a teether) and one art material (modeling clay) were made with PVC; both were plasticized with phthalate alternatives. The remaining PVC components were toys. Some of the products tested might not be subject to the CPSIA phthalates restrictions.

Of the 37 PVC components, one toy contained DINP and another contained DEHP in excess of the 0.1% regulatory limit.[*] The remainder of the PVC components contained phthalate alternatives, including acetyl tributyl citrate (ATBC), di(2-ethylhexyl terephthalate (DEHT), 1,2-cyclohexanedicarboxylic acid, diisononyl ester (DINCH®, DINX)[†], and 2,2,4-trimethyl-1,3 pentanediol diisobutyrate (TPIB) at concentrations from 2 to 60% by mass (Table E2-4). About half of these components contained more than one plasticizer.

3.2 Migration

Migration rates for phthalate alternatives ranged from 0.14 to 14.0 µg/10 cm^2-h (Table E2-5). These are roughly comparable to the migration rates previously measured with DINP (Chen, 2002), which ranged from 1.0 to 11.1 µg/10 cm^2-h. Data for DINP and DEHP are included for comparison.

Plots of migration rate against plasticizer concentration show that migration rates with ATBC, DEHT, and TPIB generally increased with increasing concentration (Figure E2-2). The slope of the migration rate over concentration was highest with TPIB and lowest with DEHT. Migration rates with DINP and DINX did not exhibit a monotonic relationship with concentration.

3.3 Oral Exposure

The mouthing duration depends on the child's age and the type of object mouthed (Greene, 2002). Generally, children up to 3 years old mouth fingers most, followed by pacifiers, and teethers and toys (Table E2-2). Mouthing duration generally decreases with age. Mouthing durations were multiplied by migration rates to estimate oral exposures for various plasticizers and types of objects.

For infants less than 12 months old, estimated mean exposures ranged from 0.60 µg/kg-d for DEHT to 3.3 µg/kg-d for ATBC (Table E2-6). Based on 95th percentile *migration rates*, upper

---

[*] The DINP-containing toy could not be placed in a child's mouth and, therefore, would comply with the CPSIA phthalates restrictions. The DEHP-containing toy would not comply because DEHP is permanently banned from toys and child care articles at levels greater than 0.1%, regardless of whether they can be placed in a child's mouth.

[†] DINCH® is a registered trademark of BASF. Although "DINCH" is the commonly used abbreviation for 1,2-cyclohexanedicarboxylic acid, diisononyl ester, the alternate abbreviation DINX is used here to represent the generic chemical.

bound exposures in this age group ranged from 1.8 µg/kg-d for DEHT to 7.2 µg/kg-d for ATBC. Based on the 95th percentile *mouthing duration*, upper bound exposures ranged from 2.8 µg/kg-d for DEHT to 5.1 µg/kg-d for ATBC.

Estimated exposures were generally lower in the older age groups. In children 12 to 23 months old, mean exposures ranged from 0.45 µg/kg-d for DEHT to 1.5 µg/kg-d for ATBC. The maximum upper bound exposure was 4.7 µg/kg-d for ATBC, based on the 95th percentile migration rate. In children 24 to 35 months old, mean exposures ranged from 0.41 µg/kg-d for DEHT to 1.4 µg/kg-d for ATBC. The maximum upper bound exposure was 4.3 µg/kg-d for ATBC, based on the 95th percentile migration rate.

Table E2-3 Children's products tested by CPSC staff.[a]

Product Type[b]	Examples	N[c]	Parts[d]	PVC (%)[e]	
Child-care articles	Teethers, sipper cups, spoons	12	18	1	(5.6)
Toys <3 years[f]	Links, stacking rings, tub toys dolls	24	43	16	(37.2)
Toys ≥3 years[f]	Action figures, trucks, balls	19	58	19	(32.8)
Art materials	Modeling clays	6	7	1	(14.3)
School supplies	Pencil grip, eraser	2	2	0	(0.0)
Total		63	128	37	(28.9)

[a] Purchased December 2008. Phthalates regulations became effective February 2009.
[b] These categories are not necessarily the same as CPSIA definitions of "children's toys" or "child care article." Some of the products tested might not be subject to the CPSIA phthalates restrictions.
[c] N – number of products tested
[d] Parts – number of component parts tested
[e] PVC – number of component parts containing polyvinyl chloride (percent)
[f] Age recommendation on product label

Table E2-4 Phthalate alternatives identified in children's products made with polyvinyl chloride (PVC) (Dreyfus, 2010).

Plasticizer	N[a]	%[b]	Mass Percent
Acetyl tributyl citrate (ATBC)	19	51.4	5 to 43
Di(2-ethylhexyl) terephthalate (DEHT)	14	37.8	3 to 60
1,2-cyclohexanedicarboxylic acid, diisononyl ester (DINX)	13	35.1	3 to 25
2,2,4-trimethyl-1,3 pentanediol diisobutyrate (TPIB)	9	24.3	2 to 19
Total	37		

[a] N – number of articles tested
[b] % – percentage of articles containing the plasticizer of interest

Table E2-5 Plasticizer migration rate (µg/10 cm^2-min) into simulated saliva measured by the Joint Research Centre method.[a]

Plasticizer	ATBC	DEHT	DINX	TPIB	DINP	DEHP
N[b]	18	13	11	8	25	3
mean	4.4	1.4	3.0	6.2	4.2	1.3
median	2.5	1.4	2.7	1.8	3.5	1.1
standard deviation	4.38	0.91	2.49	3.82	2.76	0.60
minimum	0.75	0.14	0.52	0.90	1.05	0.90
maximum	14.0	3.6	7.3	11.3	11.1	2.0
95^{th} percentile	14.0	2.7	7.0	9.8	10.1	1.9

[a] Joint Research Centre method described in Simoneau *et al.*(2001). Data on ATBC, DEHT, DINX, and DEHT are from Dreyfus (2010). DEHP, DINP, and DEHP included for comparison (Chen, 2002).
[b] N – number of articles tested

Table E2-6 Estimated oral exposure (µg/kg-d) from mouthing soft plastic objects.[a]

Plasticizer	Age Range								
	3 to <12 months			12 to <24 months			24 to <36 months		
	Mean[b]	*R(0.95)*[c]	*T(0.95)*[d]	*Mean*[b]	*R(0.95)*[c]	*T(0.95)*[d]	*Mean*[b]	*R(0.95)*[c]	*T(0.95)*[d]
ATBC	2.3	7.2	5.1	1.5	4.7	2.8	1.4	4.3	3.4
DINX	1.4	3.6	5.4	0.89	2.3	3.1	0.82	2.1	3.6
DEHT	0.69	1.8	2.8	0.45	1.2	1.5	0.41	1.1	1.8
TPIB	0.92	5.8	3.8	0.60	3.8	2.0	0.55	3.4	2.4

[a] Calculated with equation (1). Results rounded to two significant figures.
[b] Mean – calculated with the mean migration rate and mouthing duration
[c] R(0.95) – calculated with the 95th percentile migration rate and mean mouthing duration
[d] T(0.95) – calculated with the mean migration rate and 95th percentile mouthing duration

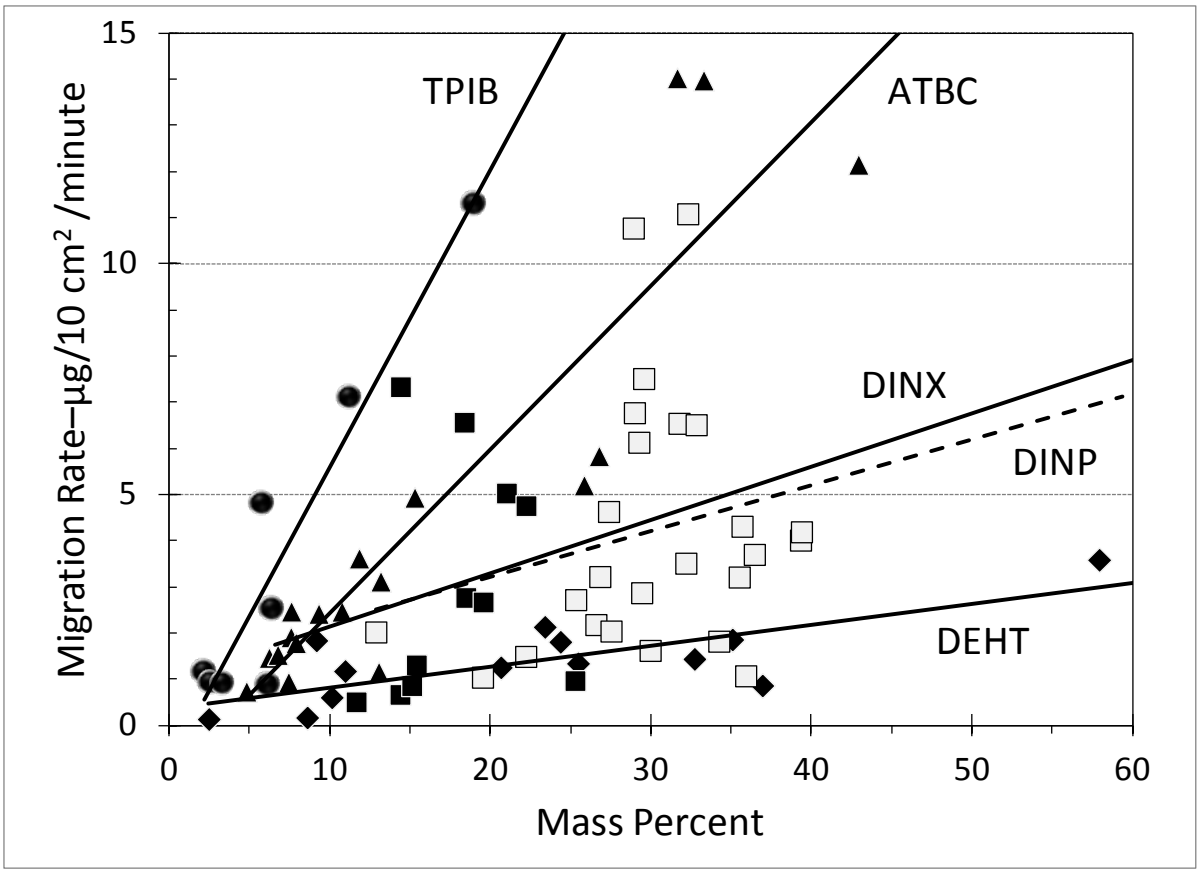

Figure E2-2 Migration of plasticizers into saliva stimulant. Migration was measured by the Joint Research Centre method (Simoneau and Rijk 2001). Lines are linear trends. DINP is from a previous study (Chen, 2002); all other data are from Dreyfus (2010). TPIB (● — ●); ATBC (▲ — ▲); DINX (■ — ■); DINP (□ - - - □); DEHT (◆ — ◆). Adapted from Dreyfus and Babich (2011). [*TPIB, solid circles; ATBC, solid triangles; DINX, solid squares; DINP, open squares; DEHT, solid diamonds.*]

4 Discussion

4.1 Methodology and Assumptions

The method for measuring plasticizer migration into simulated saliva was specifically developed and validated for the purpose of estimating children's exposure to phthalates from mouthing PVC articles (Simoneau *et al.*, 2001). The method is used here to estimate children's exposure to phthalate alternatives.

Mouthing durations are from an observational study of children's mouthing activity (Greene, 2002). Mouthing duration depends on the child's age and the type of object mouthed. The category "all soft plastic articles except pacifiers" was used to estimate children's exposure from mouthing PVC articles. This category includes articles such as teethers, toys, rattles, cups, and spoons. Pacifiers are not included in this category because they are generally made with natural rubber or silicone (CPSC, 2002). Products in the "all soft plastic articles except pacifiers" category are not necessarily made with PVC. About 35% of the soft plastic toys and less than 10% of the soft plastic child care articles tested by CPSC staff contained PVC (Table E2-3). Toys and child care articles are also made from other plastics, wood, textiles, and metal. Therefore, the use of mouthing durations for the category "all soft plastic articles except pacifiers" provides a reasonable upper bound estimate for children's exposure from mouthing PVC children's products.

The products tested by CPSC staff were purchased in 2008. The products selected for study may not necessarily be representative of children's products on the market at that time or currently. ATBC, DEHT, DINX, and TPIB are still commonly used in children's products.[*] Other nonphthalate plasticizers, such as DEHA and benzoates, are also used. There are many possible phthalate alternatives, and their uses may change in response to market demands or cost.

4.2 Other Sources of Exposure

The phthalate alternatives considered here are general purpose plasticizers and additives that have multiple uses. Three of the six alternatives (ATBC, DEHA, and DEHT) are high production volume (HPV) chemicals. That is, more than 1 million pounds per year of the alternatives are manufactured in or imported into the United States. Children and other consumers may be exposed to phthalate alternatives from a variety of sources, not only toys and child care articles.

ATBC is an HPV chemical (reviewed in Versar/SRC, 2010). It is approved for use in food packaging, including for fatty foods, and as a flavor additive. It is also used in medical devices, cosmetics, adhesives, and pesticide inert ingredients. ATBC was present in about half of the PVC toys and child care articles tested by the CPSC (Table E2-4) (Dreyfus, 2010; Dreyfus and Babich, 2011).

DEHA is also an HPV chemical (Versar/SRC, 2010). It is approved for use as an indirect food additive as a component of adhesives and in food storage wraps. Total intake of DEHA was estimated to be 0.7 µg/kg-d in a European population, based on biomonitoring data (Fromme *et*

[*] CPSC compliance test data.

al., 2007b). Dietary intake of DEHA was estimated to be 12.5 µg/kg-d in a Japanese study of duplicate dietary samples (Tsumura *et al.*, 2003). CPSC staff estimated the dietary intake of DEHA to be between 137 and 259 µg/kg-d (Carlson and Patton, 2012) from food residue data obtained in Canada in the 1980s (Page and Lacroix, 1995).

DEHA is also found in adhesives, vinyl flooring, carpet backing, and coated fabrics (Versar 2010). CPSC staff previously found DEHA in toys (Chen, 2002). It was found at 2.0 ng/m^3 in the indoor air of an office building (reviewed in Versar/SRC, 2010).

DEHT is an HPV chemical used as a plasticizer in several polymers, including PVC (Versar/SRC, 2010). It was present in more than one-third of the PVC toys and child care articles tested by CPSC staff (Table E2-4) (Dreyfus, 2010; Dreyfus and Babich, 2011).

DINX was developed as a phthalate alternative for use in "sensitive" applications, such as food packaging, toys, and medical devices (Versar/SRC, 2010). It was found in 35% of PVC toys and child care articles tested by CPSC staff (Table E2-4) (Dreyfus, 2010; Dreyfus and Babich, 2011). DINX has been approved for use in food contact materials in Europe and Japan. It is used in food packaging and food processing equipment (Versar/SRC, 2010).

TOTM is an HPV plasticizer that is preferred for use in high temperature applications (Versar/SRC, 2010). It is reported to have lower volatility and migration, as compared to other plasticizers. TOTM is used in electrical cable, lubricants, medical tubing, and controlled-release pesticide formulations.

TPIB is a secondary plasticizer used in combination with other plasticizers (reviewed in Patton, 2011). It is not an HPV chemical. TPIB is used in PVC and polyurethane. TPIB may be found in weather stripping, furniture, wallpaper, nail care products, vinyl flooring, sporting goods, traffic cones, vinyl gloves, inks, water-based paints, and toys. TPIB has been detected in indoor air in office buildings, schools, and residences (Patton, 2011). It was measured at levels from 10 to 100 µg/m^3 in the indoor air of office buildings. TPIB was found in about one-quarter of the PVC toys and child care articles tested by CPSC staff (Table E-24) (Dreyfus, 2010; Dreyfus and Babich, 2011).

4.3 Data Gaps

Migration data were available for only four of the six phthalate alternatives discussed in this report. Migration data on DEHA and TOTM are needed to estimate children's oral exposure to these plasticizers. Additional data on the occurrence of phthalate alternatives in current children's articles would be helpful.

The phthalate alternatives are general purpose compounds with multiple uses. ATBC, DEHA, and DEHT are HPV chemicals. Exposure may occur from sources other than consumer products, such as the indoor environment and diet. Other exposures to phthalate alternatives may also occur through dermal contact and inhalation of alternative-laden dust or air. Information on other exposure routes and sources is needed to estimate aggregate exposure to phthalate alternatives.

4.4 Conclusions

About 30% of the soft plastic toys and child care articles tested by CPSC staff were made of PVC. Most of the products tested were made with alternative plastics that do not require plasticizers. The most common plasticizers in PVC articles were ATBC, DEHT, DINX, and TPIB. Half of the PVC articles had two or more plasticizers. The migration rate into saliva simulant generally increased with the plasticizer concentration. The migration rate into saliva simulant at a given plasticizer concentration was, in general: TPIB >ATBC >DINX ~DINP > DEHT.

Migration rate data were used to estimate children's oral exposure from mouthing soft plastic articles except pacifiers. Estimated oral exposures for the phthalate plasticizer alternatives tested by CPSC alternatives ranged from 0.41 to 7.2 µg/kg-d. Exposure to similar phthalate alternatives from diet and the indoor environment occurs. However, quantitative estimates of total exposure to most phthalate alternatives are not available.

5 References

Carlson, K.R., Patton, L.E., 2012. U.S. CPSC staff assessment of phthalate dietary exposure using two food residue data sets and three food categorization schemes. U.S. Consumer Product Safety Commission, Bethesda, MD. July 2014. Appendix E-3.

Chen, S.-B., 2002. Screening of Toys for PVC and Phthalates Migration, Bethesda, MD. In CPSC 2002. June 20, 2002. In, CPSC, 2002.

CPSC, 2002. Response to petition HP 99-1. Request to ban PVC in toys and other products intended for children five years of age and under. U.S. Consumer Product Safety Commission, Bethesda, MD. August 2002. http://www.cpsc.gov/Newsroom/FOIA/Commission-Briefing-Packages/2002/

CPSIA, 2008. Consumer Product Safety Improvement Act (CPSIA) of 2008. Public Law 110-314. Consumer Product Safety Commission, Bethesda, MD.

Dreyfus, M., 2010. Phthalates and Phthalate Substitutes in Children's Toys. U.S. Consumer Product Safety Commission, Bethesda, MD. March 2010. http://www.cpsc.gov/PageFiles/126545/phthallab.pdf

Dreyfus, M.A., Babich, M.A., 2011. Plasticizer migration from toys and child care articles. The Toxicologist 120, 266.

EPA, 2011. Exposure Factors Handbook: 2011 Edition. U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC 20460. EPA/600/R-090/052F. September 2011. http://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=236252

Fromme, H., Gruber, L., Schlummer, M., Wolz, G., Bohmer, S., Angerer, J., Mayer, R., Liebl, B., Bolte, G., 2007b. Intake of phthalates and di(2-ethylhexyl) adipate: Results of the Integrated Exposure Assessment Survey based on duplicate diet samples and biomonitoring data. Environ Int 33, 1012-1020.

Greene, M.A., 2002. Mouthing times from the observational study. U.S. Consumer Product Safety Commission, Bethesda, MD. In CPSC 2002. June 17, 2002.

NLM, 2011. ChemID Database. National Library of Medicine (NLM), National Institutes of Health, Bethesda, MD. http://hpd.nlm.nih.gov/

Page, B.D., Lacroix, G.M., 1995. The occurrence of phthalate ester and di-2-ethylhexyl adipate plasticizers in Canadian packaging and food sampled in 1985–1989: a survey. Food Addit Contam 12, 129-151.

Patton, L.E., 2011. CPSC staff toxicity review of two phthalates and one phthalate alternative for consideration by the Chronic Hazard Advisory Panel, 2011. U.S. Consumer Product Safety Commission, Bethesda, MD. February 2011.

Simoneau, C., Geiss, H., Roncari, A., Zocchi, P., Hannaert, P., 2001. Standard Operation Procedure for the Determination of Release of Di-Isononylphthalate (DINP) in Saliva Simulant from Toys and Childcare Articles using a Head Over Heels Dynamic Agitation Device. European Commission, DG-Joint Research Center, Food Products Unit, Institute for Health and Consumer Protection, Ispra, Italy. 2001 EUR 19899 EN.

Tsumura, Y., Ishimitsu, S.S., I., Sakai, H., Y., T., Tonogai, Y., 2003. Estimated daily intake of plasticizers in 1-week duplicate diet samples following regulation of DEHP-containing PVC gloves in Japan. Food Addit Contaminants 20, 317--324.

Versar/SRC, 2010. Review of Exposure and Toxicity Data for Phthalate Substitutes Versar, Inc., Springfield, VA 22151. Syracuse Research Corporation, North Syracuse, NY 13212. Prepared for the U.S. Consumer Product Safety Commission, Bethesda, MD 20814. January 2010.