CPSC Staff Statement on the
Toxicology Excellence for Risk Assessment Report,
"Exposure Assessment: Composition, Production, and Use of Phthalates"
August 2015

The report, *Exposure Assessment: Composition, Production, and Use of Phthalates*, presents the findings of research conducted by Toxicology Excellence for Risk Assessment ("TERA") under a contract with the U.S. Consumer Product Safety Commission ("CPSC"). TERA performed this research to characterize composition, manufacturing processes, and applications of 11 specified phthalates. The phthalates researched are:

- DEHP: di-(2-ethylhexyl) phthalate
- DBP: dibutyl phthalate
- BBP: benzyl butyl phthalate
- DINP: diisononyl phthalate
- DIDP: diisodecyl phthalate
- DnOP: di-n-octyl phthalate
- DIOP: diisooctyl phthalate
- DIBP: diisobutyl phthalate
- DPENP: di-n-pentyl phthalate
- DHEXP: di-n-hexyl phthalate
- DCHP: dicyclohexyl phthalate

This research was completed in support of CPSC's work on third party testing burden reduction consistent with assuring compliance. CPSC staff will consider this information in evaluating whether staff could make a recommendation for a Commission determination that some materials do not contain any of the 11 phthalates in concentrations above 0.1 percent, and thus, may not require third party testing to assure compliance with section 108 of the Consumer Product Safety Improvement Act of 2008.

This report will be posted on CPSC's website to keep stakeholders informed of the progress of technical research related to the agency's regulatory activities.

TERA

Exposure Assessment: Composition, Production, And Use of Phthalates

Task Order 11
Contract Number
CPSC-D-12-0001

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Revised Report

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Abbreviation List

µg/L	microgram(s) per liter
µg/g	microgram(s) per gram
ACC	American Chemistry Council
ACCC	Australian Competition and Consumer Commission
ACGIH	American Conference of Governmental Industrial Hygienists
BBP	Benzyl butyl phthalate
CASRN	Chemical Abstracts Service Registry Number
CBI	Confidential Business Information
CDAT	Chemical Data Access Tool
CFR	Code of Federal Regulations
CICAD	Concise International Chemical Assessment Document
CPSC	U.S. Consumer Product Safety Commission
Danish EPA	Danish Environmental Protection Agency
DAP	Diamyl phthalate
DBP	Dibutyl phthalate
DCHP	Dicyclohexyl phthalate
°C	degree(s) Celsius
DEHP	Di (2-ethylhexyl) phthalate
DHEXP	Dihexyl phthalate
DIBP	Diisobutyl phthalate
DIDP	Diisodecyl phthalate
DINP	Diisononyl phthalate
DIOP	Diisooctyl phthalate
DnOP	D-n-octyl phthalate
DnPP	Di-n-pentyl phthalate
DPENP	Dipentyl phthalate
ECHA	European Chemicals Agency
EHPV	Extended High Production Volume
EPA	United States Environmental Protection Agency
EPA CDR	EPA Chemical Data Reporting Rule
EPA CDAT	EPA Chemical Data Access Tool
EU	European Union
g/mL	gram(s) per milliliter(s)
g/mol	gram(s) per mole
HC	Health Canada
hPa	hectopascal
HPD	Household Product Database
HPV	High Production Volume

HSDB	Hazardous Substance Database
IARC	International Agency for Research on Cancer
IFCS	Intergovernmental Forum on Chemical Safety
IPCS	International Programme on Chemical Safety
IRIS	Integrated Risk Information System
IUPAC	International Union of Pure and Applied Chemistry
IUR	Inventory Update Rule
K_{oc}	soil organic carbon-water partition coefficient
K_{ow}	octanol-water partition coefficient
kPa	kilopascal
lb	pound
log K_{ow}	logarithmic octanol-water partition coefficient
m	meter
max	maximum
mg/kg	milligram(s) per kilogram(s)
mg/kg/day	milligram(s) per kilogram(s) per day
mg/L	milligram (s) per liter
min	minimum
mm Hg	millimeter of mercury
ng	nanogram(s)
ng/mL	nanogram(s) per milliliter(s)
NICNAS	National Industrial Chemicals Notification and Assessment Scheme
NIH	National Institute for Health
NIST	National Institute of Standards and Technology
NK	not known
NTP	National Toxicology Program
NTP-CERHR	National Toxicology Program Center for the Evaluation of Risks to Human Reproduction
OECD	Organisation for Economic Co-operation and Development
PET	Polyethylene terephthalate
PLA	Polylactic acid
ppb	parts per billion
ppm	parts per million
PS	Polystyrene
PVC	Polyvinylchloride
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RTECS	Registry of Toxic Effects of Chemical Substances
SIDS	Screening Information Data Set
SPIN	Substances in Products in Nordic Countries
TSCA	Toxic Substances Control Act

UK	United Kingdom
USDA	United States Department of Agriculture
VOC	Volatile Organic Compounds
WHO	World Health Organization
WSDE	Washington State Department of Ecology

1 Introduction

The Consumer Product Safety Act (CPSA) requires third party testing of children's products for compliance with applicable children's product safety rules. Section 108 of the Consumer Product Safety Improvement Act of 2008 (CPSIA) restricts the presence of six phthalates in children's toys and child care articles: Dibutyl phthalate (DBP), Butyl benzyl phthalate (BBP), and Di-(2-ethylhexyl phthalate (DEHP) may not be present in concentrations above 0.1 percent (%) in children's toys and child care articles and Di-n-octyl phthalate (DnOP), Diisononyl phthalate (DINP), and Diisodecyl phthalate (DIDP) may not be present in concentrations above 0.1 percent in child care articles or in mouthable toys. The U.S. Consumer Product Safety Commission (CPSC) Chronic Hazard Advisory Panel (CHAP) recommended an interim ban for Diisooctyl phthalate (DIOP) until sufficient toxicity and exposure data are available to assess the potential risks. The CHAP further recommended that Diisobutyl phthalate (DIBP), Di-n-pentyl phthalate (DPENP), Di-n-hexyl phthalate (DHEXP), and Dicyclohexyl phthalate (DCHP) be permanently banned for use in children's toys and child care articles at concentrations greater than 0.1 %. This report addresses these specific 11 phthalates (see Table 1-1).

Table 1-1. Specified Phthalates

Phthalate	**CASRN**
DEHP: di-(2-ethylhexyl) phthalate	117-81-7
DBP: dibutyl phthalate	84-74-2
BBP: benzyl butyl phthalate	85-68-7
DINP: diisononyl phthalate	28553-12-0, 68515-48-0
DIDP: diisodecyl phthalate	26761-40-0, 68515-49-1
DnOP: di-n-octyl phthalate	117-84-0
DIOP: diisooctyl phthalate	27554-26-3
DIBP: diisobutyl phthalate	84-69-5
DPENP: di-n-pentyl phthalate	131-18-0
DHEXP: di-n-hexyl phthalate	84-75-3
DCHP: dicyclohexyl phthalate	84-61-7

The CPSC is seeking information upon which to base a recommendation as to whether materials used for children's toys and child care articles can be determined not to contain any of the specified phthalates in concentrations above the 0.1% limit, and thus, would not require third party testing to assure compliance.

The CPSC requested that Toxicology Excellence for Risk Assessment (TERA) investigate the following factors specified by CPSC:

- The raw materials used in the production of the specified phthalates;
- The manufacturing processes used worldwide to produce the specified phthalates;
- Estimated annual production of the specified phthalates;
- Physical properties (e.g., vapor pressure, flashpoint, water solubility, temperature at which chemical breakdown occurs);
- Applications for phthalates use in materials and consumer and nonconsumer products; and
- Other potential routes by which phthalates can be introduced into an otherwise phthalates-free materials (e.g., migration from packaging, recycling, reuse, product breakdown).

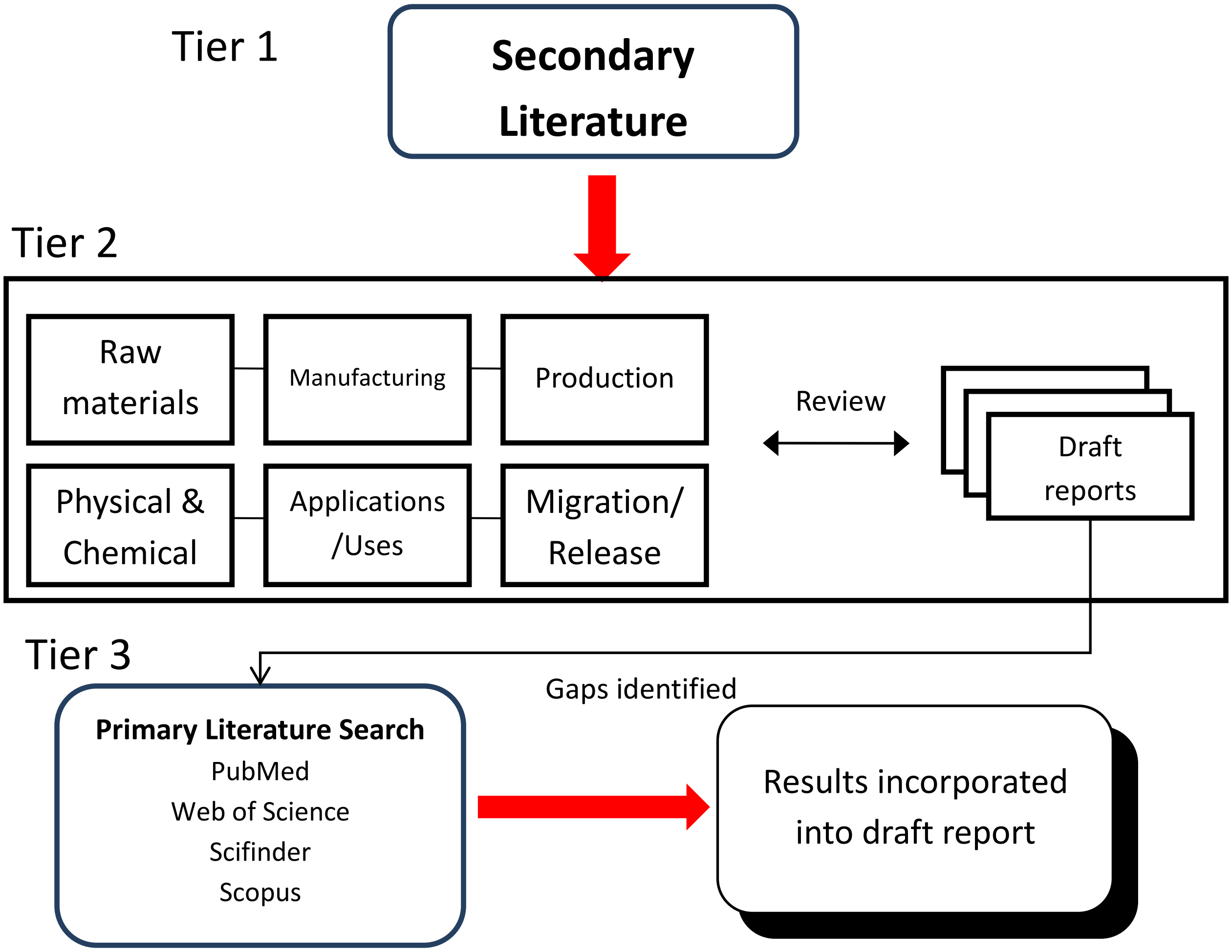
Our research approach is described in Section 2. Our research was not exhaustive of the worldwide primary literature. We screened secondary sources and some of the available primary literature to identify information on only the six factors for only the 11 specified phthalates. We focused on finding concentration data, particularly those where the specified phthalate was present in materials at greater than 0.1%. In cases where data indicated that concentrations did not exceed 0.1%, we presented that information so as to be as comprehensive as possible.

2 Literature Review Strategy

To research each of the 11 phthalates for each of the six factors, a multi-tiered approach for collection, review and compilation of the information was undertaken.

The research involved a three-tiered strategy. First (Tier 1), the "universe" of information about phthalates was pared down to identify authoritative secondary sources for the 11 specified phthalates ("background search"). To conduct and screen primary literature searches on all of specified phthalates would have required more resources than those available; there are hundreds of thousands of reports and manuscripts on phthalates. The secondary sources were searched and screened for each of the six factors for the 11 specified phthalates (Tier 2). Following preparation of a draft report based on the information gathered in the second tier, missing information or "gaps" were identified. The third tier involved gap-searching of the primary literature to identify missing information not previously located with the research approach used in the first two tiers. The overall approach for research for this project is shown in Figure 1.

Figure 1. Research Approach for Six Factors for 11 Specified Phthalates



2.1 Tier 1, Secondary Literature

In Tier 1, searches of the internet for authoritative secondary sources using chemical name, acronym and/or Chemical Abstracts Service Registry Number (CASRN) were conducted for each of the specified phthalates. Searches were conducted approximately from November 2014 to March 2015. Table 2-1 shows the acronyms, chemical name and CASRN for phthalates searched in Tier 1.

Sources considered secondary, authoritative sources were those that did not present original data or primary research reports but were compendia or reviews of literature on the phthalates in reputable peer journals, workshop reports from government, professional societies or international agencies, or peer review panel reports. Many of the sources from government regulatory agencies contained reports of chemical agents and were familiar to TERA. Other authoritative sources were identified through broad internet searches using the specified phthalates as key terms. When government agencies or organizations have multiple offices, a detailed examination of the different sites for the agency was conducted. While, we searched only in English, we identified sources from all over the world. Forty-seven websites were searched (December 2014-April 2015) to delineate the sites from which we would determine potentially relevant reports (see Table 2-2). We formed the background or basis for our search for potentially relevant phthalate-specific information on the six factors and bounded our resources in Tier 2.

Table 2-1. Tier 1 Secondary Literature Search Terms

DEHP, di-(2-ethylhexyl) phthalate, CASRN 117-81-7
DBP, dibutyl phthalate, CASRN 84-74-2
BBP, benzyl butyl phthalate, CASRN 85-68-7
DINP, diisononyl phthalate, CASRN 28553-12-0; 68515-48-0
DIDP, diisodecyl phthalate, CASRN 26761-40-0; 68515-49-1
DnOP, di-n-octyl phthalate, CASRN 117-84-0
DIOP, diisooctyl phthalate, CASRN 27554-26-3
DIBP, diisobutyl phthalate, CASRN 84-69-5
DPENP, di-n-pentyl phthalate, CASRN 131-18-0
DHEXP, di-n-hexyl phthalate, CASRN 84-75-3
DCHP, dicyclohexyl phthalate, CASRN 84-61-7

Table 2-2. Tier 1 Sites Researched for Phthalates

Country	Office	Website
Australia	Department of Health	http://www.nicnas.gov.au/home
	NICNAS	http://www.nicnas.gov.au/industry/aics/search.asp
Canada	Canadian Centre for Occupational Health & Safety - RTECS	http://www.ccohs.ca/search.html
	Environment Canada	http://www.ec.gc.ca/default.asp?lang=En&n=ECD35C36
	Health Canada	http://www.hc-sc.gc.ca/index-eng.php
	Health Canada First Priority List Assessments	http://www.hc-sc.gc.ca/ewh-semt/pubs/contaminants/psl1-lsp1/index-eng.php
	Health Canada Second Priority List Assessments	http://www.hc-sc.gc.ca/ewh-semt/pubs/contaminants/psl2-lsp2/index-eng.php
	Risk Manageme	http://www.ec.gc.ca/lcpe-cepa/default.asp?lang=En&xml=09F567A7-B1EE-1FEE-73DB-8AE6C1EB7658

	nt reports - Final Assessments	
Europe	ECHA	http://echa.europa.eu/
	ECHA	http://echa.europa.eu/en/search?p_p_id=echasearch_WAR_echaportlet&p_p_lifecycle=0&p_p_state=normal&p_p_mode=view&p_p_col_id=column-
International	eChemPortal	http://www.echemportal.org/echemportal/participant/page.action?pageID=9
	ITER TERA Database	https://iter.ctc.com/publicURL/pub_search_list.cfm
	OECD	http://www.echemportal.org/echemportal/substancesearch/page.action?pageID=9
Norway, Sweden, Denmark and Finland	SPIN	http://195.215.202.233/DotNetNuke/
U.S.	ACGIH	http://www.acgih.org/home.htm
	CPSC	http://www.cpsc.gov/
	Federal Docket	http://www.regulations.gov/#!home
	National Service Center for Environmental Publications (NSCEP)	http://www.epa.gov/nscep/
	OSHA	https://www.osha.gov/dts/chemicalsampling/toc/toc_chemsamp.html

U.S. - NIH	ChemIDPlus	http://chem.sis.nlm.nih.gov/chemidplus/rn/117-81-7
	HPD	http://householdproducts.nlm.nih.gov/cgi-bin/household/searchall
	HSDB	http://toxnet.nlm.nih.gov/newtoxnet/hsdb.htm
	NTP	http://ntp.niehs.nih.gov/index.cfm
	PubChem	https://pubchem.ncbi.nlm.nih.gov/search/
	Haz-Map	http://hazmap.nlm.nih.gov/index.php
U.S. - CA	Biomonitoring - Priority Chemicals California	http://www.oehha.ca.gov/multimedia/biomon/pdf/PriorityChemsCurrent.pdf
	Biomonitoring California-Designated Chemicals	http://www.oehha.ca.gov/multimedia/biomon/pdf/DesignatedChemCurrent.pdf
	Cal/Ecotox database	http://www.oehha.ca.gov/scripts/cal_ecotox/CHEMLIST.ASP
	Draft Assessments	http://www.ec.gc.ca/lcpe-cepa/default.asp?lang=En&xml=6892C255-5597-C162-95FC-4B905320F8C9
	Non-cancer health effects Table (RELs) and Cancer Potency Factors (Appendix	http://www.oehha.ca.gov/air/hot_spots/index.html

	A & B)	
	Office of Environmental Health Hazard Assessment (OEHHA)	http://www.oehha.ca.gov/risk.html
	OEHHA Toxicity Criteria Database	http://www.oehha.ca.gov/tcdb/index.asp
	OEHHA	http://www.oehha.ca.gov/
	Toxic Substances Managed under CEPA	http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=98E80CC6-1
U.S. - CDC	ATSDR	http://www.atsdr.cdc.gov/substances/index.asp
	NIOSH	http://www.cdc.gov/niosh/topics/
U.S. - EPA	AEGLs	http://www.epa.gov/oppt/aegl/pubs/chemlist.htm
	CDR-CDAT	http://java.epa.gov/oppt_chemical_search/
	EPA Science Inventory	http://cfpub.epa.gov/si/
	IRIS Track/New Assessment	http://www.epa.gov/ncepihom/

	s & Reviews / NSCEP	
	OPPT	http://iaspub.epa.gov/apex/pesticides/f?p=INERTFINDER:1:1395578990735::NO:1::
	RfD/RfC & CRAVE meeting notes	http://cfpub.epa.gov/si/
	TRI	http://www.epa.gov/enviro/facts/tri/search.html
U.S. - WA	WSDE	http://www.ecy.wa.gov/programs/swfa/cspa/
WHO	IARC	http://monographs.iarc.fr/ENG/Monographs/PDFs/index.php
	IFCS	http://www.who.int/ifcs/en/
	IPCS - INCHEM	http://www.inchem.org/

* NICNAS - National Industrial Chemicals Notification and Assessment Scheme; RTECS - Registry of Toxic Effects of Chemical Substances; ECHA - European Chemicals Agency; SPIN - Substances in Products in Nordic Countries; ACGIH - American Conference of Governmental Industrial Hygienists; CPSC - Consumer Product Safety Commission; ITER – International Toxicity Estimates for Risk; TERA – Toxicology Excellence for Risk Assessment; OECD – Organisation for Economic Cooperation and Development; NSCEP – National Service Center for Environmental Publications; OSHA – Occupational Safety and Health Administration; HPD – Household Products Database; HSDB – Hazardous Substances Data Bank; U.S. NIH – U.S. National Institutes of Health; NTP – National Toxicology Program; OEHHA – Office of Environmental Health Hazard Assessment; REL – Reference Exposure Levels; CEPA – Canadian Environmental Protection Act; U.S. CDC – U.S. Center for Disease Control; ATSDR – Agency for Toxic Substances and Disease Registry; NIOSH – National Institute for Occupational Safety and Health; U.S. EPA – U.S. Environmental Protection Agency; AEGL – Acute Exposure Guideline Levels; CDR-CDAT – Chemical Data Reporting-Chemical Data Access Tool; IRIS – Integrated Risk Information System; OPPT – Office of Pollution Prevention and Toxics; RfD/RfC – reference dose/reference concentration; CRAVE - Carcinogen Risk Assessment Verification Endeavor; TRI – Toxics Release Inventory Program; WSDE – Washington State Department of Ecology; WHO – World Health Organization; IARC – International Agency for Research on Cancer; IFCS – Intergovernmental Forum on Chemical Safety; IPCS – International Programme on Chemical Safety

2.2 Tier 2, Reviewing Secondary Sources

From screening the 47 websites for secondary literature sources identified in Tier 1, or reviews, factsheets, regulatory documents or risk assessments, a subset of 20 sources was selected that contained potentially relevant information pertaining to the six factors for the phthalates. In Tier 2, this subset of 20 sources was searched using key words for the six factors for each phthalate (see Table 2-3). Table 2-4 shows the six factors stratified by the subset of 20 relevant sources. Using information from the secondary sources, we drafted reports for each of the 11 phthalates to summarize available information on each of the six factors. Information or data that were lacking were identified as a "gap" and searching was conducted to fill that data or information gap performed in Tier 3. TERA considers the data reported as representative of the universe of information because there was duplicative or overlapping information between several of these sources, giving us confidence that we had found the relevant public information. The six factors used for search terms for Tier 2 for all 11 phthalates are as follows:

- Raw Materials, Synthesis
- Production
- Physical and Chemical Properties
- Applications
- Uses, Toys, Children's Products
- Migration, Recycling, Packaging

Table 2-3. Types of Information gathered from Tier 2 Sources for Six Factors

	Raw Materials	Manufacturing Process	Annual Production	Physical / Chemical Characteristics	Applications	Migration
ChemIDPlus				√		
Chem Sources Online		√				
CPSC			√		√	
EPA	√					
ECHA	√	√	√	√	√	
Haz-Map				√		
Health Canada			√			
HPD					√	
HSDB	√	√	√	√	√	√
IARC	√		√	√		
IFCS					√	
INCHEM				√	√	
IRIS		√	√	√	√	
NICNAS			√			
NTP		√	√	√	√	
OECD		√	√	√	√	
OEHHA			√	√	√	
PubChem		√	√	√		√
SPIN					√	
WSDE					√	

* CPSC – Consumer Product Safety Commission; EPA – U.S. Environmental Protection Agency; ECHA – European Chemicals Agency; HPD – Household Products Database; HSDB – Hazardous Substances Data Bank; IARC – International Agency for Research on Cancer; IFCS – Intergovernmental Forum on Chemical Safety; IRIS – Integrated Risk Information System; NICNAS – National Industrial Chemicals Notification and Assessment Scheme; NTP – National Toxicology Program; OECD – Organisation for Economic Cooperation and Development; SPIN – Substances in Products in Nordic Countries; WSDE – Washington State Department of Ecology

2.3 Tier 3, Gap Searching

The third tier involved gap-searching of the primary literature to locate required information not found in the approaches used in the first two tiers. As anticipated, the most significant gaps were information on worldwide production, annual production data for more recent years than 2005-2006, and concentrations of each of the specified phthalates in toys, childcare articles or other children’s products.

TERA performed gap searches for each phthalate to ascertain if the data were available. The gap search strategy consisted of first utilizing specific databases, based on type of data needed, followed by textbooks and reference books. The databases were searched using chemical names and CAS numbers, and further refined using relevant keywords (e.g., "migration"). The U.S. EPA's Chemical Data Access Tool (CDAT) provided information on recent national production volumes and the Chemical Abstract Service's SciFinder provided primary literature regarding possible phthalate migration into (or out of) children's toys and other products. TERA searched the National Library of Medicine PubMed database (http://www.ncbi.nlm.nih.gov/pubmed) and Scopus (www.scopus.com), SciFinder (www.scifinder.cas.org), and Web of Science (webofscience.com) for primary literature. The Scopus and Web of Science were searched for the time period of 2011 to May 2015. The keywords searched and resultant hits for each search string are found in Table 2-3. All hits for each search string were recorded, saved, and downloaded into a raw Endnote library. After an initial prescreen to remove duplicates, extraneous, and irrelevant studies, a second, more thorough screening was performed to determine relevancy and likelihood for a study to contain phthalate concentration data.

Textbooks and reference books, including Sax's Dangerous Properties of Industrial Materials and Patty's Industrial Hygiene and Toxicology, were consulted courtesy of the University of Cincinnati's Engineering Library.

After book resources were exhausted, TERA conducted Internet searches to fill any remaining data gaps, primarily through Google (www.google.com) and Google Scholar (www.scholar.google.com). Based on the phthalate and type of information still needed, searches were performed using CASRN, chemical names, and keywords. Results were reviewed until ten consecutive non-relevant hits were returned in the results list, at which point TERA ceased reviewing any further results.

TERA first screened the gap literature search results for relevance (removing those studies that obviously were not relevant to this research), and then reviewed the potentially relevant studies for the information lacking for the factors(s) for each phthalate. Relevant sources and primary studies to fill in gaps were screened, retrieved and evaluated for inclusion. Screening of the literature search focused on English language articles in accessible and reputable journals; literature in obscure journals, or in foreign language articles were not obtained for this report.

The gap searching performed to gain information on the 11 specified phthalates in children's products and keywords and search terms are shown in Table 2-4.

Table 2-4. Keywords and Topics Searched

Database & Search dates	Terms	Hits
Web of Science - 2011 to present	TOPIC: (phthalate*) AND TITLE: (child* OR infant* OR teen* or adolescent*)	178
Scopus – 2011 to present	(TITLE-ABS-KEY (*phthalate*)) AND (TITLE ((child* OR infant* OR teen* OR adolescent*)) AND (LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2013) OR LIMIT-TO (PUBYEAR , 2012) OR LIMIT-TO (PUBYEAR , 2011)	125
Both sets were put into EndNote for deduplication	Results	167
Scifinder – all dates	"84-69-5"" searched, refined with topic "migration"	129
	"84-69-5" searched, refined with topic "children, toys"	7
	"84-61-7"" searched, refined with topic "migration	69
	"84-61-7" searched, refined with topic "children, toys"	1
	"85-68-7" searched, refined with topic "migration"	58
	"85-68-7" searched, refined with topic "children, toys"	18
	"117-81-7" searched, refined with topic "migration, DEHP"	858
	"117-84-70" searched, refined with topic "migration"	115
	"84-74-2" searched, refined with topic "migration”	429
	"28553-12-0" searched, refined with topic "migration"	105
	"68515-48-0" searched	8
	"26761-40-0" searched, refined with topic "migration"	96
	"68515-49-1" searched	8
	"27554-26-3" searched, refined with topic "migration"	24
	"84-75-3" searched, refined with topic "migration"	49
	"84-75-3" searched, refined with topic "children, toys"	11
	"131-18-0" searched, refined with topic "migration"	42

Table 2-5. The Number of References used for each Phthalate

Phthalate	Number of References Used
DEHP, di-(2-ethylhexyl) phthalate, CASRN 117-81-7	47
DBP, dibutyl phthalate, CASRN 84-74-2	29
BBP, benzyl butyl phthalate, CASRN 85-68-7	38
DINP, diisononyl phthalate, CASRN 28553-12-0; 68515-48-0	57
DIDP, diisodecyl phthalate, CASRN 26761-40-0; 68515-49-1	17
DnOP, di-n-octyl phthalate, CASRN 117-84-0	29
DIOP, diisooctyl phthalate, CASRN 27554-26-3	21
DIBP, diisobutyl phthalate, CASRN 84-69-5	22
DPENP, di-n-pentyl phthalate, CASRN 131-18-0	12
DHEXP, di-n-hexyl phthalate, CASRN 84-75-3	16
DCHP, dicyclohexyl phthalate, CASRN 84-61-7	15

As we were preparing the revised draft, we discovered the Europeans Commissions database *"Rapid Alert System for dangerous non-food products (RAPEX)"* (RAPEX, 2015). This database has data dating from 2004; however, we report the last year available and the reader is encouraged to evaluate this database for more information. As an example, a search for the last five years excluding the originating country of China using only "Toys" and "Childcare articles and children's equipment", using the key word phthalate, only 59 items show up over the past five years (14 of unknown origin country). Looking at the originating country of China, there are 711 entries under the same search. Thus, since 2011–2015 there are 770 toys and child care articles and children's equipment entries in the RAPEX database that have been reported containing phthalates.

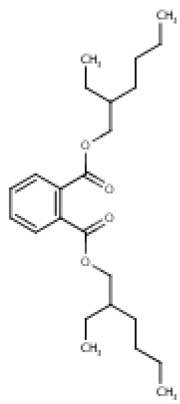
The factor with the most limited information was Factor 6: the potential to introduce any of the specified phthalates into an otherwise phthalate-free material, such as by migration from packaging, recycling, product breakdown or reuse. We found some data with evidence for migration of the some of the specified phthalates primarily from studies with food or with simulated saliva. Therefore, physical and chemical characteristics were used to as the basis for opinion as to the potential for phthalates to move between materials and provide some indirect support for this possibility.

We were not able to find any information as to the temperature at which each specified phthalate decomposes, changes, and loses its chemical identity. Information about incompatibilities between the phthalate and other chemicals were reported when available in the sources searched.

3 Di-(2-ethylhexyl) phthalate (DEHP) CASRN: 117-81-7

Di-(2-ethylhexyl) phthalate (DEHP) is included in the phthalate ester class referred to as dioctyl phthalates (DOP) and is used primarily as a plasticizer, a substance that increases flexibility of a material (ATSDR, 2002). Other phthalates in the dioctyl class include diisooctyl phthalate and di-n-octyl phthalate (ATSDR, 2002). DEHP can be considered a mid-molecular weight phthalate on the basis of the ester chain length (NICNAS, 2010); however, the U.S. EPA classified DEHP as a high molecular weight phthalate ester (U.S. EPA, 2010).

The structure of DEHP is as follows:



3.1 Raw Materials Used in Production of DEHP

DEHP is produced by esterification of 2-ethylhexanol and phthalic anhydride either with an acid or metal catalyst (such as sulfuric acid or para-toluenesulfonic acid) or at high temperature (HSDB, 2015; ATSDR, 2002; CPSC, 2010).

The following chemicals are used as raw materials in the production of DEHP:

- 2-ethylhexanol
- phthalic anhydride
- acid or metal catalyst: sulfuric acid, para-toluenesulfonic acid, or other

Synonyms and trade names for DEHP are shown in Table 3-1 below.

3.2 Chemical and Physical Properties of DEHP

DEHP is a long-chain branched phthalate that is a clear to colorless oily liquid at room temperature with slight to no odor (HSDB, 2015; CPSC, 2010). DEHP has very low water solubility but is soluble in hydrophobic compounds, oils, and solvents such as blood, fluids containing lipoproteins, gasoline, paint removers, and mineral oil (HSDB, 2015; ATSDR, 2002). DEHP is soluble in organic solvents such as hexane and carbon tetrachloride (HSDB, 2015). The true water solubility of DEHP is difficult to determine and has been suggested to range from 0.0006–0.40 mg/L depending on the method used (ATSDR, 2002).

DEHP was reported as semi-volatile based on a low vapor pressure (CPSC, 2010). No volatilization of DEHP is expected from moist or dry soil or from water surfaces based on the vapor pressure (HSDB, 2015).

DEHP is incompatible with nitrates, strong oxidizers, acids, and alkalis (HSDB, 2015). DEHP emits acrid smoke when decomposed through heating (HSDB, 2015); however, the temperature at which this occurs was not reported.

Table 3-1 summarizes the chemical and physical characteristics of DEHP (HSDB, 2015; ATSDR, 2002; CPSC, 2010; ECB, 2008). The data for several of these characteristics varies depending on the source.

Table 3-1 Physical/Chemical Characteristics of DEHP

Characteristic	Value	Reference
IUPAC Name	Bis(2-ethylhexyl) phthalate	ECB, 2008; CPSC, 2010
CASRN	117-81-7	HSDB, 2015; ATSDR, 2002; ECB, 2008; CPSC, 2010
EC Number	204-211-0	ECB, 2008
Synonyms and Trade Names	AI3-04273; BEHP; 1,2-benzenedicarboxylic acid, bis(ethylhexyl) ester; 1,2-benzenedicarboxylic acid, bis(2-ethylhexyl) ester; bis(2-ethylhexyl)-1,2-benzenedicarboxylate; Bis(2-ethylhexyl) o-phthalate; DEHP; Di(2-ethylhexyl) orthophthalate; Di-sec-octyl phthalate; Diethylhexyl phthalate;	HSDB, 2015

	ethylhexyl phthalate; 2-ethylhexyl phthalate; Octyl phthalate; phthalic acid, Bis(2-ethylhexyl) ester; Phthalic acid di(2-ethylhexyl) ester; Phthalic acid dioctyl ester U.S. EPA/OPP Pesticide Code 295200; Bisoflex dop; Celluflex dop; Compound 889; DAF 68; Diacizer DOP; Diplast; DOP; Essochem DOP; Eastman DOP Plasticizer; Ergoplast; Etalon Eviplast 80; Fleximel; Flexol dop; Genomoll 100; Good-rite GP 264; Hatco-DOP; Hercoflex 260; Jayflex; Kodaflex dop; Monocizer DOP; NCI-C52733; Octoil; Palatinol AH; Pittsburgh PX-138; Plasthall DOP; Platinol AH; Polycizer 162; PX-138; RC Plasticizer DOP; Reomol D 79P; Sicol 150; Staflex DOP; Truflex DOP; Union Carbide Flexol 380; Vestinol AH; Vinicizer 80; Witcizer 312	
Molecular Formula	$C_{24}H_{38}O_4$	HSDB, 2015; ATSDR, 2002; CPSC, 2010
Molecular Weight	390.56 g/mol	HSDB, 2015; ATSDR, 2002; CPSC, 2010
Physical description	Colorless to lightly colored oily liquid	HSDB, 2015; ATSDR, 2002; CPSC, 2010
Odor	Slight odor to odorless	HSDB, 2015; ATSDR, 2002
Solubility in water	2.70×10^{-1} mg/L at 25 °C 4.1×10^{-2} mg/L at 25 °C 3.0×10^{-3} mg/L at 20 °C 2.49×10^{-3} mg/L (temperature not specified)	HSDB, 2015; CPSC, 2010 ATSDR, 2002; CPSC, 2010 ECB, 2008; CPSC, 2010 CPSC, 2010
Octanol Water Partition	7.6	HSDB, 2015; CPSC, 2010

Coefficient (Log K_{ow})	7.5 7.73 9.64 4.2–8.39 5.11	ATSDR, 2002; ECB, 2008; CPSC, 2010 CPSC, 2010 CPSC, 2010 CPSC, 2010 HC, 1994
Boiling Point	384˚C (at 1013 hPa) 230˚C at 5 mm Hg	HSDB, 2015; ATSDR, 2002; ECB, 2008 ECB, 2008
Melting Point	-55˚C -50˚C -47˚C	HSDB, 2015; ECB, 2008 ECB, 2008 ATSDR, 2002
Vapor Pressure	1.42×10^{-7} mm Hg at 25˚C 1.0×10^{-7} mm Hg at 25˚C 3.4×10^{-5} Pa at 20˚C 2.52×10^{-5} Pa; 1.89×10^{-5} Pa; 1.33×10^{-5} Pa; 1.33×10^{-5} Pa at 25°C, 4.8×10^{-8} to 1.4×10^{-4} 8.3×10^{-6} – 8.6×10^{-4} Pa at 25°C	HSDB, 2015; CPSC, 2010 ATSDR, 2002; CPSC, 2010 ECB, 2008; CPSC, 2010 CPSC, 2010 HC, 1994
Flash Point	215˚C 196˚C 200˚C	HSDB, 2015 ATSDR, 2002; CPSC, 2010 ECB, 2008; CPSC, 2010

3.3 Worldwide Manufacturing Processes for DEHP

DEHP has been manufactured for over eight decades. Worldwide processes are likely similar as DEHP is manufactured through a relatively simple chemical synthesis process.

Commercial production of DEHP began in Japan in 1933 and in the U.S. in 1939 (IARC, 2012; NTP, 2014). The European Chemical Bureau (ECB, 2008) reports that all DEHP manufacturers use a similar manufacturing process. During DEHP production, phthalic anhydride is reacted with 2-ethylhexanol to form esters in two steps (ECB, 2008).

Three U.S. manufacturers of DEHP were identified from the Hazardous Substances Data Bank (HSDB, 2015). However, ATSDR (2002) reports five companies as the primary U.S. producers of DEHP. A third source reported that DEHP was produced by 23 companies in the U.S. (IARC, 2012). Two Canadian companies were identified as DEHP manufacturers (HC, 1994). From data in 2010, 19 producers were reported in Mexico, nine producers in China, four producers in the UK, three producers in Germany, two producers each in China, India, and Japan, and one each in Belgium, Bulgaria, Canada, the Czech Republic, France, South Africa, Switzerland, and the former state union of Serbia and Montenegro (IARC, 2012). However, this same source also reported production by five German companies, three in Austria and France, two in Belgium, and one in Finland, Spain, and Sweden (IARC, 2012). A Chem Sources Online search identified at least 23 U.S. manufacturers, 10 Chinese manufacturers, 9 Mexican manufacturers, 4 manufacturers in the United Kingdom, 3 in Germany, 2 each in Belgium, India, Japan, and Switzerland, and 1 each in Canada, the Czech Republic, France, South Africa, and Yugoslavia (Chem Sources Online, 2015).

3.4 Annual Production of DEHP

DEHP is widely manufactured and used throughout the world. In 1994, the global production volume of DEHP was estimated from 2,200,000,000 to 8,800,000,000 pounds (1–4,000,000 tonnes) per year (ECB, 2008; IARC, 2012). Health Canada (1994) reported worldwide production levels at 2,200 million pounds (1,000,000 tonnes). In 2006, the estimated global production volume was 2,205 to 8,818 million pounds per year (CPSC, 2010).

U.S. production peaked in 1976 at 397,000,000 pounds, was at its lowest in 1993 at 240,000,000 pounds, and remained fairly steady between 1976 and 1993 (NTP, 2014). From 1950-1954, DEHP production was greater than 230,000,000 pounds (IARC, 2012). U.S. production was reported in 1982 at roughly 251,067,000 pounds (HSDB, 2015). From 1986 through 2002, DEHP was considered by EPA as a High Production Volume (HPV) chemical and was categorized within a production range of 100 million–500 million pounds (HSDB, 2015). Chemicals are considered as having a HPV if production exceeds one million pounds annually in the U.S. In 2002, annual U.S. Production of DEHP was reported to range from roughly 265,000,000 to 4,000,000,000 pounds (CPSC, 2010). The U.S. EPA Chemical Data Access Tool (CDAT) reports that the 2012 national production volume was 152,694,720 lb/yr, and shows at least 15 companies listed as importing or manufacturing DEHP (U.S. EPA, 2015).

In 1991, DEHP production in Canada was roughly 11,000,000 pounds, down from 31,000,000 pounds in 1984 (HC, 1994).

In 2007, the EU manufactured 750,000,000 pounds, showing a decrease in production over time from roughly 1,300,000,000 pounds per year in 1997 (CPSC, 2010; ECHA, 2009; ECHA 2010). ECHA (2010) also estimated annual production at 460,000,000 pounds per year in the last 2 to 3 years (assuming from the year of the assessment publication, meaning 2007-2008). DINP and DIDP are expected to replace DEHP as a plasticizer given current concerns over wide-spread use of DEHP and possible toxicity (Fernandez et al., 2012).

In 1994-1995, German production was reported as 550,000,000 pounds (Fromme et al., 2004). In 1997, the production volume in Western Europe was reported as 1,300,000,000 pounds per year, compared to 490,000,000 pounds per year in 2004 (ECB, 2008; IARC, 2012). In 2006, the estimated annual production volume in Western Europe was 1,300,000,000 pounds per year (CPSC, 2010). The Danish EPA reported the EU production volume and import of DEHP at 460,000,000 pounds in 2009-2010, compared to 770,000,000 pounds in 2007, with an almost 60% reduction in use over the same time frame (Danish EPA, 2011).

In Nordic countries, 1,700,000 pounds of DEHP was used in 2012 (SPIN, 2015). Total DEHP use, however, has shown a downward trend since high usage in 2000 of 43,000,000 pounds. Overall, use has steeply declined in Sweden since 2000, and has remained slowly decreasing in use through 2012. In Finland, use has declined since 2003, and in Norway and Denmark since 2000 (SPIN, 2015). Production data are not reported in this database.

In 1993, the production volume of DEHP in Japan was 770,000,000 pounds (ECB, 2008; CPSC, 2010). In 1995, DEHP production was 660,000,000 pounds (IARC, 2012). In 1995, production in Taiwan and China was 460,000,000 pounds which showed a decrease in production from 1994 (IARC, 2012).

No production of DEHP was reported in Australia (NICNAS, 2010). There was no production information for DEHP in South America, Africa, or other countries in the literature searched for this report.

3.5 Application of DEHP in Materials, Consumer Products and Nonconsumer Products

DEHP is used as a general purpose plasticizer to impart flexibility in PVC, rubber, adhesives, PVA emulsion paints, and lacquers. As a plasticizer, it is used in a wide variety of consumer and nonconsumer products. The majority (95%) of manufactured DEHP is reported to be used as a polyvinyl chloride (PVC) plasticizer and the remaining manufactured DEHP has non-plasticizer uses (HSDB, 2015; ATSDR, 2002). In 2005, 30% of the use of DEHP as a plasticizer was attributed to use in consumer products (NTP, 2014). Plastics commonly contain concentrations of up to 40% DEHP by weight, and in some cases may contain more (HSDB, 2015; ECHA, 2009; NTP, 2014: RAPEX, 2015).

From 2000-2012, industrial uses of DEHP in Nordic countries include use in: adhesives, binding agents and sealants; aerosol propellants; cleaning/washing agents; coloring agents; construction materials (such as flooring, roofing, wires, cables); fillers; flame retardants and extinguishing agents; heat transferring agents; non-agricultural pesticides and preservatives; paints, lacquers, and varnishes; agricultural pesticides,; process regulators; reprographic agents; softeners; solvents; surface treatments; surface-active agents; and others (ECHA, 2010; SPIN, 2015). The volume of use in Denmark has steadily decreased from 2003 to 2012 (SPIN, 2015). Finland reported having no uses post-2007, Sweden having no uses post-2006, and other than one use identified for Norway in 2001, zero uses were reported for that country (SPIN, 2015).

3.5.1 Children's Products

DEHP was the most widely used plasticizer in children's products until voluntary standards were adopted and usage discontinuation began in the 1980s, when DEHP was replaced with DINP and other plasticizers (ATSDR, 2002; CPSC, 2010). CPSC (2010) has enacted a ban prohibiting the manufacture, distribution, and sale of children's toy and child care articles that contain more than 0.1% DEHP. In a report by CPSC, DEHP was not detected in pacifiers or nipples currently found on the market in 1998 (ATSDR, 2002). DEHP is used in children's toys and products including dolls and baby pants; however, it has been discontinued in products intended for mouthing, such as baby teethers and rattles (HSDB, 2015; ATSDR, 2002). Other children's products containing DEHP include squeeze toys, bath toys, mattresses, and bedding accessories (CPSC, 2010). A study analyzing plastic bags used by children (school bags, toy bags, and pencil cases) found DEHP concentrations above 1% (Danish EPA, 2011). In children's products, DEHP was reported at concentrations ranging from 11–42% (ATSDR, 2002). Other reports include one in the Netherlands that found 43% of plasticized PVC soft toys contained DEHP (ECHA, 2009). In a separate analysis spanning 17 countries, DEHP was found in trace amounts in a number of samples, but ranged from 10–35% in seven tested toys (ECHA, 2009). Other studies report that in 1998, tested children's products from the U.S., China, and Thailand contained DEHP; in pacifiers, concentrations ranged from 31.4–41.6% (ECHA, 2009). In Spain, DEHP was present in 40% of tested toys with concentrations ranging from <0.1–34% (ECHA, 2009). The maximum reported concentration in toys from Europe was 44%, while teethers contained a maximum of 22.4% (ECHA, 2009). In Canadian children's products, some concentrations were found as high as 23% DEHP, but the full range of concentrations was from <0.05–23% (HC, 1994). More recent data from the Europeans Commissions database *"Rapid Alert System for dangerous non-food products (RAPEX)"* (RAPEX, 2015) reports DEHP detected in 73 toys and children's products with concentrations of DEHP has high as 88% in one toy horse (see Table 3-2). This database has data dating from 2004; however, we report on the last year available and the reader is encouraged to evaluate this database for more information.

In a study by Bouma and Schakel (2002), DEHP was detected in a number of children's toys ranging from 3–44%. In a study of plasticized PVC toys, DEHP was detected in 20 of 68 samples at concentrations ranging from 0.2–38% (2,000–380,000 mg/kg) with a mean concentration of 16.2% (162,000 mg/kg) (Sugita et al., 2001, as cited in CSE, 2010). These same authors also reported detection of DEHP in 60% of domestic toys. In five children's toys containing PVC, DEHP was detected from 6.3%–45.3% (63,000–453,000 mg/kg), while no plasticizers were detected in toys intended for infant mouthing (Niino et al., 2001, as cited in CSE, 2010). DEHP was detected in four of 15 samples at concentrations from 0.037–29% (Rastogi et al., 2003). In a study conducted by the Center for Science and the Environment (CSE, 2010), DEHP was detected in 23 of 24 tested children's toys with 20 of the toys containing less than 0.1%, and three of the toys containing DEHP at 0.2–2.6%. In this study, DEHP was detected in one baby teether made from food-grade silicone rubber at 0.3%. The published version of this study included some additional details on DEHP concentrations in specific toy products (Johnson et al., 2011). In an additional study, DEHP was detected at high concentrations (~38%) in three of four tested toys, with only one toy having trace amounts (Ozer and Gucer, 2011). In 20 tested children's toys, DEHP was only detected in one, although at a concentration of 5.1% (51,000 ppm) (Schreder, 2007). In another study, children's toys were reported as having DEHP concentrations of 20–34%, depending on the analytical method used (Schulz et al., 2015). Simoneau and colleagues (2012) found DEHP concentrations less than 0.0001% (0.025–0.050 ppm) in baby bottles made of silicones. Another study testing phthalate concentrations in toys reported DEHP detected in 48% of sampled plasticized PVC toys (Stringer et al., 2000). Al-Natsheh et al. (2015) measured DEHP in PVC toys (n=13) from a Jordanian market and found concentrations of 0.50±0.09 to 29.60±0.50%. Uththamawadu et al., (2010) measured phthalate concentrations in various toys from a market in Sri Lanka and reported DEHP in 14 of 30 hard (or rigid) toys at concentrations ranging from 0.01–0.15%. Additional studies that have identified DEHP at a range of concentrations in children's toys and products are listed in Table 3-2.

The Washington State Department of Ecology (WSDE, 2015), under the 2008 Washington Children's Safe Product Act has been testing consumer products for toxic chemicals and receiving and posting data from manufacturers on children's products sold in Washington if their product contains a chemical of high concern to children, which includes phthalates.

Of the 239 products WSDE tested for DEHP, 93 products contained DEHP over the reporting limit, 23 of which were reported with DEHP greater than 0.1% (1000 ppm) (WSDE, 2015). The limit at which the laboratory can accurately quantify the analyte above a certain concentration is defines the reporting limit for this database; for DEHP the reporting limit is 20 ppm. These items are listed in Table 3-2. From the manufacturers' testing results, the State of Washington has received a list of 845 items that contained DEHP. Of these 845 items, 10 items were listed with DEHP concentrations greater than 1.0% (10,000 ppm), 2 items between 1.0–0.5% (10,000–5,000 ppm), 22 items between 0.5–0.1% (5,000–1,000 ppm), and the remaining 811 were less than 0.1%. The items with DEHP concentrations greater than 0.1% (1000 ppm) are listed in Table 3-2.

Table 3-2. DEHP Concentrations in Children's Products

Use	Product	DEHP Concentration	Reference
Toy	Plastic toy horses	13.8 and 88%	RAPEX, 2015
Toy	Toy samples (unspecified)	Median: 0.003% (25 ppm) Maximum: 69% (686,000 ppm)	Ionas et al., 2014
Toy	Plastic dolls	2.5–50%	RAPEX, 2015
Toy	Loom band charms	0.91–45%	RAPEX, 2015
Toy	Toys	44.0%	CPSC, 2010
Toy	Dolls	3–44%	Bouma and Schakel, 2002
Toy	Doll, doll parts	3–44%	IFCS, 2006
Toy	Inflatable furniture	37 and 41%	Bouma and Schakel, 2002
Toy	Toy 4 (unspecified)	37.9 ± 2.0%	Ozer and Gucer, 2011
Toy	Soft toy - frog	36–38%	RAPEX, 2015
Toy	Swimming tool	33–37%	IFCS, 2006; Bouma and Schakel, 2002
Toy	Fancy-dress accessory	36.9 %	RAPEX, 2015
Toy	Plastic toy - dolphin	36.5%	RAPEX, 2015
Toy	Toys bought in France	35.5%	Stringer et al., 2000
Toy	Toys or toy parts	0.008–35.5%	IFCS, 2006
Toy	Ball	34%	IFCS, 2006; Bouma and Schakel, 2002
Toy	Stethoscope	31% or 33.9 ± 8.4%,	Schulz et al., 2015
Toy	Toys- 2 (unspecified)	33.9 ± 1.4%	Ozer and Gucer, 2011
Toy	Swimming equipment	33%	Danish EPA, 2011
Toy	Water wing	33% (333,000 ppm)	ECHA, 2012
Toy	Plastic toy with sweets	31.4 %	RAPEX, 2015
Toy	Plastic pony sets- 2	25 and 29%	RAPEX, 2015
Toy	Swim ring	28% or 22.5 ± 1.2%,	Schulz et al., 2015
Toy	Toy 1 (unspecified)	27.8 ± 1.2%	Ozer and Gucer, 2011
Toy	Swimming pool	0.007–26% (66–258,000 ppm)	ECHA, 2012

Toy	Puppet	25.9% or 34.4 ± 2.9%,	Schulz et al., 2015
Toy	Toys bought in Belgium	0.05–25.7%	Stringer et al., 2000
Toy	Swimming aid	24.7% or 28.6 ± 1.5%, depending on method	Schulz et al., 2015
Toy	Key-ring with figurine	23 %	RAPEX, 2015
Toy	Soft toy dog	21.5 %	RAPEX, 2015
Toy	Plastic toy cubes	20.3 %	RAPEX, 2015
Toy	Swimming aid	20% or 27.2 ± 1.9%, depending on method	Schulz et al., 2015
Toy	Toys bought in Japan	15.4–19.1%	Stringer et al., 2000
Toy	Soft toy - pig	17 %	RAPEX, 2015
Toy	Play Jewels, Clear plastic pouch	16.8% (168,000 ppm)	WSDE, 2015
Toy	Turquoise teenage curtain, clear plastic pouch	16.8% (168,000 ppm)	WSDE, 2015
Toy	Toys bought in Philippines	0.003–16.7%	Stringer et al., 2000
Toy	Toy boxing set	16.5 %	RAPEX, 2015
Toy	Toys or toy parts	0.004–16%	IFCS, 2006
Toy	Soft Lion toy	14.8%	RAPEX, 2015
Toy	Toys bought in India	0.78–13.8%	Stringer et al., 2000
Toy	Plastic bath toy	13%	RAPEX, 2015
Toy	Clear plastic pouch	12.4% (124,000 ppm)	WSDE, 2015
Toy	Toys or toy parts	0.005–11.4%	IFCS, 2006
Toy	Plastic toy guns	11.1 %	RAPEX, 2015
Toy	3 Wiffle balls, flexible plastic bag	9.5% (95,300 ppm)	WSDE, 2015
Toy	Bath book, plastic pouch	6.4% (64,000 ppm)	WSDE, 2015
Toy	Toy gun set	6.1 %	RAPEX, 2015
Toy	Bow and arrow sets	4.7–5.5%	RAPEX, 2015
Toy	Snowman soft toy	5.3 %	RAPEX, 2015
Toy	Plastic strings	5.2 %	RAPEX, 2015

Toy	Doll	5.1% (51,000 ppm)	Schreder, 2007
Toy	Toy police set	3.6–5.1%	RAPEX, 2015
Toy	Plastic charms	3.2 %	RAPEX, 2015
Toy	Bath duck	2.6%	CSE, 2010
Toy	Inflatable-2	2.6%	Johnson et al., 2011
Toy	Plastic toy animals	2.5 %	RAPEX, 2015
Toy	Twistable crayons, Clear plastic pouch	2.4% (23,700 ppm)	WSDE, 2015
Toy	Toys bought in Denmark	1.62%	Stringer et al., 2000
Toy	Pink/purple polka dot bag, Pink/purple polka dot bag side fabric	1.5% (15,400 ppm)	WSDE, 2015
Toy	Toy bus	1.5 %	RAPEX, 2015
Toy	Toy 2 (unspecified)	0.76±0.02%	Yacob et al., 2013
Toy	Toy 3 (unspecified)	0.68±0.02%	Yacob et al., 2013
Toy	Toy 1 (unspecified)	0.65±0.02%	Yacob et al., 2013
Toy	Toy 4 (unspecified)	0.56±0.02%	Yacob et al., 2013
Toy	Bracelet and hairclip accessories set	0.5% (5,100 ppm)	PIRG, 2014
Toy	Remote-controlled toy robot	0.39 %	RAPEX, 2015
Toy	Toys bought in Canada	0.043–0.24%	Stringer et al., 2000
Toy	Bath duck	0.2%	Johnson et al., 2011
Toy	Glow in the dark plastic bugs, Clear plastic pouch	0.2% (2,020 ppm)	WSDE, 2015
Toy	Bath book, plastic page of book	0.2% (1,630 ppm)	WSDE, 2015
Toy	Inflatable bop bag dinosaur	0.2%	CSE, 2010
Toy	Toys bought in Netherlands	0.09–0.16%	Stringer et al., 2000
Toy	Animal Figurine	0.1%	Johnson et al., 2011
Toy	Bath Fish	0.1%	Johnson et al., 2011
Toy	Swim wing	0.1% (1,310 ppm)	IFCS, 2006
Toy	12 Roll-on lip glosses, flexible plastic	0.1% (1,030 ppm)	WSDE, 2015

Toy	18 of 24 toys tested	<0.1%	Johnson et al., 2011
Toy	Toys bought in Argentina	0.006–0.1%	Stringer et al., 2000
Toy	Toy 5 (unspecified)	0.09±0.02%	Yacob et al., 2013
Toy	Finger paints	0.005–<0.06%	HSDB, 2015
Toy	Toy 3 (unspecified)	0.051 ± 0.004%	Ozer and Gucer, 2011
Toy	Toys bought in Canada	0.042%	Stringer et al., 2000
Toy	Modeling material	0.04% (364 ppm)	IFCS, 2006
Toy	Toys bought in Indonesia	0.03%	Stringer et al., 2000
Toy	Baby book	0.03% (280 ppm)	IFCS, 2006
Toy	Toys bought in Germany	0.02%	Stringer et al., 2000
Toy	Toys bought in UK	0.01%	Stringer et al., 2000
Toy	Snail	0.006% (57 ppm)	IFCS, 2006
Toy	Doll	0.002% (24 ppm)	IFCS, 2006
Toy	Doll	Not detected	Johnson et al., 2011
Toy and Child care articles	PVC toys and childcare articles	0.50±0.09–29.60±0.50%	Al-Natsheh et al., 2015
Toys and child care articles	Bathing ring	28.976%	Rastogi et al., 2003
Toys and child care articles	Soft lining material	14.800%	Rastogi et al., 2003
Toys and child care articles	Soft lining material	0.189%	Rastogi et al., 2003
Toys and child care articles	Keys 0 and 1 of the keyboard	0.0365%	Rastogi et al., 2003
Toys and Child care articles	Non-PVC plasticized toys and child care articles	0.02±0.01%	Al-Natsheh et al., 2015
Child care articles	Teethers	22.4%	CPSC, 2010
Child care articles	Teethers, pacifier	0.005–0.34%	IFCS, 2006
Child care article	Teether-2	0.3%	Johnson et al., 2011
Child care articles	Baby teether	0.3%	CSE, 2010
Child care	Teethers	0.2–0.26%	IFCS, 2006

articles			
Child care articles	Disposable diapers	0.007% (74.1 ppm)	CPSC, 2010
Child care article	Teether bought in U.S.	0.06%	Stringer et al., 2000
Child care articles	Silicone baby bottles	0.003–0.005% (25–50 µg/kg)	Simoneau et al., 2012
Child care articles	Cool animal teether	0.01% (100 ppm)	IFCS, 2006
Children's clothing	Plastic sandals ("realistic case"), 2 year old	0.001–34% (11–344,500 ppm)	ECHA, 2012
Children's clothing	Plastic sandals ("realistic case"), 6-7 year old	0.001–34% (10–335,000 ppm)	ECHA, 2012
Children's clothing	General	17%	ECHA, 2010
Children's clothing	Mitten labels	14.7%	ECHA, 2010
Children's clothing	Undies, Clear plastic bag	8.5% (84,800 ppm)	WSDE, 2015
Children's clothing	Apron	7%	Bouma and Schakel, 2002
Children's clothing	Body stockings	1.8%	ECHA, 2010
Children's clothing	Printing on shirts	1.1%	ECHA, 2010
Children's product	Toy manufacturing paints	2.01–46.16%	HSDB, 2015
Children's product	Pencil Erasers	17–44% (170,000–440,000 PPM)	Danish EPA, 2011; ECHA, 2012
Children's product	Can (coated fabric)	34%	Bouma and Schakel, 2002
Children's product	Pencil case	20% (204,000 ppm)	IFCS, 2006
Children's product	Peanut butter tennis balls, Clear plastic pouch	20% (202,000 ppm)	WSDE, 2015
Children's product	Decorative plastic panel on a backpack	20% (200,000 ppm)	PIRG, 2014

Children's product	Backpack	15% (150,000 ppm)	PIRG, 2010
Children's product	Pencil Case	15% (150,000 ppm)	PIRG, 2013
Children's product	Pencil Case	14%	ECHA, 2010

*Concentrations < 0.1% are shaded.

3.5.2 Other Products

DEHP use includes industrial applications such as insulating fluid in electrical transformers, hydraulic fluid, dielectric fluid, industrial tubing and conduits, defoaming agents in manufacturing paper, lacquers, adhesives, munitions, paints, wire and cable, and lubricating oils (HSDB, 2015). Household uses include floor tiles, various furnishings, decorative inks, wall coverings, and food packaging materials (HSDB, 2015; ATSDR, 2002). Medical and personal care products that contain DEHP include medical tubing, catheters and blood containers, dental materials, coatings for drugs, surgical gloves, vehicles for perfumes in cosmetic products, insect repellants, and rubbing alcohol (HSDB, 2015). It has been suggested that the highest exposures to DEHP comes from diffusion from medical products (Corea-Tellaz et al., 2008), while others suggest that the highest exposure is through food products because medical exposure is likely to be acute in nature (Erythropel et al., 2014). Other consumer products containing DEHP include imitation leather, rainwear, footwear, upholstery, tablecloths, garden hoses, pool liners, liquid soap, detergents, and shower curtains (HSDB, 2015; ATSDR, 2002). There are also a number of uses in laboratory equipment and plastics, and DEHP has been reported as a common laboratory contaminant (HSDB, 2015; ATSDR, 2002). Linde and Gedde (2014) looked at DEHP concentrations in PVC cable insulation. Other scientists have reported DEHP concentrations of 22.1 – 41.0% in different PVC gloves used to handle food products (Tsumura et al., 2001).

DEHP has been detected in bottled water, but it is not clear if the DEHP in the water comes from the container itself, from previous contamination of the water, or possibly even contamination from the laboratory materials (Erythropel et al., 2014).

Table 3-3 Consumer Products that contain DEHP

Category	**Use**	**DEHP Concentration**		**Reference**
Personal Care	Nail polish	0.003% (25.1 ppm)		CPSC, 2010
Personal Care	Shower and bath gel; shower and bath gel stored for 6 months	0.02–0.40%; 0.068–0.74%		Amberg-Muller et al., 2010

Category	Use	DEHP Concentration		Reference
Personal Care	Perfumes, deodorants, hair products	0.001–0.01% (18.3–130 ppm)		CPSC, 2010
Clothing, Footwear	Sandals, flip-flops, thermo boots	Up to 23.2%, 46%, 20–35%,		Danish EPA, 2011; ECHA, 2010
Clothing	Loose reflector pieces on jackets	21.3%		ECHA, 2010
Clothing, Footwear	Rubber clogs	1.6%		ECHA, 2010
Consumer Products	Sex toy	0.07–70.2% (730–702,000 ppm)		WSDE, 2015
Consumer Products	Balance ball	0.05–43.9% (462–439,000 ppm)		ECHA, 2012
Consumer Products	Gloves	42% (420,000 ppm)		CPSC, 2010
Consumer Products	PVC gloves	22.1–41.0%		Tsumura et al., 2001
Consumer Products	Air mattresses	8.2–30.4%		Danish EPA, 2011
Consumer Products	Shower curtains	6.7–30%; 0.002–30% (15.3–296,000 ppm)		Danish EPA, 2011; ECHA, 2013
Consumer Products	Shower and bath gel packaging	<1 – 23%		Amberg-Muller et al., 2010
Consumer Products	White sleep mask, Clear plastic pouch	19.6% (196,000 ppm)		WSDE, 2015
Consumer Products	Textile	19.56%		HSDB, 2015

Category	**Use**	**DEHP Concentration**		**Reference**
Consumer Products	Waterproof pouches, Clear plastic packaging pouch	16.6% (166,000 ppm)		WSDE, 2015
Consumer Products	Pillow protector, Clear plastic pouch	7.5–15% (75,400 ppm, 150,000 ppm)		WSDE, 2015
Consumer Products	Khaki curtain, Clear plastic pouch	14% (139,000 ppm)		WSDE, 2015
Consumer Products	Tablecloths	14%		Danish EPA, 2011
Consumer Products	Makeup brush, eyeshadow brush, Clear plastic pouch	12.5–13.6% (125,000–136,000 ppm)		WSDE, 2015
Consumer Products	PVC containing soap packaging	8%		ECHA, 2010
Consumer Products	Eyebrow razors, 2, plastic pouch	1.4% (13,900 ppm)		WSDE, 2015
Consumer Products	PVC-coated wall paper	0.1% (940 ppm)		CPSC, 2010
Consumer Products	Training ball	<0.001% (9.2 ppm)		ECHA, 2012
Home Maintenance	Paint roller	5.5% (55,000 ppm)		WSDE, 2015
Home Maintenance	Wall coverings and flooring materials – heterogeneous PVC	3.0%		Danish EPA, 2011
Home Maintenance	Adhesives, glues, and sealing compounds	1.8% (18,200 ppm)		CPSC, 2010

Category	Use	DEHP Concentration		Reference
Home Maintenance	Wall coverings and flooring materials – semi-flexible PVC	1.54%		Danish EPA, 2011
Home Maintenance	Wall coverings and flooring materials – cushioned PVC	1.36%		Danish EPA, 2011
Home Maintenance	Wall coverings and flooring materials – homogeneous PVC	0.57%		Danish EPA, 2011
Home Maintenance	PVC flooring	≤33.0%		Danish EPA, 2011
Building materials	PVC cable insulation - unexposed jacketing	4.6 ± 0.1		Linde and Gedde, 2014
Other	Oilcloths	0.006–25% (5.7–254,000 ppm)		Danish EPA, 2011; ECHA, 2012
Other	Bags	12–21%		Danish EPA, 2011; ECHA, 2012

*Concentrations < 0.1% are shaded.

3.6 Routes of Introduction of DEHP into Phthalate-Free Material

DEHP is not covalently bound to the actual polymer and may slowly migrate out of the product over time, especially when exposed to heat or certain materials or after environmental weathering (ECB, 2008; CPSC, 2010). Products containing DEHP are expected to age over time and lose DEHP; as such, concentrations are expected to be higher in the new product compared to an older product (ATSDR, 2002). A number of factors were identified that contribute to the breakdown of PVC and lead to the release of DEHP, including: presence of dust and other airborne particles in the air for DEHP to adsorb to; physical contact with materials that can adsorb DEHP; chemical reactions, such as microbial degradation that can hydrolyze 2-ethylhexanol from DEHP; pH changes, particularly for DEHP migration to water; and gamma irradiation (Ekelund et al., 2010). Specifically, plasticizer migration from PVC products can occur via volatilization into the air, extraction into a liquid, migration into a solid, or exudation, and will depend on the type of polymer, concentration of DEHP, homogeneity of the product, and test conditions (Marcilla et al., 2008). Diffusion coefficients for PVC and polystyrene (PS) were calculated for DEHP in Marcilla et al. (2008), who found that within plasticizer families diffusion was heavily dependent upon compound molecular weight, with lower molecular weight compounds having higher diffusion rates.

ECB (2008) lists toys and child care articles, building materials and home furnishings, clothing, gloves, and footwear, medical devices, and food contact materials as product groups with expected consumer exposure to DEHP, meaning DEHP is expected to migrate out of these products. The migration rate for DEHP was reported in the range of equal to or less than 0.1–1% per year (Danish EPA, 2014).

Migration of DEHP into saliva and sweat has been investigated through multiple extraction methods (CPSC, 2010; ECHA, 2012). Many studies have shown evidence of DEHP migrating from plastics to artificial saliva (i.e., Al-Natsheh et al., 2015; Bouma and Schakel, 2002). In a study comparing methods for testing the migration of DEHP from toys into saliva, the authors noted a trend in DEHP release with increasing DEHP concentration (Ozer and Gucer, 2011). These authors suggest that DEHP migration also depends on agitation methods as well as physical properties of each product (Ozer and Gucer, 2011). ECHA (2012) reported DEHP migration rates from sandals, bags, shower curtains, oilcloths, pool accessories, workout equipment, and other materials into artificial sweat. Mechanical chewing of products coupled with fresh saliva when DEHP containing items are placed in the mouth is suggested as an effective extraction procedure for DEHP (ECB, 2008). The rate of DEHP migration is difficult to estimate given that it can be impacted by the solubility of DEHP in the polymer as well as in saliva, mouthing frequency, temperature, strength of the DEHP bond to the polymer, and physical properties of the polymer (ECB, 2008; CPSC, 2010).

DEHP has been shown to migrate from plastic medical products (such as blood bags and plastic tubing) into blood products (such as whole blood, platelet concentrates, red cell concentrates, plasma) and intravenous fluids (such as saline and glucose) (ATSDR, 2002). DEHP exposure from medical products occurs through migration into lipid containing fluids and depends on lipophilicity of the fluid and the plastic, duration of storage, and temperature (ECB, 2008).

There is a large body of literature on DEHP contamination of food packaging and subsequent leaching of DEHP into food products; particularly foods with high lipid content (Erythropel et al., 2014). DEHP has also been shown to migrate from plastic food packaging into food products, juice, and water (Bang et al., 2012). DEHP concentrations in water stored in PET bottles was reported in trace amounts (ranging from <0.002–1.254 μg/L) (Jeddi et al., 2015). In a study looking at storage conditions of PET water bottles and the concentration of DEHP over time, the highest migration value was found at the highest temperature (40˚C), and suggested that little migration is expected to occur at lower temperatures (refrigerator and freezing conditions) as compared to higher temperatures (greater than 25˚C) (Jeddi et al., 2015). Other studies have shown DEHP to migrate from PVC into dry materials (ATSDR, 2002). Tsumura et al. (2001) reported that DEHP migrated from PVC gloves into packed lunches and served lunches, which explained the increased DEHP concentrations between uncooked and cooked/packed food products. Other studies have shown DEHP to migrate from PVC into dry materials (ATSDR, 2002). Analysis of paper packaging identified concentrations of DEHP ranging from 0.19-5.1 ppm (reported as mg/kg) in 14 of 20 samples (Pocas, 2010); from 12.5-21.0 ppm (reported as mg/kg) (Summerfield and Cooper, 2001 as cited by Cao, 2010), various paper towels.

When looking at DEHP migration from wire cables, it was found that the plasticizer first had to diffuse to the boundary edge of the product, and then had to migrate from the product into outside media (Linde and Gedde, 2014). It has been found that DEHP evaporation rate then controlled this migration and that this rate is constant above 10% DEHP concentrations, suggesting that DEHP forms a film or 'pool' on the material surface (Linde and Gedde, 2014).

DEHP can be emitted into the atmosphere from indoor products such as flooring and upholstery under normal indoor conditions (ECB, 2008). DEHP volatilization as either an aerosol or particulate can occur, and depends on the air flow in the room, the surface area of the product, and product use pattern (ECB, 2008). However, DEHP volatilizes at a low rate (ECB, 2008; CPSC, 2010). An emission rate half-life was estimated from end-use products at 69 years (meaning half the DEHP is released after 69 years) (ECB, 2008). In a study looking at the concentration of phthalates in indoor air and dust, DEHP was detected in household and kindergarten air, in household dust and rooms with new PVC flooring, depending on multiple factors, including indoor DEHP use (Fromme et al., 2004; Fernandez et al., 2012). The body of literature on phthalate concentrations in air and dust was not researched for this report.

3.7 References

Al-Natsheh, M., Alawi, M., Fayyad, M., Tarawneh, I. 2015. Simultaneous GC–MS determination of eight phthalates in total and migrated portions of plasticized polymeric toys and childcare articles. J Chromat B. 985, 103-109.

Amberg-Muller, J.P., Hauri, U., Schlegel, U., Hohl, C., Brüschweiler, B.J. 2010. Migration of phthalates from soft PVC packaging into shower and bath gels and assessment. J Verbr Lebensm. 5, 429-442.

ATSDR (Agency for Toxic Substances and Disease Registry). 2002. Toxicological Profile for Di (2-Ethylhexyl) Phthalate. U.S. Department of Health and Human Services. Public Health Service. Agency for Toxic Substances and Disease Registry. Available at: http://www.atsdr.cdc.gov/toxprofiles/tp9.pdf.

Bang, D.Y., Kyung, M., Kim, M.J., Jung, B.Y., Cho, M.C., Choi, S.M., Kim, Y.W., Lim, S.K., Lim, D.S., Won, A.J., Kwack, S.J., Lee, Y., Kim, H.S., Lee, B.M. 2012. Human risk assessment of endocrine-disrupting chemicals derived from plastic food containers. Compr Rev Food Sci Food Safety. 11, 453-470.

Bouma, K., Schakel, D.J. 2002. Migration of phthalates from PVC toys into saliva simulant by dynamic extraction. Food Addit Contam. 19(6), 602-610.

Cao, X-L. 2010. Phthalate esters in foods: sources, occurrence, and analytical methods. Compr Rev Food Sci F. 9, 21-43.

Chem Sources Online. 2015. Chem Sources Online database. Chem Sources International, Inc. Available at: http://www.Chemsources.com/chemonline.html.

Corea-Tellaz, K.S., Bustamante-Montes, P., Garcia-Fabila, M., Hernandez-Valero, M.A., Vazquez-Moreno, F. 2008. Estimated risks of water and saliva contamination by phthalate diffusion from plasticized polyvinyl chloride. Int Perspect. 71, 34-40.

CPSC (U.S. Consumer Product Safety Commission). 2010. Review of Exposure Data and Assessments for Selected Dialkyl Ortho-Phthalates. Consumer Product Safety Commission, CPSC-D-06-0006, Bethesda, MD.

CSE (Center for Science and Environment). 2010. Phthalates in Toys. CSE/PML/PR-36/2010. Center for Science and Environment. Available at: http://www.cseindia.org/userfiles/cselab_report_toxictoys.pdf.

Danish EPA (Danish Environmental Protection Agency). 2011. Annex XV Restriction Report: Proposal for a Restriction. Bis(2-Ethylhexyl) Phthalate (DEHP), Benzyl Butyl Phthalate (BBP), Dibutyl Phthalate (DBP), Diisobutyl Phthalate (DIBP). Danish Environmental Protection Agency, Copenhagen, Denmark. Available at: http://echa.europa.eu/documents/10162/c6781e1e-1128-45c2-bf48-8890876fa719.

Danish EPA (Danish Environmental Protection Agency). 2014. Hazardous substances in plastics. Survey of chemical substances in consumer products No. 132, 2014. Danish Environmental Protection Agency, Copenhagen K, Denmark. Available at: http://www2.mst.dk/Udgiv/publications/2014/12/978-87-93283-31-2.pdf.

ECB (European Chemicals Bureau). 2008. European Union Risk Assessment Report. Bis(2-ethylhexyl) Phthalate (DEHP). Volume 80. Institute for Health and Consumer Protection. European Chemicals Bureau. Available at: http://echa.europa.eu/documents/10162/e614617d-58e7-42d9-b7fb-d7bab8f26feb.

ECHA (European Chemicals Agency). 2009. Background document for bis (2-ethylhexyl) phthalate (DEHP). European Chemicals Agency. Available at: http://www.qsartoolbox.org/documents/10162/a2559f79-51cb-4004-bde1-0bf93bb5f2aa.

ECHA (European Chemicals Agency). 2010. Evaluation of scientific evidence concerning the restrictions contained in Annex XVII to Regulation (EC). Review of new available information for Bis (2-Ethylhexyl) Phthalate (DEHP). European Chemicals Agency. Available at: https://echa.europa.eu/documents/10162/13641/dehp_echa_review_report_2010_6_en.pdf.

ECHA (European Chemicals Agency). 2012. Background document to the Opinion on the Annex XV dossier proposing restrictions on four phthalates. Committee for Risk Assessment (RAC). Committee for Socio-economic Analysis (SEAC). European Chemicals Agency. Available at: http://www.echa.europa.eu/documents/10162/3bc5088a-a231-498e-86e6-8451884c6a4f.

Ekelund, M., Azhdar, B., Gedde, U.W. 2010. Evaporative loss kinetics of di(2-ethylhexyl)phthalate (DEHP) from pristine DEHP and plasticized PVC. Polymer Degrad Stabil. 95, 1789-1793.

Erythropel, H.C., Maric, M., Nicell, J.A., Leask, R.L., Yargeau, V. 2014. Leaching of the plasticizer di(2-ethylhexyl)phthalate (DEHP) from plastic containers and the question of human exposure. Appl Microbiol Biotechnol. 98, 9967-9981.

Fernandez, M.A., Gomara, B., Gonzalez, M.J. 2012. Occurrence of phthalates and their metabolites in the environment and human health implications. Emerg Organ Contam Human Health. 20, 307-336.

Fromme, H., Lahrz, T., Piloty, M., Gebhart, H., Oddoy, A., Ruden, H. 2004. Occurrence of phthalates and musk fragrances in indoor air and dust from apartments and kindergartens in Berlin (Germany). Indoor Air. 14, 188-195.

Health Canada, 1994. Bis(2-ethylhexyl) Phthalate. Priority Substances List Assessment Report. Canadian Environmental Protection Act. Health Canada.

HSDB (Hazardous Substances Data Bank). 2015. Hazardous Substances Data Bank online database, Toxnet Toxicology Data Network, U.S. National Library of Medicine. Available at: http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB.

IARC (International Agency for Research on Cancer). 2012. Di(2-Ethylhexyl) Phthalate. IARC Monograph 101, pp. 149-284. Available at: http://monographs.iarc.fr/ENG/Monographs/vol101/mono101-006.pdf.

IFCS (Intergovernmental Forum on Chemical Safety), 2006. Toys and Chemical Safety: A Thought Starter. Intergovernmental Forum on Chemical Safety. IFCS/Forum-V/03-TS, Budapest, Hungary. Available at: http://www.who.int/ifcs/documents/forums/forum5/03_ts_en.pdf.

Ionas, A.C., Dirtu, A.C., Anthonissen, T., Neels, H., Covaci, A. 2014. Downsides of the recycling process: Harmful organic chemicals in children's toys. Environ Int. 65, 54-62.

Jeddi, M.Z., Rastkari, N., Ahmadkhaniha, R., Yunesian, M. 2015. Concentrations of phthalates in bottled water under common storage conditions: Do they pose a health risk to children? Food Res Int. 69, 256-265.

Johnson, S., Saikia, N., Sahu, R. 2011. Phthalates in toys available in Indian market. Bull Environ Contam Toxicol. 86, 621-626.

Linde, E., Gedde, U.W. 2014. Plasticizer migration from PVC cable insulation – The challenges of extrapolation methods. Polymer Degrad Stabil. 101, 24-31.

Marcilla, A., Garcia, S., Garcia-Quesada, J.C. 2008. Migrability of PVC plasticizers. Polymer Testing. 27, 221-233.

NICNAS (National Industrial Chemicals Notification and Assessment Scheme). 2010. Diethylhexyl Phthalate. Priority Existing Chemical Assessment Report. Department of Health and Ageing. National Industrial Chemicals Notification and Assessment Scheme. Available at: http://www.nicnas.gov.au/__data/assets/word_doc/0003/5088/DEHP-PEC-Report-FINAL-accessible-version-Mar2014.doc.

Niino, T., Ishibashi, T., Itho, T., Sakai, S., Sugita, T., Ishiwata, H., Yamada, T., Onodera, S., 2001. Analysis of phthalate ester plasticizers in polyvinyl chloride children's toys, after 1998. Jpn. J. Food Chem. 8.

NTP (National Toxicology Program). 2014. Di(2-ethylhexyl) Phthalate. Report on Carcinogens, Thirteenth Edition. Department of Human and Health Services, National Toxicology Program. Available at: http://ntp.niehs.nih.gov/ntp/roc/content/profiles/diethylhexylphthalate.pdf.

Ozer, E.T., Gucer, S. 2011. Determination of some phthalate acid esters in artificial saliva by gas chromatography–mass spectrometry after activated carbon enrichment. Talanta. 84, 362-367.

PIRG (U.S. Public Interest Research Groups). 2010. Trouble in Toyland. The 25th Annual Survey of Toy Safety. U.S. PIRG Education Fund. U.S. Public Interest Research Group.

PIRG (U.S. Public Interest Research Groups). 2013. Trouble in Toyland. The 28th Annual Survey of Toy Safety. U.S. PIRG Education Fund. U.S. Public Interest Research Group.

PIRG (U.S. Public Interest Research Groups). 2014. Trouble in Toyland. The 29th Annual Survey of Toy Safety. U.S. PIRG Education Fund. U.S. Public Interest Research Group.

Pocas, M.F., Oliveira, J.C., Pereira, J.R., Hogg, T. 2010. Consumer exposure to phthalates from paper packaging: an integrated approach. Food Addit Contam. 27(10), 1451-1459.

PubChem, 2015. The Pubchem online database. National Library of Medicine. Available at: https://pubchem.ncbi.nlm.nih.gov/.

Rastogi, S.C., Jensen, G.H., Worsoe, I.M. 2003. Compliance testing of phthalates in toys. NERI Research Notes No. 185. National Environmental Research Institute. Ministry of the Environment. Available at: http://www2.dmu.dk/1_viden/2_Publikationer/3_arbrapporter/rapporter/AR185.pdf.

RAPEX. 2015. Rapid Alert System for dangerous non-food products. Latest Reports Online database. European Commission. Available at: http://ec.europa.eu/consumers/safety/rapex/alerts/main/index.cfm?event=main.listNotifications.

Schreder, E. 2007. Not So Squeaky Clean. A Study of Phthalates in Toys. Washington Toxics Coalition. Available at: http://www.watoxics.org/files/Phthalates_Report.pdf.

Schulz, S., Wagner, S., Gerbig, S., Wachter, H., Sielaff, D., Bohn, D., Spengler, B. 2015. DESI MS based screening method for phthalates in consumer goods. Analyst. 140, 3484-3491.

Simoneau, C., Van den Eede, L., Valzacchi, S. 2012. Identification and quantification of the migration of chemicals from plastic baby bottles used as substitutes for polycarbonate. Food Addit Contam. Part A. Chem Anal Control Expo Risk Assess. 29, 469-480.

SPIN (Substances in Preparation in Nordic Countries). 2015. SPIN Database. Danish Environmental Protection Agency. Available at: http://195.215.202.233/DotNetNuke/default.aspx.

Stringer, R., Labunska, I., Santillo, D., Johnston, P., Siddorn, J., Stephenson, A. 2000. Concentrations of phthalate esters and identification of other additives in PVC children's toys. Environ Sci Pollut Res. 7, 1-10.

Sugita, T., Hirayama, K., Nino, R., Ishibashi, T., Yamada, T. 2001. Contents of phthalate in polyvinyl chloride toys. Shokuhin Eiseigaku Zasshi. 42, 48-55. (As cited in CSE, 2010).

Summerfield, W., Cooper, I. 2001. Investigation of migration from paper and board into food-development of methods for rapid testing. Food Addit Contam. 18(1), 77-88.

Tsumura, Y., Ishimitsu, S., Kaihara, A., Yoshii, K., Nakamura, Y., Tonogai, Y. 2001. Di(2-ethylhexyl) phthalate contamination of retail packed lunches caused by PVC gloves used in the preparation of foods. Food Addit Contam. 18, 569-579.

U.S. EPA (U.S. Environmental Protection Agency). 2010. Screening-Level Hazard Characterization. Phthalate Esters Category. Hazard Characterization Document. U.S. Environmental Protection Agency.

U.S. EPA (U.S. Environmental Protection Agency), 2015. Chemical Safety and Pollution Prevention: Pollution Prevention and Toxics. Vol. 2014. Chemical Data Access Tool (CDAT). Available at: http://java.epa.gov/oppt_chemical_search/.

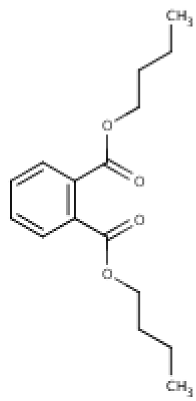
Uththamawadu, D. P., Wijesekera, R. D., Rajasingham, S. L. 2010. A study of human exposure to selected phthalates in toys in Sri Lanka. Department of Chemistry, University of Colombo, Vauxhall St., Colombo. Available at: http://www.cmb.ac.lk/wp-content/uploads/2014/02/A-STUDY-OF-HUMAN-EXPOSURE-TO-SELECTED-PHTHALATES-IN-TOYS-IN-SRI-LANKA.pdf.

WSDE (Washington State Department of Ecology ECY). (2015). "Children's Safe Product Act Reported Data." Available at: https://fortress.wa.gov/ecy/cspareporting/.Yacob, A.R., Ayub, A.M., Said, N.B. 2013. Detection and characterization of children's soft toy for phthalate esters. Ind J Foren Med Toxicol. 7, 210-214.

4 Dibutyl phthalate (DBP) CASRN: 84-74-2

Di-n-butyl phthalate (DBP) is a low molecular weight phthalate ester typically added to hard plastics to make them flexible and soft (HSDB, 2015). DBP is used primarily as a plasticizer in polyvinyl chloride and polyvinyl acetate plastics and in nitrocellulose films and lacquers. DBP has many uses including as a solvent, antifoam agent, and plasticizer to make many consumer and nonconsumer products. It is also used in paints, glues, insect repellents, hair spray, nail polish, and as a solvent for perfume oils and perfume fixatives (ATSDR, 2001; NICNAS, 2013). DBP does not occur in nature but is an ubiquitous environmental contaminate present in the food, air, water and soil at low levels (ATSDR, 2001; IPCS, 1997). Daily intakes for the general population are estimated to be between 2-5 ppb, and these levels are considered to be low (ATSDR, 2001).

The structure of DBP (HSDB, 2015) is as follows:



4.1 Raw Materials used in Production of DBP

DBP is manufactured by esterification of n-butyl alcohol with phthalic anhydride in the presence of a catalyst such as sulfuric acid or p-toluene sulfonic acid (ATSDR, 2001). DBP can also be made from phthalic anhydride and butyl halide in the presence a tertiary aliphatic amine (HSDB, 2015).

Depending on which synthesis process is used, the following are used as raw materials in the production of DBP (HSDB, 2015; ATSDR, 2001):

- n-butyl alcohol
- phthalic anhydride
- tertiary aliphatic amines
- catalyst: sulfuric acid or p-toluene sulfonic acid

- butyl halide
- tertiary aliphatic amine

Synonyms and trade names for DBP are shown in Table 4-1.

4.2 Chemical and Physical Properties of DBP

DBP is a colorless or faint yellow, oily liquid with a slight aromatic odor and a low vapor pressure. It is soluble in most organic solvents, but only slightly soluble in water (ATSDR, 2001; IPCS, 1997). DBP is considered a high molecular weight phthalate. Table 4-1 summarizes the physical and chemical characteristics of DBP.

Table 4-1. Physical/Chemical Characteristics of DBP

Characteristic	Value	Reference
IUPAC Name	dibutyl benzene-1,2-dicarboxylate	PubChem, 2015
CASRN	84-74-2	PubChem, 2015
EC Number	201-577-4	PubChem, 2015
Synonyms and Trade Names	1,2-Benzenedicarboxylic acid, dibutyl ester; 4-09-00-03175 (Beilstein Handbook Reference); AI-3-00283; Benzene-o-dicarboxylic acid di-n-butyl ester; BRN 1914064; Butyl phthalate; Caswell No. 292; CCRIS 2676; Celluflex DPB; DBP; DBP (ester); Di-n-butyl phthalate; Di-n-butylester kyseliny ftalove; Di-n-butylester kyseliny ftalove [Czech]; Dibutyl 1,2-benzenedicarboxylate; Dibutyl phthalate; Dibutyl-o-phthalate; EC 201-557-4; EINECS 201-557-4; Elaol; EPA Pesticide Chemical Code 028001; Ergoplast FDB; Ersoplast FDA; Genoplast B; Hatcol DBP; Hexaplas M/B; HSDB 922; Kodaflex DBP; n-Butyl phthalate; N-Butylphthalate; NSC 6370; o-Benzenedicarboxylic acid, dibutyl ester; Palatinol C; Phthalate, di-n-butyl; Phthalate, dibutyl-; Polycizer DBP; PX 104; RC Plasticizer DBP; RCRA waste number U069; Staflex DBP; Uniflex DBP; UNII-2286E5R2KE; Unimoll db; Witcizer 300; 1,2-Benzenedicarboxylic acid, dibutyl ester; Di-n-butyl phthalate; Dibutyl phthalate; n-Butyl phthalate; ortho-Dibutyl phthalate; Phthalic acid, dibutyl ester	ChemIDPlus, 2015
Molecular Formula	$C_{16}H_{22}O_4$	HSDB, 2015
Molecular Weight	278.34 g/mol	HSDB, 2015
Physical description	Clear to faint yellow oily liquid	HSDB, 2015
Odor	Slight aromatic odor	HSDB, 2015
Solubility in water	11.2 mg/L at 25 °C	HSDB, 2015
Octanol/Water Partition Coefficient (log K_{ow})	4.9	HSDB, 2015
Boiling Point	340 °C	HSDB, 2015
Melting Point	-35 °C, -65 °C	HSDB, 2015; CPSC, 2010a
Vapor Pressure	2.01–2.7 X 10^{-5} mm Hg at 25°C	ATSDR, 2001
Flash Point	157 °C	ATSDR, 2001

4.3 Worldwide Manufacturing Processes for DBP

Information is inconsistent as to how many companies throughout the world manufacture DBP.

Two sources reported that DBP was produced by two companies in the United States (ATSDR, 2001; HSDB, 2015); recently, Chem Sources Online (2015) reported 27 companies. In 2005, three manufactures in the European Union (EU) produced DBP, one each in Belgium, Poland and the Czech Republic; however in 2009, only two manufacturers were reported (ECHA, 2009). NICNAS (2013) reported that there were no records for the manufacture of DBP in Australia, but that DBP is imported.

The Chem Sources Online Database (2015) provides information for suppliers of chemicals from national and international companies. The locations of the 63 companies worldwide that manufacture DBP are listed in Table 4-2. These data indicate that the U.S. is the largest worldwide producer of DBP.

No other information for worldwide manufacture of DBP was located in the literature searched for this report.

Table 4-2. Location of Companies Reporting Manufacture of DBP (Chem Sources Online, 2015)

Location	Number of Companies
U.S.	27
Mexico	11
China	9
United Kingdom	5
Germany	2
Hong Kong	2
India	2
Belgium	1
Canada	1
Czech Republic	1
Japan	1
Switzerland	1

4.4 Annual Production of DBP

There are 13 companies listed under Chemical Data Reporting (CDR) for the U.S. EPA (2015). The CDR provides information on the production and/or use of chemicals manufactured or imported into the United States. Confidential Business Information precludes the ability to discern whether a company only produces, only uses, or produces and uses DBP. In the U.S. from 1986 to 2002, production of DBP ranged from 10 to 50 million pounds (Table 4-3). In 2012, the production of DBP in the U.S. had decreased to seven million pounds (U.S. EPA, 2015). DBP is listed as a High Production Volume (HPV) chemical because it is produced or imported in the U.S. in amounts greater than 1 million pounds per year (U.S. EPA, 2015).

Table 4-3. Production of DBP in the United States

Year	Production Range (pounds)	Reference
1986	>10,000,000 – 50,000,000	HSDB, 2015
1990	>10,000,000 – 50,000,000	HSDB, 2015
1994	>10,000,000 – 50,000,000	HSDB, 2015
1998	>10,000,000 – 50,000,000	HSDB, 2015
2002	>10,000,000 – 50,000,000	HSDB, 2015
2012	7,005,890	U.S. EPA, 2015

During 1982-1986, the average annual production was reported as 44,092,452 pounds in Germany (IPCS, 1997). More recently in the EU, DBP production decreased from approximately 108,000,000 pounds in 1994 and 57,000,000 pounds in 1998 to less than 22,000,000 in 2007 (ECHA, 2009). It is estimated that there were approximately 41,000,000 pounds of DBP in end products in the EU during 2007 (ECHA, 2012). Production of DBP in the EU from 1994-2010 is shown in Table 4-4.

In Nordic countries, the total use of DBP has remained at approximately 69,000 pounds from 2000 to the last year reported in 2012. Production data are not reported in this database, but indicate that usage volume has varied amongst the countries (SPIN, 2015).

Asia and Pacific Rim countries each produced amounts of DBP similar to the U.S. (ATSDR, 2001). In Japan, production of 37,478,585 pounds was reported during 1994 (IPCS, 1997). Korea reported 15,432,400 pounds produced in 2010 (Lee et al., 2014).

Table 4-4. Production of DBP in the European Union

Year	Pounds	Reference
1994	108,000,000	CPSC, 2010a
1998	57,320,000	ECHA, 2009
2005	>22,046,000	ECHA, 2009
2007*	<22,046,000	ECHA, 2009
2008**	≈19,841,600	ECPI, 2008 (as cited by ECHA, 2009)
2009-2010	28,660,100	ECHA, 2012

* Information was obtained from two manufacturers
**For Western Europe

No data are available regarding the global production volume of DBP in the literature searched for this report.

4.5 Application of DBP in Materials, Consumer Products and Nonconsumer Products

DBP is used as a softener in the following: plastics, adhesives, printing ink, sealants, paints, film coatings, glass fibers, insect repellants, safety glass, and cosmetics (HSDB, 2015).

ATSDR (2001) noted that the high volatility of DBP relative to that of other phthalate esters makes it unsuitable as a plasticizer in products that will be exposed to continual high temperature conditions (temperature not specified). At lower temperatures, it is very suitable in imparting high flexibility.

4.5.1 Children's Products

In 2001, ATSDR reported that the use of DBP in toys appears to be rare.

Several studies, however, have shown DBP at concentrations of 16–46% in toys and children's products, particularly in some foreign markets. Uththamawadu et al. (2010) found that 18 of 30 squeeze toys from shops in the Colombo market in Sri Lanka contained DBP at concentrations of 24–46% (by weight). Korfali et al. (2013) analyzed toys and modeling clays purchased in "dollar stores" in Lebanon for metals, phthalates and benzene derivatives. DBP detection was reported from the surface of a whistle (one gram was scraped off) at a concentration of 16%, but was not detectable in other toys, such as dolls, cars, animals, instruments or clays.

Other studies have found lower concentrations of DBP in toys ranging from 0.05% to 0.6%. In a study of toys collected in a local market in India by Johnson et al. (2011), DBP was detected in 5 of 24 toys or child care articles; concentrations ranged from <0.1 to 0.2%. Yacob et al. (2013) designed a study to analyze six phthalates in five types of rubber toys purchased from a Malaysian market. Chemical analysis showed that none of the toys were made of natural rubber, but were likely plasticized PVC. DBP was measured in two of five toys with concentrations of 0.05–0.06%. In a recent study in Belgium conducted by Ionas and colleagues (2014), DBP was detected in 94% of 50 toys collected from public donations, or purchased at a flea market or in a local store. One of the toys was made of wood, eight of foam and textile, 25 of hard plastic, and 16 of soft plastic and rubber; no other information about the materials was presented. Several phthalates were reported in the toys, with the highest concentrations of DBP were found in the soft plastic and rubber toys, and hard (rigid) plastic toys at 0.6% (6200 ppm) and 0.2% (1700 ppm), respectively. The RAPEX (2015) database reports 17 toys or children’s products that contained DBP in 2015: two police sets, two bow and arrow sets, a remote control toy robot, toy gun set, snowman soft toy, plastic dolls and false nails. These data are summarized in Table 4-5.

Concentrations of DBP in children’s toys appear to be dependent on the type of material from which the toy is made (PVC toys appear to have the highest concentrations) as well as the location where the toy is made (such as local foreign markets).

Table 4-5. DBP in Children's Products

Use	Product	Concentration	Reference
Toy	Squeeze type toys	24–46%	Uththamawadu et al., 2010
Toy	Remote-controlled toy robot	21.9 %	RAPEX, 2015
Toy	Whistle	16 %	Korfali et al., 2013
Toy	Bow and arrow set	2.2 and 15%	RAPEX, 2015
Toy	Toy police sets	9.7 and 10%	RAPEX, 2015
Toy	Soft plastic and rubber toys	0.006–0.6% (median-maximum)	Ionas et al., 2014
Toy	Plastic dolls	0.23%	RAPEX, 2015
Toy	Hard plastic toys	0.0004–0.2% (median-maximum)	Ionas et al., 2014
Toy	Toys (unspecified)	0.18%	CPSC, 2010b
Toy	Squirty bath toy	0.1% (942 ppm)	WSDE, 2015
Toy	Soft toys	<0.1%	Yacob et al., 2013
Toy	Foam and textile toys	0.0009–0.02% median-maximum)	Ionas et al., 2014
Toy	Modeling material	0.02% (162 ppm)	IFCS, 2006
Toy	Wood toy	0.02% (median, maximum)	Ionas et al., 2014
Toy	Wow rackets, 2 rackets, ball & birdy, water proof pouches	0.001–0.003% (10.5 & 29.6 ppm)	WSDE, 2015
Toy	Bath toys, rubber duck, baby books, plastic farm animals, twistable crayons, glow in the dark plastic bugs, play putty, whiffle balls, toy soldiers, plastic recorder, doll head, washable fine	< 0.01%	WSDE, 2015; IFCS, 2006; NTP-CERHR, 2003

Table 4-5. DBP in Children's Products

Use	Product	Concentration	Reference
	point markers		
Toys and child care articles	Teethers, gum soother, soft & hard biter, doll	<0.1%–0.2%	Johnson et al., 2011
Child care article	Cool animal teether	0.04% (380 ppm)	IFCS, 2006
Child care article	Cherry body lotion and scent	0.01% (116 ppm)	WSDE, 2015
Child care articles	Manicure set, pink bib	<0.01% (11.9–81.3 ppm)	WSDE, 2015
Children's product	Plastic pouch for Turquoise teenage curtain	0.001% (11.5 ppm)	WSDE, 2015
Clothing, textiles and fashion items	False nails	unspecified concentration	RAPEX, 2015

*Concentrations less than 0.1% or with unknown concentrations are shaded.

The Washington State Department of Ecology (WSDE), under the 2008 Washington Children's Safe Product Act has been testing consumer products for toxic chemicals and receiving and posting data from manufacturers on children's products sold in Washington if their product contains phthalates, or other chemicals of high concern. Of the 239 products tested by WSDE, 22 products contained DBP over the reporting limit of 5 ppm, but none of these items have more than 0.1% (1000 ppm) DBP (WSDE, 2015). The item of maximum concentration was from the container of a "squirty" bath toy that had less than 0.1% (942 ppm) DBP. From the manufacturers' testing results, the State of Washington has received data containing a total of 709 items that contained DBP. Of these 709 items, DBP was found in: one item at more than 1.0% (10,000 ppm), three items between 0.5 and less than 1.0% (5,000 to <10,000 ppm), two items between 0.1 and less than 0.5 % (1,000 to 5,000 ppm), and the remaining 702 items less than 0.1% (1000 ppm). The items with DBP concentrations between 0.1 to 1.0% from WSDE database are listed in Table 4-6.

Table 4-6. Items in WSDE Database with DBP Concentrations of 0.1% (1000 ppm) or Greater

Product Family: Description	Chemical Function	No. Samples	Concentration	Target Age
Arts/Crafts/Needlework Supplies : Arts/Crafts Variety Packs, Artists Painting/Drawing Supplies	Plasticizer /Softener	3	>5,000–<10,000 ppm	3 –12

Product Family: Description	**Chemical Function**	**No. Samples**	**Concentration**	**Target Age**
Greeting Cards/Gift Wrap/Occasion Supplies	Coloration/Pigments/Dyes/Inks	1	>1,000– <5,000 ppm	Under 3
Toys/Games: Toys/Games Variety Packs	Coloration/Pigments/Dyes/Inks	1 1 1	>10,000 ppm; >5000–<10,000 ppm; >1,000–<5,000 ppm	3–12

4.5.2 Other Products

DBP is used as a plasticizer, a solvent and in adhesives, explosives, fillers, and sealants (PubChem, 2015). DBP was a plasticizer in PVC in the 1970s and 1980s. It is no longer used in this manner; it is currently used in combination with other plasticizers because it is too volatile for PVC applications (ECHA, 2009; HSDB, 2015).

DBP is used to plasticize polyvinyl acetate (PVA), polysulfides and polyurethanes (ATSDR, 2001). It is used for bonding cellulosic materials and for plastic coated fabric and film sheets for bags, briefcases or suitcases, tablecloths, curtains, shower curtains, water and air mattresses, and plastic coated wall paper or tapestry. As a plasticizer, it is also used in nail polish and fingernail elongations (EC, 2001). DBP has been detected in PVC floorings at 1.3 percent concentration (CPSC, 2010b).

DBP is used as a component in adhesives primarily for paper and packaging, wood building and the automobile industry (ECHA, 2009; SPIN, 2015; no further information on the materials was reported. In latex adhesives, the NTP-CERHR reported DBP to be used as a coalescing aid (as cited by CPSC, 2010b).

DBP is used in some polychloroprene rubbers (neoprene) and in polypropylene catalytic systems; in insulation on wires and cables; and in electronic devices (Danish EPA, 2011).

Insecticides, oil-soluble dyes, and other organic compounds; production of epoxy based fiberglass; and nitrocellulose lacquers may have DBP as a solvent. In cosmetics, it is used as a perfume solvent and fixative (EC, 2001).

DBP is used as a component in the following: preparation of grouting agents and paints, lacquers and varnishes; antifoam agent; a fiber lubricant in textile manufacturing; is used in polishing agents and corrosion materials, sealants, film coatings, and in safety glass (ECHA, 2009; HSDB, 2015; SPIN, 2015). Use of DBP in safety glass is within the films that provide a protective sheath on the interior of glass to hold fractured shards of glass together in events of glass breakage (Rosato, 2011).

The use of DBP as a softener in printing inks has become obsolete according to the European Council of producers and importers of paints, printing inks and artists' colors (ECHA, 2009).

The concentration of DBP in paints has been reported to be as high as 6% (55,000 ppm) (Wormouth et al., 2006, as cited by CPSC, 2010b). Other consumer products that contain DBP are building materials used in home maintenance, PVC-coated wallpaper, nail care products, perfume and cosmetics. Reported concentrations for these items are listed in Table 4-7. With the exception of PVC-coated wallpaper, the uses of DBP in these items are found as ingredients of many products in the U.S. that are reported in the Households Products Database (HPD, 2015).

Other products in which DBP could be found include footwear, bathing equipment, balls for training and physical exercise (less than 1%), and erasing rubber made of PVC (less than 1%) (type of eraser not specified) (Danish EPA, 2011; CPSC, 2010b). DBP was reported at concentrations as great as 9.6% in sandals and flip-flops (CPSC, 2010b). Some of these items could be used by children, but were not specified as such in the reference.

Table 4-7. Products that contain DBP

Category	Use	Form	Concentration	Reference
Personal Care	Nail polish and nail care products	liquid	1–6%	CPSC, 2010b; HPD, 2015
Personal Care	Perfumes, deodorants, hair products	NA	0.005–0.5%	CPSC, 2010b
Clothing, Footwear	Footwear (unspecified), shoes	NA	<0.1%–9.6%	ECHA, 2012
Home maintenance	Surface coating	Liquid, paste; wallpaper paste, sealants	<2–40.0%	HPD, 2015
Home maintenance	Adhesives, glues, fillers, sealers	liquid, paste	0.5–10%	CPSC, 2010b; HPD, 2015
Home maintenance	Paint	liquid	6%	CPSC, 2010b; HPD, 2015
Home Maintenance	Wallpaper	NA	<0.1%	Danish EPA, 2011
Home Maintenance	PVC-coated wallpaper	NA	<0.1%	Danish EPA, 2011
Other	Erasing rubber, Plastic bags, oilcloths	solid	<0.1%	Danish EPA, 2011
Clothing, textiles and fashion items	False nails	NA	Unspecified concentration	RAPEX, 2015

*Concentrations less than 0.1% are shaded.

4.6 Routes of Introduction of DBP into Phthalate-free Material

Danish EPA (2011) noted that the phthalates are not chemically bound to plastics but can migrate slowly at a rate of approximately 0.1–1% per year. DBP is a liquid at environmental temperatures and is susceptible to migration from leaching to the surface where it then can evaporate or be removed by washing. Danish EPA (2011) concluded that migration for DBP occurs by mechanisms similar to other phthalates, such as DEHP.

In general, the tendency of the phthalate to migrate depends on solubility (*e.g.*, expressed as log K_{ow}), the concentration of the phthalate, the vapor pressure and the exposure route. Migration from toys and child care products seems to increase with increasing percentage of phthalate present (Al-Natsheh et al., 2015).

DBP used in plastic toys can migrate from the product during children's mouthing of toys as shown in studies of simulated mouthing actions of children (Osman et al., 2013).

DBP is present in foodstuff as a result of migration from plastic and aluminum packaging (IPCS, 2015; IPCS, 1997). The phthalates can migrate from packaging especially into fatty foods (e.g., vegetable oils), which could cause contamination of the food (Danish EPA, 2014). Based on the lipophilic characteristics of the phthalates, including DBP, it could be expected that migration could occur into children's products that are oil-based, such as oils or lotions.

As DBP is used in a number of household maintenance products, the release of DBP into air may result in DBP binding to dust particles present in the home.

During mechanical recycling, DBP is expected to remain in the plastic due to its relatively high boiling point (greater than 300 °C). Decomposition of DBP is expected to occur in feed stock recycling and energy recovery incineration plants (Tukker, 1999).

4.7 References

Al-Natsheh, M., Alawi, M., Fayyad, M., Tarawneh, I. 2015. Simultaneous GC–MS determination of eight phthalates in total and migrated portions of plasticized polymeric toys and childcare articles. J Chromat B. 985, 103-109.

ATSDR (Agency for Toxic Substances and Disease Registry). 2001. Toxicological Profile for Di-n-Butyl Phthalate. U.S. Department of Health and Human Services. Public Health Service. Agency for Toxic Substances and Disease Registry. Available at: http://www.atsdr.cdc.gov/toxprofiles/tp135.pdf.

ChemID Plus, 2015. ChemID Plus, A Toxnet Database. U.S. National Library of Medicine. Available at: http://householdproducts.nlm.nih.gov/.

Chem Sources Online. 2015. Chem Sources Online database. Chem Sources International, Inc. Available at: http://www.chemsources.com/chemonline.html.

CPSC (U.S. Consumer Product Safety Commission). 2010a. Review of Exposure Data and Assessments for Selected Dialkyl Ortho-Phthalates. Consumer Product Safety Commission, CPSC-D-06-0006, Bethesda, MD. Available at: http://www.cpsc.gov/pagefiles/126552/pthalexp.pdf.

CPSC (U.S. Consumer Product Safety Commission). 2010b. Toxicity Review for Di-n-Butyl Phthalate. Consumer Product Safety Commission, Bethesda, MD. Available at: https://www.cpsc.gov/PageFiles/126528/toxicityDBP.pdf.

Danish EPA (Danish Environmental Protection Agency), 2011. Annex XV Restriction Report: Proposal for a Restriction. Bis(2-Ethylhexyl) Phthalate (DEHP), Benzyl Butyl Phthalate (BBP), Dibutyl Phthalate (DBP), Diisobutyl Phthalate (DIBP). Danish Environmental Protection Agency, Copenhagen, Denmark. Available at: http://echa.europa.eu/documents/10162/c6781e1e-1128-45c2-bf48-8890876fa719.

Danish EPA (Danish Environmental Protection Agency). 2014. Hazardous substances in plastics. Survey of chemical substances in consumer products No. 132, 2014. Danish Environmental Protection Agency, Copenhagen K, Denmark.

EC (European Commission). 2001. Opinion on the results of the Risk Assessment Report of Dibutyl Phthalate. C2/JCD/csteeop/DBP.24042001/D(01). Health and Consumer Protection. Scientific Committee on Toxicity, Ecotoxicity, and the Environment. European Commission. Available at: http://ec.europa.eu/health/ph_risk/committees/sct/documents/out96_en.pdf.

ECHA (European Chemicals Agency). 2009. Data on Manufacture, Import, Export, Uses and Releases of Dibutyl Phthalate (DBP) as well as Information on Potential Alternatives to Its Use. European Chemicals Agency. Available at: http://echa.europa.eu/documents/10162/6ce77be0-6c61-4e95-9241-0c262817555a.

ECHA (European Chemicals Agency). 2012. Background document to the Opinion on the Annex XV dossier proposing restrictions on four phthalates. Committee for Risk Assessment (RAC). Committee for Socio-economic Analysis (SEAC). European Chemicals Agency.

ECPI (European Council for Plasticisers and Intermediates). 2008. European Council for Plasticisers and Intermediates (ECPI). Information on website at: http://www.ecpi.org. (As cited by ECHA, 2009).

HPD (Household Products Database). 2015. Household Products Database online. National Library of Medicine, National Institutes of Health. Available at: http://householdproducts.nlm.nih.gov/.

HSDB (Hazardous Substances Data Bank). 2015. Hazardous Substances Data Bank online database, Toxnet Toxicology Data Network. U.S. National Library of Medicine. Available at: http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB.

IFCS (Intergovernmental Forum on Chemical Safety), 2006. Toys and Chemical Safety: A Thought Starter. Intergovernmental Forum on Chemical Safety. IFCS/Forum-V/03-TS, Budapest, Hungary. Available at: http://www.who.int/ifcs/documents/forums/forum5/03_ts_en.pdf.

IPCS (International Programme on Chemical Safety). 2015. INCHEM Online Database. International Programme on Chemical Safety. Available at: http://www.inchem.org/.

Ionas, A.C., Dirtu, A.C., Anthonissen, T., Neels, H., Covaci, A. 2014. Downsides of the recycling process: Harmful organic chemicals in children's toys. Environ Int. 65, 54-62.

IPCS (International Programme on Chemical Safety). 1997. Di-n-Butyl Phthalate. Environmental Health Criteria 189. International Programme on Chemical Safety, World Health Organization. Available at: http://www.inchem.org/documents/ehc/ehc/ehc189.htm.

Johnson, S., Saikia, N., Sahu, R. 2011. Phthalates in toys available in Indian market. Bull Environ Contam Toxicol. 86, 621-626.

Korfali, S.I., Sabra, R., Jurdi, M., Taleb, R.I. 2013. Assessment of toxic metals and phthalates in children’s toys and clays. Arch Environ Contam Toxicol. 65, 368-381.

Lee, J., Lee, J-H., Kim, C-K., Thomsen, M. 2014. Childhood exposure to DEHP, DBP and BBP under existing chemical management systems: A comparative study of sources of childhood exposure in Korea and in Denmark. Environ Int. 63, 77-91.

NICNAS (National Industrial Chemicals Notification and Assessment Scheme). 2013. AICS Listing. 1,2-Benzenedicarboxylic acid, diisooctyl ester. National Industrial Chemicals Notification and Assessment Scheme. Available at: http://www.nicnas.gov.au/regulation-and-compliance/aics/aics-search-page/chemical?id=17004.

NTP (National Toxicology Program). 2003. Center for the Evaluation of Risks to Human Reproduction (NTP-CERHR). NTP-CERHR Monograph on the Potential Human Reproductive and Developmental Effects of Dibutyl Phthalate (DBP). Center for the Evaluation of Risks to Human Reproduction, National Toxicology Program (NTP-CERHR). Available at: http://ntp.niehs.nih.gov/ntp/ohat/phthalates/dbp/dbp_monograph_final.pdf.

Osman, B., Ozer, E.T., Besirli, N., Gucer, S. 2013. Development and application of a solid phase extraction method for the determination of phthalates in artificial saliva using new synthesized microspheres. Polymer Test. 32(4), 810-818.

PubChem, 2015. The PubChem online database. National Library of Medicine. Available at: https://pubchem.ncbi.nlm.nih.gov/.

RAPEX. 2015. Rapid Alert System for dangerous non-food products. Latest Reports Online database. European Commission. Available at: http://ec.europa.eu/consumers/safety/rapex/alerts/main/index.cfm?event=main.listNotifications.

Rosato, D.V. 2011. Plastics End Use Applications. Springer Briefs in Materials. Springer, New York.

SPIN (Substances in Preparation in Nordic Countries). 2015. SPIN Database. Danish Environmental Protection Agency. Available at: http://195.215.202.233/DotNetNuke/default.aspx.

Tukker, A., de Groot, I.H., Simons, L., Wiegersma, S. 1999. Chemical Recycling of Plastics Waste (PVC and other resins). TNO Report STB-99-55 Final. TNO Institute of Strategy, Technology and Policy.

U.S. EPA (U.S. Environmental Protection Agency), 2015. Chemical Safety and Pollution Prevention: Pollution Prevention and Toxics. Vol. 2014. Chemical Data Access Tool (CDAT). Available at: http://java.epa.gov/oppt_chemical_search/.

Uththamawadu, D. P., Wijesekera, R. D., Rajasingham, S. L. 2010. A study of human exposure to selected phthalates in toys in Sri Lanka. Department of Chemistry, University of Colombo, Vauxhall St, Colombo. Available at: http://www.cmb.ac.lk/wp-content/uploads/2014/02/A-STUDY-OF-HUMAN-EXPOSURE-TO-SELECTED-PHTHALATES-IN-TOYS-IN-SRI-LANKA.pdf.

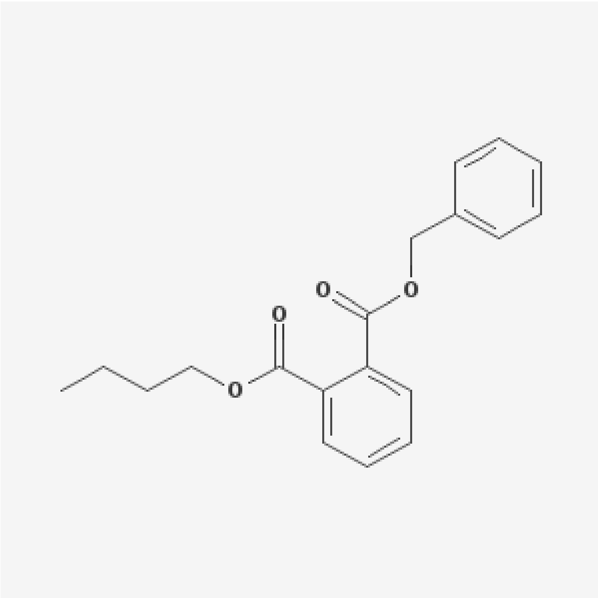
Wormouth, M., Hirosawa, N., Sakamoto, Y., Katayama, H., Moriguchi, T., Asaoka, K. 2006. What are frequently used phthalic acid esters in Europeans? Risk Anal. 26, 803-824. (As cited by CPSC, 2010.

WSDE (Washington State Department of Ecology ECY). (2015). "Children's Safe Product Act Reported Data." Available at: https://fortress.wa.gov/ecy/cspareporting/.Yacob, A.R., Ayub, A.M., Said, N.B. 2013. Detection and characterization of children's soft toy for phthalate esters. Ind J Foren Med Toxicol. 7, 210-214.

5 Benzyl butyl phthalate (BBP) CASRN: 85-68-7

BBP (CASRN 85-68-7) is an aromatic ester with the molecular formula $C_{19}H_{20}O_4$ and molecular weight of 312.4 g/mol (IPCS, 1999). BBP is a clear, oily liquid at room temperature and is considered a viscous, high boiling point solvent. BBP is a component of many commercial plastic products, used to increase the flexibility of the materials.

The structure of BBP (PubChem, 2015) is as follows:



5.1 Raw Materials Used in Production of BBP

BBP is produced through simple chemical synthesis, generally through a two-step reaction process. Phthalic anhydride is first converted to monobutyl phthalate by alcoholysis with n-butyl alcohol in the presence of an acid catalyst. The monobutyl phthalate is then converted to BBP either by esterification with benzyl alcohol or by reaction with benzyl chloride in the presence of an acid catalyst (HSDB, 2015; ECHA, 2009). Either sulfuric acid or p-toluene sulfonic acid can be used as the acid catalyst (U.S. EPA, 1981).

Commercial production of BBP in the U.S. involves first monobutyl ester production by the reaction of phthalic anhydride with n-butyl alcohol in the presence of an acidic catalyst, followed by reaction with benzyl chloride (HSDB, 2015). In Japan, the monobutyl ester is treated with benzyl alcohol in the presence of an acid catalyst to yield BBP. Technical specifications of BBP differ slightly between the product made in the U.S. and in Japan (IARC, 1982).

Depending on the process, the following chemicals are used as raw materials in the production of BBP:

- benzyl chloride
- benzyl alcohol
- phthalic anhydride
- n-butyl alcohol
- acid catalyst: sulfuric acid or p-toluene-sulfonic acid

Synonyms and trade names for BBP are shown in Table 5-1.

5.2 Chemical and Physical Properties of BBP

Benzyl butyl phthalate (BBP) is a long-chain branched compound that is a clear, oily liquid at room temperature with a slight odor and a bitter taste (NTP, 1997; HSDB, 2015). It is almost insoluble in water and is soluble in organic solvents such as acetone and benzene (U.S. EPA, 1981).

The high boiling point and low vapor pressure contribute to BBP's physical stability. BBP has low volatility, as indicated by its vapor pressure, although when a material with BBP is heated, the partial pressure of BBP increases and evaporation is more likely (Danish EPA, 2011; ECHA, 2012). The thermal decomposition temperature of BBP has not been determined, but BBP decomposes into toxic gases (PubChem, 2015).

Table 5-1 summarizes the chemical and physical characteristics of BBP (HSDB, 2015; HPD, 2014). The data for several of these characteristics varies depending on the source.
BBP is incompatible with strong acids, nitrates and oxidizers (HSDB, 2015). IPCS (1999) confirmed that BBP reacts with oxidants and decomposes on burning. BBP is reduced to the alcohol by the action of hydrogen and hydrolyzed in the presence of strong aqueous acid (U.S. EPA, 1987).

Table 5-1. Physical/Chemical Characteristics of BBP

Characteristic	Value	Reference
IUPAC Name	2-o-benzyl 1-o-butyl benzene-1,2-dicarboxylate	PubChem, 2015
CASRN	85-68-7	HSDB, 2015
EC Number	201-622-7	ECHA, 2012
Synonyms and Trade Names	BBP; 1,2-Benzenedicarboxylic acid, 1-butyl 2-(phenylmethyl) ester; 1,2-Benzenedicarboxylic acid, butyl phenylmethyl ester; benzyl butyl phthalate; benzyl-butylester kyseliny ftalove; benzyl n-butyl phthalate; butyl benzyl phthalate; n-butyl benzyl phthalate; butyl phenylmethyl 1,2-benzenedicarboxylate; Palatinol BB; phthalic acid, benzyl butyl ester; Santicizer 160; Sicol; Sicol 160; Unimoll BB; NCI-C54375	NTP, 1997; ChemIDPlus, 2015; U.S. EPA, 2014; HSDB, 2015; NIST, 2015
Molecular Formula	$C_{19}H_{0}O_{4}$	HSDB, 2015
Molecular Weight	312.36 g/mol	HSDB, 2015
Physical description	Clear, viscous oily liquid	HSDB, 2015; ECHA, 2012
Density	1.1 g/mL at 20 °C	Sigma-Aldrich, 2015
Odor	Slight odor	HSDB, 2015
Solubility in water	2.7 to 2.9 mg/L at 25 °C	U.S. EPA, 1987; HSDB, 2015
Octanol/Water Partition Coefficient (Log K_{ow})	4.73 to 4.91	U.S. EPA, 1987; ECHA, 2012; HSDB, 2015
Boiling Point	370–377 °C	IARC, 1982; HSDB, 2015
Melting Point	-35°C	HSDB, 2015
Vapor Pressure	8.25 to 8.6 X 10^{-6} mm Hg at 25°C	U.S. EPA, 1987; HSDB, 2015
Flash Point	198 °C	NTP, 1997

5.3 Worldwide Manufacturing Processes for BBP

In the United States, one manufacturer was reported by IARC (1982) and U.S. EPA (1987), whereas two manufacturers are reported by HSDB (2015). U.S. EPA (2012) and U.S. EPA (2015) reported five and four manufacturers of BBP, respectively.

In Europe, IARC (1982) reported three manufacturers, one in Germany, one in the UK and one in Belgium. Effting and van Veen (1998) reported three manufacturers, whereas ECHA (2009) reported two manufacturers in 2007. It is not clear whether the two manufacturers reported in Germany were included in the earlier sources (Chem Sources Online, 2015).

Chem Sources Online (2015) reports the following number of manufacturers: two in Mexico, two in Switzerland, one in Japan, one in Hong Kong and one in China.

It is difficult to obtain information on worldwide manufacturing processes for BBP. In particular, there is a paucity of information for South America. One company manufacturing BBP in Brazil in 1980 has been reported by IARC (1982).

5.4 Annual Production of BBP

In the United States, BBP is listed as a High Production Volume (HPV) chemical (65FR81686). Chemicals listed as HPV were produced in or imported into the U.S. in amounts more than 1 million pounds (or more than 500 tons) per year in 1990 and/or 1994. The HPV list is based on the 1990 Inventory Update Rule (IUR) (CFR, 2015; U.S. EPA, 1987; HSDB, 2015). U.S. EPA (2015) notes that manufacturing information, such as volume produced, is sometimes considered confidential business information (CBI) and is not reported.

Table 5-2 U.S. Production Volumes for BBP from Non-confidential Chemicals Reported under the Inventory Update Rule*

Year	Production Range (pounds)
1968	100,200
1971	105,200
1974	134,200
1977	132,200
1977	>150,000,000
1978	>100,000,000
1981	>164,000,000
1986	>50,000,000–100,000,000
1990	>100,000,000–500,000,000
1994	>50,000,000–100,000,000
1998	>100,000,000–500,000,000
2002	>50,000,000–100,000,000
2012	>50,000,000–100,000,000

Source: U.S. EPA, 1981; U.S. EPA, 2014; HSDB, 2015.

Production of BBP in the EU appears to have decreased over the last decade (ECHA, 2009). In 1994-1997, 90,000,000 pounds/year of BBP where manufactured, whereas maximum tonnage in 2007 was 36,000,000 pounds, with significant export outside the EU (ECHA, 2009). There has been an approximate 35 percent decrease in the use of phthalates in Europe during recent years (2007 to 2009/2010) (ECHA, 2012). In Nordic countries, over 240,000 pounds of BBP were used in 2011, decreased from over 1,800,000 pounds in years 2002-2007 (SPIN, 2015).

BBP is not manufactured in Canada (Health Canada, 1999). Phthalates are no longer manufactured in Australia (ACCC, 2015). Production of BBP in other countries could not be located in the sources searched for this project.

5.5 Application of BBP in Materials, Consumer Products and Nonconsumer Products

BBP is used in a wide variety of consumer and non-consumer products, including children's products, household products and personal use products. BBP is used primarily as a plasticizer in PVC to soften the material and to add flexibility (NTP, 1997; ECHA, 2012). It is reported to be used with other polymers including acrylic resins, ethyl cellulose, polyvinyl formal and polyvinyl butyral (IARC, 1982). BBP is also formulated as a component in printing inks, paints, adhesives and sealants (ECHA, 2009).

Overall in the United States, the only item that has been identified to contain BBP in concentrations above 0.1% (1000 ppm) is modeling clay. Items identified that contain BBP in lower concentrations are arts/crafts/needlework supplies, clothing, footwear, tableware, personal accessories, and toys/games.

5.5.1 Child Care Products

According to ACC (2010), BBP was not used in children's products (presumably in the U.S.) and was found only as an impurity in trace amounts. IFCS (2006) reported phthalates in toys and their concentrations. BBP was found at 0.05% (448 ppm) in a rubber duck from Thailand, 0.02% (220 ppm) in a swim ring from Australia, <0.001% (3.6 ppm) in play putty and 3.2% (32,349 ppm) in modeling material (IFCS, 2006). Polymer modeling clay from the U.S. contained 4.0% (39,800 ppm) BBP (CPSC, 2010). BBP was found in toys from Asia in trace amounts (0.02%), likely due to impurities from manufacture (CPSC, 2010). The content of plasticizers in plastic teethers and toys from 17 countries was determined by Stringer et al. (2000). Of 72 toys tested, BBP was detected in six samples ranging from 0.001 to 0.02% (10 to 200 ppm) of the weight of the toys (CPSC, 2010). In another study by Johnson et al. (2011), BBP was detected in three of 24 toys that were analyzed, with concentrations of 0.1–0.2% (1000–2000 ppm). The authors stated this concentration of BBP was too low to have plasticizing function and could be present as a contaminant. In a more recent study conducted in Belgium, BBP was detected in 68% (n=106) of toys collected from public donations. In this study, the median concentration of BBP was only 0.0005% (5 ppm) but the maximum concentration detected was 0.2% (1900 ppm) (items not specified) (Ionas et al., 2014). These data, as well as the findings from several other studies, are summarized in Table 5-3.

Table 5-3. BBP Concentrations in Some Children's Products

Use	Product	BBP Concentration	Study Location	Reference
Toy	Toys (unspecified)	3.9–11.9% (39,000–119,000 ppm)	Tokyo	Niino et al., 2002
Toy	Modeling Clay	3.98% (39,800 ppm)	U.S.	CPSC, 2010
Toy	Modeling material	3.23% (32,349 ppm)	Netherlands	IFCS, 2006
Toy	Toys (unspecified)	0.1–0.2 %	India	Johnson et al., 2011
Toy	Toys (unspecified)	<0.001–0.2%	Belgium	Ionas et al., 2014
Toy	Baby Toys	0.001–0.02 %	Asia	Stringer et al., 2000; CPSC, 2010
Toy	Sandals	0.0046–0.0079% (46–79 mg/kg)	Netherlands	ECHA, 2012
Toy	Rubber duck	0.045% (448 ppm)	Thailand	IFCS, 2006
Toy	Swim ring	0.022% (220 ppm)	Australia	IFCS, 2006
Toy	Play Putty	< 0.001% (3.6 ppm)	Netherlands	IFCS, 2006

The Washington State Department of Ecology (WSDE) has been testing consumer products for toxic chemicals and receiving and posting data from manufacturers on children's products sold in Washington if their product contains a chemical of high concern to children, which includes phthalates under the 2008 Washington Children's Safe Product Act. Of the 239 products tested for BBP, eight products contained BBP over the reporting limit but none of these items are greater than 0.1% (1000 ppm). The item of maximum concentration was from a container of "squirty" bath toys that contained BBP at 0.0978% (978 ppm) (WSDE, 2015). From the manufacturers' testing results, the State of Washington has received a list containing a total of 563 items that contained BBP. Of these 563 items, none had concentrations greater than 0.1% (1000 ppm). WSDE

5.5.2 Other Products

BBP is used in personal use products as well as household products, such as flooring, wires and cables, adhesives, and sealants. It is also found in electrical equipment and wall paper backing (Danish EPA, 2011). BBP is used in sealants, foams, adhesives, coating and inks and paints and varnishes (ECHA, 2012; HSDB, 2015). In the United States, aerosol spray in cans, tubes containing pastes, plastic repair, or adhesives, and paints and sealants in cans can contain BBP. Table 5-4 shows the concentrations of BBP in other consumer products, such as arts and crafts and home maintenance products.

ECHA (2009, 2012) reported that BBP is used as a plasticizer in both polymer and non-polymer products, including PVC flooring. The NTP (1997) noted BBP is a plasticizer added to polymers at relatively high levels (generally at concentrations of 50 to 75 parts per 100 parts (50 – 75%) of resin by weight) to provide flexibility and softness. BBP is used in PVC-based flooring such as vinyl floor tiles, vinyl foams, carpet tile, carpet backing and Astroturf (NTP, 1997; CICAD, 1999; ACC, 2010; HSDB, 2015).The NTP-CERHR BBP report (2000) stated that the largest use of BBP is in vinyl tile. The European Industry reported BBP concentration in three types of PVC flooring at concentrations less than 1%: heterogeneous PVC (0.89%), PVC with foam backing (0.44) and cushioned PVC (0.64%) (Danish EPA, 2011). Analysis of 8 PVC floorings detected BBP below 0.1 % and another analysis of 25 PVC floorings reported BBP <6.8% (Danish EPA, 2011).

BBP was detected in adhesives, glues and sealants at maximum concentrations of 6.8% (67,900 ppm) and in paints at concentrations of 5.5% (55,000 ppm), respectively (CPSC, 2010). CPSC (2014) reported BBP in general purpose adhesives and aerosol paint coating at mean concentrations of 0.9% and 0.1%, respectively. Ranges (3.6 and 5.0% or 36,200 and 50,000 ppm, respectively) were reported with BBP concentration in the 95th percentile of 3.1% (30,800 ppm) for general purpose adhesives and 0 % (measure values not reported) for aerosol paints/coatings, respectively (CPSC, 2014).

BBP is also used as an ingredient in formulations, emulsifiers, repellents and biocides (ECHA, 2009; 2012). It is a carrier and dispersant for pesticides, colorants, solvents, catalysts, munitions, industrial oils, insect repellents, perfumes and as a plasticizer in aerosol hairsprays at concentrations of less than one percent (additional information not provided).

From 2000-2012, industrial uses of BBP in Nordic countries were primarily for manufacture of chemicals and chemical products, manufacture of rubber and plastics, construction, manufacture of wood and products of wood and cork, wholesale trade and commission trade (SPIN, 2015). The volume of BBP used shows a significant downward trend from 2000 to 2011, with uses changing to primarily manufacture of chemicals and chemical products and specialized construction activities. In 2007 and years prior, BBP was used in “softeners” in large quantities (~800,000 tons or more). Specific uses of BBP during the decade reported were in fillers; paints, lacquers and varnishes; adhesives, and binding agents (SPIN, 2015).

BBP uses include personal care consumer products such as hair products, nail care products and perfumes (CPSC, 2010). Concentrations varied from 0.004–0.01% (43 to 107 ppm) in hair spray and nail enamels, respectively, in the U.S. to 0.006% (62.8 ppm) in perfumes from Asia. Plastic gloves contained BBP with highest concentration of 3.3% (33,000 ppm) (CPSC, 2010).

BBP is found in clothing and footwear and other products, such as waterbeds and air mattresses (ECHA, 2012), footwear, bathing equipment (such as swim wings, belts, and pools), shower curtains, table clothes, and balls for training and physical exercises (ECHA, 2009; 2012). BBP was reported in plastic bags (including plastic bags for children), briefcases and suitcases, and in air and water mattresses at concentrations less than 1%. In a dermal exposure analysis, articles including exercise balls, swimming pools, and bags were examined but BBP was not detected (ECHA, 2012).

Table 5-4. Consumer Products that contain BBP as Ingredient*

Category	**Use**	**Form**	**Percent**
Arts & Crafts	Surface Coating	Aerosol; spray paint	5
Home maintenance	Surface coating	Liquid, paste; wallpaper paste, sealants	<2–40
Home maintenance	Adhesive	Caulk tube, liquid, paste	1.0–30
Home maintenance	Paint	Aerosol and liquid; waterproofing paint	0.1–5

*Source: HPD, 2015

5.6 Routes of Introduction of BBP into Phthalate-free Material

There is little information available about the transfer or introduction of BBP in to phthalate-free material. BBP is considered a semi-volatile organic compound and can be emitted from consumer products. It is considered an important manufactured environmental contaminant (Chatterjee and Karlovsky, 2010). Most notably BBP has been identified in carpet and PVC flooring emissions.

BBP has been detected in regenerated cellulose film, PVC gaskets in metallic caps for glass jars, paper and boxboard-packaging materials, PVC gloves and aluminum foil-paper (Xu-lian Cao, 2010). The items that come into contact with these will most likely contain BBP since it is not bound to the polymer in plastic and may migrate (Autian, 1973, cited in NTP, 1997). The extent of migration is not clear since phthalate plasticizers are not covalently, but physically bound within the polymer matrix and migrate only under severe conditions such as with strong solvents (Stales et al., 1997). In laboratory conditions, BBP detected at low levels 0.003-0.008% (25-79 mg/kg) in plastic sandals was not found to migrate to artificial sweat (ECHA, 2012).

BBP is also used as a plasticizer in PVC that is subsequently used to manufacture food conveyor belts, carpet tile, artificial leather, tarps, automotive trim, weather stripping, traffic cones, and, to a limited extent, vinyl gloves (CPSC, 2010). It has been detected in plastic water bottles (maximum concentration of <0.0001%; 0.43 µg/L) made out of polyethylene terephthalate (PET) (Greifenstein et al., 2013). BBP may be released to the environment during its production and also during incorporation into plastics or adhesives.

Phthalates, including BBP, were found in disposable contact lenses and in cleaning solutions. BBP was detected in the two contact lenses and the levels found were below 0.001% (5 µg/ L). A migration test using artificial tears suggested migration of phthalates including BBP from soft contact lens (Perez-Feas et al., 2011).

Phthalates in recycled materials can represent a further source of contaminants, and recycled materials can be exempted from REACH (Registration, Evaluation, Authorization and Restriction of Chemicals) when they comprise less than 20% of the recyclate (Gärtner et al., 2009).

5.7 References

ACC (American Chemistry Council). 2010. Before The Chronic Hazard Advisory Panel On Phthalates and Phthalate Substitutes. Public Comment Session, July 26, 2010. Comments Of The Phthalate Esters Panel Of The American Chemistry Council. American Chemistry Council. Available at: http://www.cpsc.gov/PageFiles/126406/accComments.pdf.

ACCC (Australian Competition and Consumer Commission). 2015. Phthalates in consumer products. Australian Competition and Consumer Commission. Canberra, Australia. Available at: http://www.productsafety.gov.au/content/index.phtml/itemId/972486.

Autian, J. (1973). Toxicity and health threats of phthalate esters: Review of the literature. Environ, Health Perspect. 4, 3-26. (As cited in NTP, 1997).

CFR (Code of Federation Regulations). 2015. Title 40, Part 710 subpart B Compilation of the TSCA Chemical Substance Inventory. Code of Federal Regulations, Washington, D.C., Available at: http://www.ecfr.gov/cgi-bin/text-idx?SID=1a45f84adbf028c202e5062cd73db5f9&mc=true&node=se40.31.710_11&rgn=div8.

Chatterjee, S., Karlovsky, P., 2010. Removal of the endocrine disrupter butyl benzyl phthalate from the environment. Appl Microbiol Biotechnol. 87, 61-73.

ChemIDPlus. 2015. Butyl Benzyl Phthalate (BBP), CASRN: 85-68-7. A TOXNET database. U.S. National Library of Medicine. Bethesda, MD. Available at: http://www.chem.sis.nlm.nih.gov/chemidplus/rn/85-68-7.

Chem Sources Online, 2015. Butyl Benzyl Phthalate (BBP), CASRN: 85-68-7. Chemical Sources International online. Available at: http://www.Chemsources.com/chemonline.html.

CICAD (Concise International Chemical Assessment Document). 1999. Butyl Benzyl Phthalate. (BPP). CICAD 17. World Health Organization, Geneva, Switzerland.

Cao, X-L. 2010. Phthalate esters in foods: sources, occurrence, and analytical methods. Compr Rev Food Sci F. 9, 21-43.

CPSC (U.S. Consumer Product Safety Commission), 2010. Review of Exposure Data and Assessments for Selected Dialkyl Ortho-Phthalates. Consumer Product Safety Commission, CPSC-D-06-0006, Bethesda, MD.

CPSC (U.S. Consumer Product Safety Commission). 2014. Appendix E1 Modeling Consumer Exposure to Phthalate Esters. Chronic Hazard Advisory Panel (CHAP) on Phthalates and Phthalate Alternatives. Bethesda, MD.

Danish EPA (Danish Environmental Protection Agency), 2011. Annex XV Restriction Report: Proposal for a Restriction. Bis(2-Ehtylhexyl)Bis(2-Ethylhexyl) Phthalate (DEHP), Benzyl Butyl Phthalate (BBP), Dibutyl Phthalate (DBP), Diisobutyl Phthalate (DIBP). Danish Environmental Protection Agency, Copenhagen, Denmark. Available at: http://echa.europa.eu/documents/10162/c6781e1e-1128-45c2-bf48-8890876fa719.

Danish EPA (Danish Environmental Protection Agency). 2014. Hazardous substances in plastics. Survey of chemical substances in consumer products No. 132, 2014. Danish Environmental Protection Agency, Copenhagen K, Denmark.

ECHA (European Chemicals Agency), 2009. Background document for Benzyl Butyl Phthalate (BBP). Document developed in the context of ECHA’s first recommendation for the inclusion of substances in Annex XIV. Available at: http://echa.europa.eu/documents/10162/13640/bbp_en.pdf.

ECHA (European Chemicals Agency). 2012. Background document to the Opinion on the Annex XV dossier proposing restrictions on four phthalates. Committee for Risk Assessment (RAC). Committee for Socio-economic Analysis (SEAC). European Chemicals Agency. Available at: http://www.echa.europa.eu/documents/10162/3bc5088a-a231-498e-86e6-8451884c6a4f.

Effting, S.E., van Veen, M.P. 1998. Human Exposure to Benzylbutyl Phthalate. A Source-Effect Chain Effect. National Institute of Public Health and the Environment (RIVM), Bilthoven, Netherlands.

Gärtner, S., Balski, M., Koch, M., Nehls, I., 2009. Analysis and migration of phthalates in infant food packed in recycled paperboard. J Agric Food Chem. 57, 10675-10681.

Greifenstein, M., White, D. W., Stubner, A., Hout, J., Whelton, A. J., 2013. Impact of temperature and storage duration on the chemical and odor quality of military packaged water in polyethylene terephthalate bottles. Sci Total Environ. 456–457, 376-383.

Health Canada. 1999. Butylbenzyl Phthalate. Priority Substances List Assessment Report. Canadian Environmental Protection Act. Health Canada. Available at: http://www.hc-sc.gc.ca/ewh-semt/pubs/contaminants/psl2-lsp2/butylbenzylphthalate/index-eng.php.

HPD (Household Products Database). 2015. Household Products Database online. National Library of Medicine, National Institutes of Health. Available at: http://householdproducts.nlm.nih.gov/.

HSDB (Hazardous Substances Data Bank). 2015. Hazardous Substances Data Bank online database, Toxnet Toxicology Data Network. U.S. National Library of Medicine. Available at: http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB.

IARC (International Agency for Research on Cancer), 1982. IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. Some Industrial Chemicals and Dyestuffs. Vol. 29. International Agency for Research on Cancer. Lyon, France. Available at: http://monographs.iarc.fr/ENG/Monographs/vol1-42/mono27.pdf.

IFCS (Intergovernmental Forum on Chemical Safety), 2006. Toys and Chemical Safety: A Thought Starter. Intergovernmental Forum on Chemical Safety. IFCS/Forum-V/03-TS, Budapest, Hungary.

Ionas, A. C., Dirtu, A. C., Anthonissen, T., Neels, H., Covaci, A., 2014. Downsides of the recycling process: Harmful organic chemicals in children's toys. Environ Int. 65, 54-62.

IPCS (International Programme on Chemical Safety). 1999. Butylbenzyl Phthalate (BBP). Vol. 71. International Programme on Chemical Safety, World Health Organization.

Johnson, S., Saikia, N., Sahu, R., 2011. Phthalates in toys available in Indian market. Bull Environ Contam Toxicol. 86, 621-626.

Niino, T., Ishibashi, T., Itoh, T., Sakai, S., Ishiwata, H., Yamada, T., Onodera, S., 2002. Comparison of diisononyl phthalate migration from polyvinyl chloride products into human saliva in vivo and into saliva simulant in vitro. J Health Sci. 48, 277-281.

NIST (National Institute of Standards and Technology). 2015. NIST WebBook. NIST Standard Reference Database Number 69. Available at: http://webbook.nist.gov/.

NTP (National Toxicology Program), 1997. NTP Technical Report on the Toxicology and Carcinogenesis Studies of Butyl Benzyl Phthalate (CAS 85-68-7) in F344/N Rats (Feed Studies). U.S. Department of Health and Human Services. NIH Publication No. 97-3374, Research Triangle Park, NC. Available at: http://ntp.niehs.nih.gov/ntp/htdocs/lt_rpts/tr458.pdf.

NTP (National Toxicology Program). 2000. NTP-CERHR Monograph on the Potential Human Reproductive and Developmental Effects of Butyl Benzyl Phthalate. (BBP). Center for the Evaluation of Risks to Human Reproduction. U.S. Department of Health and Human Services. National Toxicology Program. Available at: http://ntp.niehs.nih.gov/ntp/ohat/phthalates/bb-phthalate/bbp_monograph_final.pdf.

Perez-Feas, C., Barciela-Alonso, M.C., Bermejo-Barrera, P. 2011. Presence of phthalates in contact lens and cleaning solutions. Microchem J. 99, 108-113.

PubChem. 2015. The PubChem online database. National Library of Medicine. Available at: https://pubchem.ncbi.nlm.nih.gov/.

Sigma-Aldrich, 2015. Material Safety Data Sheet. Butyl Benzyl Phthalate. 308501. Sigma-Aldrich. Available at: http://www.sigmaaldrich.com/catalog/product/aldrich/308501?lang=en&region=US.

SPIN (Substances in Preparation in Nordic Countries). 2015. SPIN Database. Danish Environmental Protection Agency. Available at: http://195.215.202.233/DotNetNuke/default.aspx.

Stales, C.A., Peterson, D.R., Parkerton, T.F., Adams, W.J. 1997. The environmental fate of phthalate esters: A literature review. Chemosphere. 35, 667-749.

Stringer, R., Labunska, I., Santillo, D., Johnston, P., Siddorn, J., Stephenson, A., 2000. Concentrations of phthalate esters and identification of other additives in PVC children's toys. Environ Sci Pollut Res Int. 7, 27-36.

U.S. EPA (U.S. Environmental Protection Agency), 1981. An exposure and risk assessment for phthalate esters. EPA-440/4-81-020. NTIS No. PB85-211936. Office of Water Regulations and Standards, U.S. Environmental Protection Agency, Washington, D.C.

U.S. EPA (U.S. Environmental Protection Agency). 1987. Health Effects Assessment for Selected Phthalic Acid Esters. EPA/600/8-88/053. Office of Research and Development. U.S. Environmental Protection Agency. Available at: http://nepis.epa.gov/Exe/ZyNET.exe/2000T8QN.TXT?ZyActionD=ZyDocument&Client=EPA&Index=1986+Thru+1990&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=pubnumber%5E%22600888053%22&QFieldYear=&QFieldMonth=&QFieldDay=&UseQField=pubnumber&IntQFieldOp=1&ExtQFieldOp=1&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C86thru90%5CTxt%5C00000013%5C2000T8QN.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=10&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=p%7Cf&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x#.

U.S. EPA (U.S. Environmental Protection Agency). 2012. Phthalates Action Plan. U.S. Environmental Protection Agency. Available at: http://www.epa.gov/oppt/existingchemicals/pubs/actionplans/phthalates_actionplan_revised_2012-03-14.pdf .

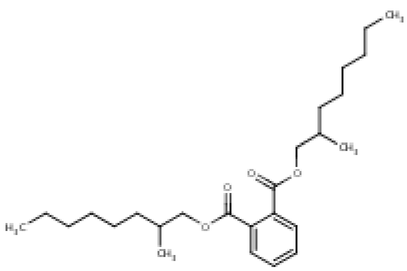
U.S. EPA (U.S. Environmental Protection Agency). 2014. Preliminary Materials for the Integrated Risk Information System (IRIS). Toxicological Review of Butyl Benzyl Phthalate (BBP). EPA/635/R-14/352. National Center for Environmental Assessment. U.S. Environmental Protection Agency. Accessed 1/25/15.

U.S. EPA (U.S. Environmental Protection Agency), 2015. Chemical Safety and Pollution Prevention: Pollution Prevention and Toxics. Vol. 2014. Chemical Data Access Tool (CDAT). Available at: http://java.epa.gov/oppt_chemical_search/.

WSDE (Washington State Department of Ecology ECY). (2015). "Children's Safe Product Act Reported Data." Available at: https://fortress.wa.gov/ecy/cspareporting/.

6 Di-isononyl phthalate (DINP) CASRN: 28553-12-0, 68515-40-0

Di-isononyl phthalate (DINP) is a high molecular weight phthalate dialkyl phthalate ester (NICNAS, 2012; CPSC, 2001) and is a variable mixture of isomers of phthalate esters (IFCS, 2006). This report will focus on two isomers: CASRN 28553-12-0 and CASRN 68515-48-0. The structure of DINP isomer in this report (Pubchem, 2015) is as follows:



6.1 Raw Materials Used in Production of DINP

DINP is a variable mixture made from two separate processes. Therefore, side-chain branches can be asymmetrical and are either C_8H_{17}- $C_{10}H_{21}$ for 'polygas' DINP or C_9H_{19} isomers for n-butene-based DINP (ECHA, 2013). The isomers of DINP can vary in the structure of the alkyl ester side chains, but typically contain 9 carbons with some isomers in the mixture containing 8 or 10 carbons. This mixture of both chain length esters (CAS RN 68515-48-0 and 28553-12-0) are considered interchangeable and is considered together in most assessments (CalEPA, 2013; CPSC, 2001 EU, 2008).

DINP produced by the 'polygas' technique (CASRN 68515-48-0) contains mainly different isomers of dimethyl heptan-1-ol groups derived from octene, and has a majority of alkyl diesters of 9 carbons in length (70% by weight) (ECHA, 2013; CalEPA, 2013). DINP produced from n-butene (CASRN 28553-12-0) contains mainly methyl octanol and dimethyl heptanol groups (ECHA, 2013).

In both processes, DINP is made through esterification of phthalic anhydride and alcohol (either an octene- or n-butene-based alcohol) in a closed system (ECHA 2013; HSDB, 2015; Danish EPA, 2011). The reaction is catalyzed with the presence of an acid or through high temperature (specific catalyst or temperature not specified) (HSDB, 2015). The following chemicals are used as raw materials in the production of DINP (NTP, 2003; HSDB, 2015):

- octene-based alcohols including: 3,4-, 4,6-, 3,6-, 3,5-, 4,5-, and 5,6-dimethyl-heptan-1-ol

- n-butene-based alcohols including: methyloctanols and dimethylheptanols (such as isononyl alcohol)
- phthalic anhydride
- catalyst (not specified)

Synonyms and trade names for DINP are shown in the Table 6-1.

6.2 Chemical and Physical Properties of DINP

DINP is a branched phthalate that is a clear, odorless, oily liquid at room temperature (CPSC, 2010; CalEPA, 2013; HSDB, 2015; Sigma Aldrich, 2015). It is almost insoluble in water, but is soluble in solvents such as acetone, methanol, benzene, and ethyl ether (HSDB, 2015). It has not been known to occur naturally (Health Canada, 1998).

DINP has low volatility, as indicated by its vapor pressure (HSDB, 2015). When a material with DINP is heated to decomposition (temperature not specified), acrid smoke and irritating vapors are emitted (HSDB, 2015). DINP has been reported as incompatible with oxidizing agents in one MSDS (ExxonMobil, 2001) but additional information on incompatibilities could not be found elsewhere (HSDB, 2015).

Table 6-1 summarizes the chemical and physical characteristics of DINP. The data for several of these characteristics varies depending on the source, and likely because DINP is a mixture of variable make-up, meaning the physical and chemical properties are likely to vary.

Table 6-1. Physical/chemical characteristics of DINP

Characteristic	Value	Reference
IUPAC Name	1,2-benzenedicarboxylic acid, di-C8-10-branched alkyl esters, C9-rich; Di-isononyl phthalate; 1,2-benzenedicarboxylic acid, diisononyl ester	ECHA, 2013; CalEPA, 2013; NICNAS, 2012
CASRN	68515-48-0 and 28553-12-0	ECHA, 2013
EC Number	271-090-9 and 249-079-5	ECHA, 2013; EU, 2003
Synonyms and Trade Names	<u>68515-48-0</u> CCRIS 7927; Di(C8-10, C9 rich) branched alkyl phthalates; Di(isononyl) phthalate branched; EC 271-090-9; EINECS 271-090-9; 1,2-Benzenedicarboxylic acid,	ECHA, 2013; HSDB, 2015; ChemIDPlus, 2015; Common Chemistry, 2015

	di-C8-10-branched alkyl esters, C9-rich; Diisononyl phthalate, technical grade; Di(C8-C10) branched alkyl phthalate <u>28553-12-0</u> 1,2-Benzenedicarboxylic acid, 1,2-diisononyl ester; 1,2-Benzenedicarboxylic acid, diisononyl ester; Baylectrol 4200; bis-isononyl phthalate; CCRIS 6195; Diacizer DINP; Diisononyl phthalate; DI-isononyl phthalate; di-"isononyl" phthalate; Di-"isononyl"phthalate; DINP; DINP2; DINP3; EC 249-079-5; EINECS 249-079-5; ENJ 2065; Enj 2065; 1,2-Benzenedicarboxylic acid, diisononyl ester; ftalato de di-"isononilo'; HSDB 4491; Isononyl alcohol, phthalate (2:1); JAY-DINP; Jayflex DINP; Monocizer DINP; Palatinol DINP; Palatinol DN; Palatinol N; Phthalate de diisononyle; phthalate de di-"isononyle"; Phthalate, Diisononyl; Phthalic acid, diisononyl ester; Phthalisocizer DINP; Phthalsaeure-Diisononylester; Sansocizer DINP; UNII-4010KIX4CK; Vestinol 9; Vestinol NN; Vinylcizer 90; Witamol 150.	
Molecular Formula	$C_{26}H_{42}O_4$	CPSC, 2014, 2010; HSDB, 2015
Molecular Weight	418.6 g/mol	CPSC, 2010; CalEPA, 2013; HSDB, 2015

	419 g/mol 420.6 g/mol	CPSC, 2010 CPSC, 2010; EU, 2003
Physical description	Oily, colorless, viscous liquid	CPSC, 2010; CalEPA, 2013; HSDB, 2015
Odor	Odorless	ExxonMobil, 2001
Density	0.972 g/cu m at 20°C/20°C	HSDB, 2015
Solubility in water	0.6 µg/l at 20°C 0.2 mg/L at 20°C <0.001 mg/L (temperature not specified) 3.08×10^{-4} mg/L at 25°C	ECHA, 2013; CPSC, 2010; EU, 2003 HSDB, 2015 CPSC, 2010; CalEPA, 2013 CPSC, 2010
Octanol/Water Partition Coefficient ($\log K_{ow}$)	8.8 9.37 ~9	ECHA, 2013; CPSC, 2010; EU, 2003 CPSC, 2010; HSDB, 2015 CPSC, 2010; CalEPA, 2013
Boiling Point	> 400°C 370°C 252°C at 5 mm Hg	ECHA, 2013; EU, 2003 CPSC, 2010; CalEPA, 2013 HSDB, 2015
Melting Point	ca. -50°C -48°C	ECHA, 2013; CPSC, 2010; EU, 2003 CPSC, 2010; CalEPA, 2013; HSDB, 2015
Vapor Pressure	6×10^{-5} Pa at 20°C 7.2×10^{-5} Pa at 25°C 6.81×10^{-6} Pa at 25°C 6×10^{-8} to 3.8×10^{-5} KPa at 20°C $5.4 \mathrm{X} 10^{-7}$ mm Hg at 25°C	ECHA, 2013; CPSC, 2010; EU, 2003 CPSC, 2010 CPSC, 2010 CalEPA, 2013 HSDB, 2015
Flash Point	> 200°C	ECHA, 2013; CPSC, 2010; EU, 2003

6.3 Worldwide Manufacturing Processes for DINP

There are different production processes for DINP leading to isomeric mixtures of eight to ten carbon alkyl ester chains in different proportions (CalEPA, 2013). The two major types of DINP have separate CASRN (although note that there are multiple additional forms of DINP with different CASRN). DINP CASRN 68515-48-0 is manufactured by the ‘polygas’ process using octene-based alcohols and contains side chains made up of: 5–10% methyl ethyl hexanols, 45–55% dimethyl heptanols, 5–20% methyl octanols, 0–1% n-nonanol, and 15–25% isodecanol. DINP CASRN 28553-12-0 is manufactured using n-butene-based alcohols and contains side chains made up of: 5–10% methyl ethyl hexanols, 40–45% dimethyl heptanols, 35–40% methyl octanols, and 0–10% n-nonanol (ECHA, 2013; CalEPA, 2013; NICNAS, 2012; CPSC, 2001).

Worldwide manufacturers were identified in several sources. DINP is manufactured by two companies in Germany, and one each in The Netherlands, France, and Italy (Danish EPA, 2011). A Chem Sources Online search identified at least 12 U.S. manufacturers and one each in China, Germany, Hong Kong, Mexico, and Switzerland (Chem Sources Online, 2015). HSDB (2015) lists two U.S. manufacturers.

No other information about manufacturers or manufacturing processes in other countries was reported in the specific sources searched for this report.

6.4 Annual Production of DINP

Of the roughly one million tons of phthalates produced each year, 93% are used as PVC plasticizers, to make PVC flexible (ECHA, 2013). DINP is one of three phthalates (including diisodecyl phthalate and dipropylheptyl phthalate) that account for the majority of the C9/C10 class of phthalates in the EU and globally, which as a class are produced at approximately 1,800,000,000 pounds (830,000 tonnes) per year (ECHA, 2013). Global production of DINP has increased consistently since 1994, with an assumed growth rate of 2.5% annually (CalEPA, 2013).

U.S. production of DINP has been estimated at 356,000,000 pounds (178,000 tons) per year (CPSC, 2010). National production volume from CDAT was reported at 100,000,000–250,000,000 lb/yr with at least six companies listed as using or producing DINP (U.S. EPA, 2015).

In the EU, total production volume was 408,000,000 pounds per year (204,000 tonnes) in 1994 (CPSC, 2010). In another 1994 report, the production volume in the EU was 410,000,000 pounds (185,200 tonnes/year) (Danish EPA, 2011). Based on the volume reported from 1964-1994, a steady increase in DINP consumption is seen at an approximate increase of 22,050 pounds (10 tonnes) every five years (Danish EPA, 2011). This trend was confirmed between the years of 1999-2004 with an increase use of DINP from 35% to 58% (Fernandez, 2012). That trend was expected to continue when the source document was published in 2011 (Danish EPA, 2011).

Total manufacturing volume of DINP in Australia was not reported (NICNAS, 2015).

Table 6-2. U.S. Production Volumes for DINP from Non-confidential Chemicals Reported under the Inventory Update Rule

Year	Production Range (pounds)
1986	>1,000,000–10,000,000
1990	>10,000,000–50,000,000
1994	>10,000,000–50,000,000
1998	>10,000,000–50,000,000
2002	>10,000,000–50,000,000
2012	100,000,000–250,000,000

Source: HSDB, 2015

Use of DINP is increasing in Nordic countries, especially in the manufacturing of rubber and plastic products (SPIN, 2015). Sweden, the largest user of the Nordic countries, used 22,000,000 to 29,000,000 pounds (10,000 to 13,000 tonnes) of DINP per year in the years 2004 to 2010 (the usage of DINP has been reduced to <6,000,000 pounds [<2500 tonnes] in recent years) (SPIN, 2015).

Production volumes for other countries were not available in the sources searched for this report.

6.5 Application of DINP in Materials, Consumer Products and Nonconsumer Products

DINP has a wide range of applications as a plasticizer in PVC products, including: toys, construction, and additional consumer products (NTP, 2003). DINP is not used in medical products and is not heavily utilized in food packaging materials (NTP, 2003). Recently, DINP has been used as a substitute for DEHP, once the potential toxicity of DEHP became a concern (IFCS, 2006; Danish EPA, 2011).

At the request of CPSC, U.S. toy manufacturers and importers voluntarily stopped using DINP in teethers, rattles, and bottle nipples. The voluntary action, which became effective in March 1999, applies to products intended to be mouthed; it does not apply to other children's products, such as squeeze toys and rainwear (CPSC, 2001).

6.5.1 Children's Products

DINP is the most common and preferred phthalate used in polyvinyl chloride (PVC) toys to make the toys flexible and soft (IFCS, 2006). We have focused the discussion on toys and other children's products with concentrations greater than 0.1%, but have presented all concentration data we located in tables. In the U.S., DINP has been restricted in toys that can be placed in the mouth since 2009.

Average DINP in toys measures in the range of 20–40%, but has been documented above 50% in some products (CPSC, 2001). It is worth noting that detailed chromatographic analysis of DINP is challenging because DINP is a variable mixture and has a wide chromatographic peak that can overlap with other phthalates.

PVC is heavily used in child care products such as: changing mats, pushchairs, high chairs, baby diaper covers, cribs, playpens, changing table pillows, carrying slings, breastfeeding pillows, car seats; and in toys such as: play mats, inflatable soft plastic aquatic toys, masquerade masks, and sometimes pacifiers (ECHA, 2013). Other items with PVC include gloves, footwear (rain shoes, boots, shoes, shoe insoles, slippers, sandals, 'jelly' sandals), vinyl baby pants, wet weather wear (pants, coats, ponchos, hats) (ECHA, 2013). Classroom and school products can also contain DINP, including erasers (type not specified) and school bags (ECHA, 2013). DINP has been detected (but not quantified) in oilcloths, dinner mats, and child-appealing shower curtains (Danish EPA, 2011). DINP has use in pencil erasing rubber (Danish EPA, 2011).

In a study looking at phthalate concentrations in children's toys in Sri Lanka, DINP was detected in 18 of 30 samples at concentrations from 26–46% (Uththamawadu, 2010). In 24 sampled toy products, DINP (and DIDP, as these were not resolved chromatographically by the method used in the study) was detected in 42% of toys at concentrations from <0.1%–16.2% (Johnson et al., 2011; CSE, 2010). Another study found DINP in pencil erasers ranging from 32–70% (ECHA, 2013). In a large study undertaken by CPSC and published by Babich et al. (2004), DINP was detected in 42% of tested soft children's toys (36 of 85 toys). The DINP concentrations in these toys ranged from 12.9 to 39.4% and averaged 30% (Babich et al., 2004). DINP was detected in 27 of 41 tested toy products from 3.9–44% (CSE, 2010). Further studies found DINP in: 31 of 35 toys at concentrations ranging from 15.1–54.4% (CPSC, 1998); 64% of tested mouthable children's products at concentrations ranging from 3.9–44% (Gill et al., 1999, as cited in CSE, 2010); in 47 PVC toys at concentrations from 30–45% (Bouma and Schakel, 2002); in 48 of 68 tested PVC toys at concentrations from 15–580 mg/g (1.5–58%) (Sugita et al., 2001, as cited in CSE, 2010); in seven tested toys at concentrations from 196–449 mg/g (19.6–44.9%), but DINP was not found in the tested toys designed for mouthing purposes (Niino et al., 2001); and in tested toys at concentrations of 6.4%, 9.5%, and 40% (Hitchcock, 2008, as cited in CSE, 2010). Recent data from the RAPEX database identified DINP in 11 toys at concentrations greater than 0.1%. There were seven plastic dolls, a toy bracelet set, construction toy set, plastic toy set and two bath toys. These data are reported in Table 6-3.

Table 6-3. Children's Products with DINP Detected Greater Than 0.1% (1,000 ppm)

Use	Product	Concentration	Reference
Toys	Toy octopus	73%	CPSC, 2010
Toys	Toy B	58%	Sugita et al., 2003 (as cited in ECHA, 2013)
Toys	Toy duck	15–54%	NICNAS, 2012
Toys	Squeeze Toy	52.5%	CPSC, 1998
Toys	Teether	51.0%	Stringer et al., 2000
Toys	Toy Food	51.0%	CPSC, 1998
Toys	Toys or toy parts	0.4–51%	Stringer, 2000 (as cited in IFCS, 2006)
Toys	Toy Tiger	48.1%	CPSC, 1998
Toys	Doll 15	48%	Bouma and Schakel, 2002
Toys	Bath toys	40 and ≤47%	RAPEX, 2015
Toys	Doll	46.3%	Stringer et al., 2000
Toys	Squeeze toys	26–46%	Uththamawadu, 2010
Toys	Doll 13	45%	Bouma and Schakel, 2002
Toys	Doll 14	45%	Bouma and Schakel, 2002
Toys	Key ring feature 4	45%	Bouma and Schakel, 2002
Toys	Bath toy - clam	44.7%	Stringer et al., 2000
Toys	Toy food	44.1%	Stringer et al., 2000
Toys	Key ring feature 3	44%	Bouma and Schakel, 2002
Toys	Animal toy	43.9%	Stringer et al., 2000
Toys	Bath toy - frog	43.8%	Stringer et al., 2000
Toys	Toy Dolphin	43.7%	CPSC, 1998
Toys	Doll 12	43%	Bouma and Schakel, 2002
Toys	Toy Block	43.0%	CPSC, 1998
Toys	Toy Duck	42.7%	CPSC, 1998
Toys	Toy Car	42.7%	CPSC, 1998
Toys	Toy Duck#2	42.66%	Chen, 1998b (as cited in ECHA, 2013)
Toys	Bath toy 4	42%	Bouma and Schakel, 2002
Toys	Ball	42%	CPSC, 2010b
Toys	Plastic duck	41.7%	Stringer et al., 2000
Toys	Ball	41.2%	CPSC, 1998
Toys	Toy Bear	41.2%	CPSC, 1998
Toys	Toy Duck	40.8%	CPSC, 1998
Toys	Bath toy 3	40%	Bouma and Schakel, 2002

Use	Product	Concentration	Reference
Toys	Toys, 24 samples	12.9–39.4%	Chen, 2002 (as cited in ECHA, 2013)
Toys	Green whale	39.3%	Simoneau et al., 2001 (as cited in Babich et al., 2004)
Toys	Toys	12.9–39.3%	Babich, 2004 (as cited in IFCS, 2006)
Toys	Key ring feature 2	39%	Bouma and Schakel, 2002
Toys	Standard disk	39%	Bouma and Schakel, 2002
Toys	Toy A	39%	Sugita et al., 2003, (as cited in ECHA, 2013)
Toys	Disk	38.5%	NICNAS, 2012
Toys	PVC standard sample	38.5%	ECHA, 2013
Toys	Doll 9	38%	Bouma and Schakel, 2002
Toys	Rattle	38%	NICNAS, 2012
Toys	Rattle	38.0%	Niino et al., 2002
Toys	Toy C	38%	Sugita et al., 2002 (as cited in ECHA, 2013)
Toys	Animal toy	37.9%	Stringer et al., 2000
Toys	Toys or toys parts	30.6–37.9%	Stringer, 2000 (as cited in IFCS, 2006)
Toys	Animal toy	37.7%	Stringer et al., 2000
Toys	Doll 5	37%	Bouma and Schakel, 2002
Toys	Doll 6	37%	Bouma and Schakel, 2002
Toys	Doll 7	37%	Bouma and Schakel, 2002
Toys	Toy Fish	37.0%	CPSC, 1998
Toys	Toy Treehouse	36.1%	CPSC, 1998
Toys	Bath toy 2	36%	Bouma and Schakel, 2002
Toys	Key ring feature 1	36%	Bouma and Schakel, 2002
Toys	Animal toy	35.9%	Stringer et al., 2000
Toys	Tub toy	35.9%	Simoneau et al., 2001 (as cited in Babich et al., 2004)
Toys	Dolls face	35.5%	Simoneau et al., 2001 (as cited in Babich et al., 2004)
Toys	Toy Turtle	35.4%	CPSC, 1998
Toys	Spoon	35.2%	CPSC, 1998
Toys	Ball 2	35%	Bouma and Schakel, 2002

Use	Product	Concentration	Reference
Toys	Spoons	34.3%	CPSC, 1998
Toys	Animal figure 4	34%	Bouma and Schakel, 2002
Toys	Plastic doll (n=7)	0.18-33.9%	RAPEX, 2015 week 3, 9, 18, 20, 22
Toys	Animal toy	33.5%	Stringer et al., 2000
Toys	Aeroplane	33.1%	Stringer et al., 2000
Toys	Doll 4	33%	Bouma and Schakel, 2002
Toys	Bath toy 1	33%	Bouma and Schakel, 2002
Toys	Dolls leg	32.8%	Simoneau et al., 2001 (as cited in Babich et al., 2004)
Toys	Squeeze Toy	32.6%	CPSC, 1998
Toys	Animal toy	32.5%	Stringer et al., 2000
Toys	Dolls face	32.2%	Simoneau et al., 2001 (as cited in Babich et al., 2004)
Toys	Doll 3	32%	Bouma and Schakel, 2002
Toys	Toy or toy parts	31.7%	Stringer, 2000 (as cited in IFCS, 2006)
Toys	Toy food	31.1%	Niino et al., 2002a (as cited in ECHA, 2013)
Toys	Animal toy	31%	Stringer et al., 2000
Toys	Animal toys	30.4%	Stringer et al., 2000
Toys	Doll 2	30%	Bouma and Schakel, 2002
Toys	Inflatable ball	30%	Bouma and Schakel, 2002
Toys	Dolls face	30.0%	Simoneau et al., 2001 (as cited in Babich et al., 2004)
Toys	Yellow duck	29.3%	Simoneau et al., 2001 (as cited in Babich et al., 2004)
Toys	Doll 1	29%	Bouma and Schakel, 2002
Toys	Soft doll B	29%	Niino et al., 2002a (as cited in ECHA, 2013)
Toys	Animal figure 3	28%	Bouma and Schakel, 2002
Toys	Construction toy set	28%	RAPEX, 2015 week 5
Toys	Toy Book	27.5%	CPSC, 1998
Toys	Toy	27.1%	CPSC, 1998
Toys	Animal figure 2	27%	Bouma and Schakel, 2002
Toys	Ball (protrusion)	26.8%	Simoneau et al., 2001 (as cited in Babich et al., 2004)
Toys	Dolls face	26.6%	Simoneau et al., 2001 (as cited in

Use	Product	Concentration	Reference
			Babich et al., 2004)
Toys	Bath toy	26.3%	Stringer et al., 2000
Toys	Toy ball	25.6%	NICNAS, 2012
Toys	Ball C	25.6%	Niino et al., 2002a (as cited in ECHA, 2013)
Toys	Bath toy	25.5%	Stringer et al., 2000
Toys	Ball	25.5%	NICNAS, 2012
Toys	Ball	25.5%	Niino et al., 2002
Toys	Plastic discs	25.5%	TNO, 2010 (as cited in ECHA, 2013)
Toys	Blue doll	25.3%	Simoneau et al., 2001 (as cited in Babich et al., 2004)
Toys	Plastic toy set	≤24.7%	RAPEX, 2015
Toys	Bracelet doll's house	24.3%	Stringer et al., 2000
Toys	Vinyl ball	24.3%	Stringer et al., 2000
Toys	Vinyl ball	24.0%	Stringer et al., 2000
Toys	Gift set - head	23.4%	Stringer et al., 2000
Toys	Baby book	23.2%	Stringer et al., 2000
Toys	Book 3	22.2%	Simoneau et al., 2001 (as cited in Babich et al., 2004)
Toys	Toy Bear	19.9%	CPSC, 1998
Toys	Baby book	19.6%	Stringer et al., 2000
Toys	Inflatable toy	19.6%	Stringer et al., 2000
Toys	Cape 3	19.5%	Simoneau et al., 2001 (as cited in Babich et al., 2004)
Toys	Putty	19%	WSDE, 2015
Toys	30 washable fine point markers	17.5%	WSDE, 2015
Toys	Toy Book	17.5%	CPSC, 1998
Toys	Toy food	17.4%	Stringer et al., 2000
Toys	Baby book	16.4%	Stringer et al., 2000
Toys	Pip Squeaks Toy	16.2% DINP/DIDP	Johnson et al., 2011; CSE, 2010
Toys	Animal figure 1	16%	Bouma and Schakel, 2002
Toys	Soft doll	16%	NICNAS, 2012
Toys	Soft doll A	16%	Niino et al., 2002a

Use	Product	Concentration	Reference
Toys	Doll	15.2%	Peters, 2005 (as cited in IFCS, 2006)
Toys	Plastic disc	15.2%	Simoneau et al., 2009 (as cited in ECHA, 2013)
Toys	Bath Toy	15.1%	CPSC, 1998
Toys	Toy bracelet set	15%	RAPEX, 2015
Toys	Baby book	14.7%	Stringer et al., 2000
Toys	Gift set - squeeze bulb	13.1%	Stringer et al., 2000
Toys	Large reptile	12.9%	Simoneau et al., 2001 (as cited in Babich et al., 2004)
Toys	Plasticine (modelling clay)	10%	NICNAS, 2012
Toys	Doll	8.80%	Stringer et al., 2000
Toys	Action figure	8.6%	Peters 2005 (as cited in IFCS, 2006)
Toys	Squeeze Toy-4	8.0% DINP/DIDP	Johnson et al., 2011; CSE, 2010
Toys	PVC toy	7.67%	Grynkiewicz-Bylin, 2011
Toys	Squeeze Toy-2	7.1% DINP/DIDP	Johnson et al., 2011; CSE, 2010
Toys	Aqua Dive Sea Pals	6.3%	WSDE, 2015
Toys	Squeeze Toy-3; doll	6.2% DINP/DIDP	Johnson et al., 2011; CSE, 2010
Toys	Squeeze Toy-1	6.0% DINP/DIDP	Johnson et al., 2011; CSE, 2010
Toys	Doll	4.5% DINP/DIDP	Johnson et al., 2011; CSE, 2010
Toys	Inflatable-1; soft whale	4.4% DINP/DIDP	Johnson et al., 2011; CSE, 2010
Toys	Toy	4.13%	Grynkiewicz-Bylin, 2011
Toys	Various toys	3.1% mean (1.5–58% range)	Sugita, 2001 (as cited in IFCS, 2006 and CSE, 2010)
Toys	Toy	2.6%	WSDE, 2015
Toys	Rubber duck	2.3%	Stringer, 2001 (as cited in IFCS, 2006)
Toys	Squeeze toy	2.0%	Stringer, 2001 (as cited in IFCS, 2006)

Use	Product	Concentration	Reference
Toys	Modeling material	1.8%	Peters, 2003 (as cited in IFCS, 2006)
Toys	Toy	1.62%	Grynkiewicz-Bylin, 2011
Toys	PVC toy	1.08%	Grynkiewicz-Bylin, 2011
Toys	Bath toy	0.7%	Peters, 2003 (as cited in IFCS, 2006)
Toys	PVC toy	0.70%	Grynkiewicz-Bylin, 2011
Toys	Inflatable toy	0.4%	Stringer et al., 2000
Toys	Decorative plastic panel on backpack	0.3%	PIRG, 2014
Toys	Body mist	0.28%	WSDE, 2015
Toys	Toy	0.25%	WSDE, 2015
Toys	Light-up toy	0.24%	WSDE, 2015
Toys	Neon Sticky Eyeballs	0.23%	WSDE, 2015
Toys	100 assorted sticky items	0.23%	WSDE, 2015
Toys	Frog Splat Ball	0.22%	WSDE, 2015
Toys	Stretchy Sticky Bugs	0.21%	WSDE, 2015
Toys	Squigglets Bracelet	0.21%	WSDE, 2015
Toys	Baby books	0.2%	Cassidy, 2005 as cited in IFCS, 2006
Toys	Doll	0.2% DINP/DIDP	Johnson et al., 2011
Toys	Pony Toy	0.2% DINP/DIDP	Johnson et al., 2011
Toys	Sticky Icky Creatures	0.2%	WSDE, 2015
Toys	Gel Stickers, summer collection	0.2%	WSDE, 2015
Toys	Rubber toy	0.2%	WSDE, 2015
Toys	Egg Splat	0.19%	WSDE, 2015
Toys	Squirty bath toys	0.15%	WSDE, 2015
Toys	Twistable crayons, 24	0.15%	WSDE, 2015
Toys	Rubber duck	0.1%	PIRG, 2014
Toys	Squeeze ball	0.01%	Stringer, 2001 (as cited in IFCS,

Use	Product	Concentration	Reference
			2006)
Toys	Pink pig	0.01%	Cassidy, 2005 (as cited in IFCS, 2006)
Toys	Doll	<0.1% DINP/DIDP	CSE, 2010
Toys	Pony Toy	<0.1% DINP/DIDP	CSE, 2010
Child care article	Pacifier	58.3%	NICNAS, 2012
Child care article	Pacifier	58.3%	Niino et al., 2002a
Child care article	Plate	16–58.3%	NICNAS, 2012
Child care article	Teether	54%	CPSC, 1998
Child care article	Teether #5	54%	Chen, 1998a (as cited in ECHA, 2013)
Child care article	Teether	50.3%	CPSC, 1998
Child care article	Teether #6	50%	Chen, 1998a (as cited in ECHA, 2013)
Child care article	Plate A	48.8%	Niino et al., 2002a (as cited in ECHA, 2013)
Child care article	Plate	46.2%	Niino et al., 2002b
Child care article	Teething ring	45%	Bouma and Schakel, 2002
Child care article	Corner Pads	44.0%	CPSC, 1998
Child care article	Teether/pacifier	43.8%	Stringer, 2000 (as cited in IFCS, 2006)
Child care article	Teether	43.3%	CPSC, 1998
Child care article	Teething ring	43%	NICNAS, 2012
Child care article	Teething #3	43%	Chen,1998a (as cited in ECHA, 2013)
Child care article	Teethers	40%	CPSC, 2010
Child care article	Corner cushion	39.4%	Simoneau et al., 2001 (as cited in Babich et al., 2004)
Child care article	Teether	38.9%	NICNAS, 2012
Child care article	Teether	38.9%	Niino et al., 2002a
Child care article	Key teether - soft section	38.1%	Stringer et al., 2000
Child care article	Teether	37.9%	Stringer et al., 2000
Child care article	teether	37.6%	Stringer et al., 2000
Child care article	Teether	37.2%	Stringer et al., 2000

Use	Product	Concentration	Reference
Child care article	Teether	37.2%	Stringer et al., 2000
Child care article	Teether #1	37%	Chen 1998a, (as cited in ECHA, 2013)
Child care article	Teether	36.6%	CPSC, 1998
Child care article	Teether	36.3%	Stringer et al., 2000
Child care article	Teethers	36%	NICNAS, 2012
Child care article	Teether	36%	CPSC, 2001
Child care article	Yellow teether	36%	Fiala et al., 1998, 2000 (as cited in ECHA, 2013)
Child care article	Teether	35.7%	Stringer et al., 2000
Child care article	Teether	35.3%	Stringer et al., 2000
Child care article	Teether	34.6%	Stringer et al., 2000
Child care article	Inflatable cushion	34%	Bouma and Schakel, 2002
Child care article	Teether	33.5%	CPSC, 1998
Child care article	Teether #4	33%	Chen (1998a), as cited in ECHA, 2013
Child care article	Sheet	32%	NICNAS, 2012
Child care article	Teether	31.7%	Stringer et al., 2000
Child care article	Inflatable cushion	31%	Bouma and Schakel, 2002
Child care article	Gift set- teether	30.7%	Stringer et al., 2000
Child care article	Teether	30.6%	Stringer et al., 2000
Child care article	Soother	30.2%	CPSC, 1998
Child care article	Teether	30.0%	CPSC, 1998
Child care article	Teether #2	30%	Chen 1998a (as cited in ECHA, 2013)
Child care article	Blue seat	29.4%	Simoneau et al., 2001 (as cited in Babich et al., 2004)
Child care article	Teether	29.2%	Stringer et al., 2000
Child care article	Teether	20.8–28.7%	Harmon, 2001 (as cited in IFCS, 2006)
Child care article	Teether	27.7%	Stringer et al., 2000
Child care article	Teether #7	26%	Chen,1998a (as cited in ECHA, 2013)
Child care article	Teether	25.6%	CPSC, 1998
Child care article	Teether	19.3%	CPSC, 1998
Child care article	Teether #8	19%	Chen, 1998a (as cited in ECHA, 2013)

Use	Product	Concentration	Reference
Child care article	Baby changing mats/cushions	15%	NICNAS, 2012
Child care article	Pillow protector	2.9%	WSDE, 2015
Child care article	Swim Ring	2.5%	Stringer, 2001 (as cited in IFCS, 2006)
Child care article	Waterproof pouches	2.5%	WSDE, 2015
Child care article	Peanut butter tennis balls (2)	2.01%	WSDE, 2015
Child care article	Eau de toilette	1.54%	WSDE, 2015
Child care article	Pink/purple polka dot bag	1.22%	WSDE, 2015
Child care article	Cover of pacifiers	0.1%	NICNAS, 2012
Child care article	Angel tip eyeshadow brush	0.1%	WSDE, 2015
Child care article	Pillow protector	0.1%	WSDE, 2015
Child care article	Soft & Hard Biter	<0.1% DINP/DIDP	Johnson et al., 2011; CSE, 2010
Toys and Child care article	Teethers, toys	15.1–54.4%	NICNAS, 2012
Toy and Child care article	Toys, teethers	21.0–46.6%	CPSC, 2001
Toys and Child care article	Toys, teethers, 10 samples	21.0–46.6%	Rijk and Ehlert, 1999; Rijk et al. 1999 (as cited in ECHA, 2013)
Toys and Child care article	Teether, toys, pacifiers, 27 samples	4–44%	Health Canada, 1998 (as cited in ECHA, 2013)
Toys and Child care article	Teethers, toys, pacifiers	3.9–44%	CPSC, 2001
Toys and Child care article	Toys, teethers	26–41.7%	Simoneau et al. (2001), as cited in ECHA, 2013
Toys and child care articles	PVC plasticized toys and child care articles; detected in 3 articles	2.30–3.19%	Al-Natsheh et al., 2015
Children's Product	Swimming tool 1	31%	Bouma and Schakel, 2002
Children's	Rucksack	23–27%	Bouma and Schakel, 2002

Use	Product	Concentration	Reference
Product			
Children's Product	Yellow vinyl basket	15.7–17.2%	WSDE, 2015
Children's product	pencil case	0.2%	Stringer, 2001 (as cited in IFCS, 2006)

*Concentrations < 0.1% are shaded.

The State of Washington Department of Ecology under the 2008 Washington Children's Safe Product Act, has been testing consumer products for toxic chemicals and receiving and posting data from manufacturers on children's products sold in Washington if their product contains a chemical of high concern, such as phthalates. Of the 237 products tested for DINP, 40 products contained DINP over the reporting limit (50 ppm) with 14 of these items at greater than 0.1% (1000 ppm). The item of maximum concentration was from the bottom of a baby sandal that had 44% (443,000 ppm) DINP. The items with concentrations above 1000 ppm are listed in Table 6-3.

From the manufacturers, the State of Washington received a list of children's products that contain a "Chemical of High Concern" to children. There were a total of 328 items that contained DINP. Of these 328 items, two items contained DINP (equal to or greater than 0.1% but less than 0.5%), two items contained DINP equal to or greater than 0.5% but less than 1%, 88 items contained DINP equal to or more than 1%, and the remaining 236 items contained DINP less than or equal to 0.1%.

6.5.2 Other Products

DINP is a general purpose plasticizer. This means that DINP use is widespread in plastic products (ACC, 2010). Uses include: PVC film and sheeting, fabrics, coatings, electrical and PVC insulation, and vinyl flooring (ACC, 2010; Danish EPA, 2011). Due to high use levels of DINP in PVC, PVC products are anticipated to contain DINP (ECHA, 2013). For example, high use of DINP was reported in PVC flooring, with concentrations reported at ≤22.0% (Danish EPA, 2011). A number of non-PVC uses were reported for items in the Swedish market, but none of those products were accessible to consumers and so are not reported here (Danish EPA, 2011). Other consumer products include shower curtains, stationary, gloves, tubing, garden hoses, artificial leather, footwear, and roofing materials (ECHA, 2013; CalEPA, 2013). Other products include non-PVC inks, pigments, rubbers, adhesives, sealants, paints, lacquers, lubricants, and carpet tiles (ECHA, 2013; CalEPA, 2013; Danish EPA, 2011). One study (Pocas, 2010) reports levels of DINP has high as 21% in paper food packaging (1/20 samples), which authors suggest may be a result of phthalates as solvents in inks, pigments, or paints left over from recycled paperboard. A major use was reported for DINP in wallpaper/wall covering manufacture (Danish EPA, 2011). One company reported using DINP in air mattress production, but the concentration was not reported (Danish EPA, 2011). Other consumer product uses include footwear and fitness balls (Danish EPA, 2011). Concentrations in sex toys were reported to contain DINP at concentrations ranging from 18–77% (ECHA, 2013).

Table 6-4. Consumer Products that contain DINP

Use	**Product**	**DINP Concentration**	**Reference**
Home maintenance	Paints	5.5% (55,000 mg/kg)	CPSC, 2010
Home maintenance	Adhesives, glues and sealing compounds	5.46% (54,600 mg/kg)	CPSC, 2010
Home maintenance	Paint roller	4.3%	WSDE, 2015
Home maintenance	Paint/coating, aerosol	4% (40,000 µg/g)	CPSC, 2014
Consumer product	Sex toys	39% (average); 77% (maximum)	VWA, 2009 (as cited in ECHA, 2013)
Consumer product	Sex toys, 8 samples	27% (average); 55% (maximum)	VWA, 2009 (as cited in ECHA, 2013)
Consumer product	Gloves	42.9% (429,000 mg/kg)	CPSC, 2010
Consumer product	PVC flooring	≤22.0%	Danish EPA, 2011
Consumer product	Bags with PVC content, in general (no further information provided)	11% (Mix of DINP and DIDP)	Danish EPA, 2011
Consumer product	Soap packaging	8.8%	NICNAS, 2012
Consumer product	Shower curtain	8.6% (Mix of DINP and DIDP)	Danish EPA, 2011
Consumer product	Transparent tablecloth (PVC	3.2%	Danish EPA, 2011

Use	Product	DINP Concentration	Reference
	film)		
Consumer product	“Relaxation and hygiene products” per author	1.46%	Grynkiewicz-Bylin, 2011
Clothing, footwear	Baby sandals	44.3%	WSDE, 2015
Clothing	Mittens	8.6%	NICNAS, 2012
Clothing, footwear	Sandals, flip-flops	up to 3.2%	Danish EPA, 2011
Clothing, footwear	Baby sandals	1.86%	WSDE, 2015
Other	Erasers	70%	NICNAS, 2012
Other	Erasers	32–70%	ECPI, 2009; ECHA, 2013
Other	Erasing rubber	32 % DINP/DIDP mixture	Danish EPA, 2011
Other	Paint roller	4.3%	WSDE, 2015
Personal Care Product	Herbal conditioner	0.1%	WSDE, 2015

6.6 Routes of Introduction of DINP into Phthalate-free Material

DINP’s high boiling point and low vapor pressure contributes to its physical stability and resistance to migration from polymers (HSDB, 2015). However, because DINP is not incorporated into the products themselves (non-covalently bound), leaching can occur under normal use conditions (IPCS, 2006; ECHA, 2013). The plasticizer itself is inserted between the polymer chains using Van der Waals electrostatic forces (ECHA, 2013). Leaching can occur through volatilization, extraction into a liquid (lipids are more likely for extraction, because phthalates are lipophilic), or migration to a solid – but these mechanisms ultimately depend on the environmental conditions (ECHA, 2013). Conditions that are expected to induce or increase leaching of DINP from toys include heat, agitation, friction, impaction, concentration level and gradient, contact duration, toy aging, and deteriorating condition of the toy itself (IFCS, 2006; ECHA, 2013). Leaching of the plasticizer from long-life products results in decreased flexibility and brittleness of the product over time (ECHA, 2013). Migration of DINP from materials can occur through mouthing behaviors and depend upon: migration rate, time and method of mouthing, swallowing behavior, and bioavailability from saliva (EU, 2008). Specifically, plasticizer migration from PVC products can occur via volatilization into the air, extraction into a liquid, migration into a solid, or exudation, and will depend on the type of polymer, concentration of DINP, homogeneity of the product, and test conditions (Marcilla et al., 2008). Diffusion coefficients for DINP and other phthalates in PVC, PS were calculated in Marcilla et al. (2008), who found that within plasticizer families diffusion was heavily dependent upon compound molecular weight, with lower molecular weight compounds having higher diffusion rates. However, a study by Al-Natsheh et al. (2015) found no migration of DINP detected in three toy products into simulated saliva. Many researchers have found that migration rate of DINP is not correlated to DINP concentration in the product, and that migration is likely more related to product design (Wilkinson and Lamb, 1999).

Evidence of DINP migration out of containers and into shower and bath gel products has been reported (Amberg-Muller et al., 2010). Initial sampling of shower and bath gels had DINP concentrations ranging from 0.05–0.95% (500 – 9,500 ppm); but these concentrations increased 130% (up to 900 and 13,200 ppm or 0.1%–1.3%) after 6 months of storage at room temperature to 0.09–1.32% (900 – 13,200 ppm) (Amberg-Muller et al., 2010). DINP has been shown to migrate into artificial saliva, and methods to measure migration into artificial saliva have been developed and validated for children's mouthing of PVC articles (CPSC, 2014). Another potential route of DINP migration out of plastic includes through human sweat (ECPI, 2009).

DINP is expected to be found in household dust. DINP vapors and/or particles can be emitted from PVC flooring, wall coverings, and other DINP containing materials (ECHA, 2013). These vapors adsorb to particulates in the air (ECHA, 2013). Concentrations of DINP in dust are difficult to find in the literature; a few levels were reported at 0.01% (129 mg/kg) and a mean of 0.06% (639 mg/kg), with a 95th percentile of 0.19% (1,930 mg/kg) (ECHA, 2013).

6.7 References

ACC (American Chemistry Council). 2010. Before The Chronic Hazard Advisory Panel On Phthalates and Phthalate Substitutes. Public Comment Session, July 26, 2010. Comments Of The Phthalate Esters Panel Of The American Chemistry Council. American Chemistry Council. Available at: http://www.cpsc.gov/PageFiles/126406/accComments.pdf.

Al-Natsheh, M., Alawi, M., Fayyad, M., Tarawneh, I., 2015. Simultaneous GC-MS determination of eight phthalates in total and migrated portions of plasticized polymeric toys and childcare articles. J Chromatogr B Analyt Technol Biomed Life Sci. 985, 103–109.

Amberg-Muller, J.P., Hauri, U., Schlegel, U., Hohl, C., Bruschweiler, B.J. 2010. Migration of phthalates from soft PVC packaging into shower and bath gels and assessment of consumer risk. J Verbr Lebensm. 5, 429-442.

Babich, M. A., Chen, S. B., Greene, M. A., Kiss, C. T., Porter, W. K., Smith, T. P., Wind, M. L., Zamula, W. W., 2004. Risk assessment of oral exposure to diisononyl phthalate from children's products. Regul Toxicol Pharmacol. 40, 151–167. (As cited in IFCS, 2006).

Bouma, K., Schakel, D. J., 2002. Migration of phthalates from PVC toys into saliva simulant by dynamic extraction. Food Addit Contam. 19, 602-610.

Cal EPA (California Environmental Protection Agency), 2013. Evidence on the carcinogenicity of Diisononyl Phthalate (DINP). Office of Environmental Health Hazard Assessment's (OEHHA), Reproductive and Cancer Hazard Assessment Branch. Cal EPA, California, 2013.

Cassidy A. 2005. 20th Annual Toy Safety Survey, Trouble in Toy Land. U.S. PIRG, Educational Fund, Washington DC. (As cited in IFCS, 2006).

ChemIDPlus. 2015. Di-isononyl phthalate (DINP), CASRN 28553-12-0 and 68515-48-0. A TOXNET database. U.S. National Library of Medicine. Bethesda, MD. Available at: http://www.chem.sis.nlm.nih.gov/chemidplus/.

Chem Sources Online. 2015. Chem Sources Online database. Chem Sources International, Inc. Available at: http://www.Chemsources.com/chemonline.html.

Chen, S. B., 1998a. Laboratory Sciences Report on the migration of diisononyl phthalate from polyvinyl chloride children's products. U.S. Consumer Product Safety Commission, Washington, DC. (As cited in ECHA, 2013).

Chen, S. B., 2002. Screening of toys for PVC and phthalates migration. U.S. Consumer Product Safety Commission, Bethesda, MD. (As cited in ECHA, 2013).

Common Chemistry. 2015. CAS presents "Common Chemistry" online database. American Chemical Society. Available at: http://www.commonchemistry.org/.

CPSC (U.S. Consumer Product Safety Commission). 1998. The risk of chronic toxicity associated with exposure to diisononyl phthalate (DINP) in children's products. Directorate for Epidemiology and Health Sciences. U.S. Consumer Product Safety Commission. Bethesda, MD

CPSC (U.S. Consumer Product Safety Commission). 2001. Chronic hazard advisory panel on diisononyl phthalate (DINP). Directorate of Health Sciences, U.S. Consumer Product Safety Commission. Bethesda, MD.

CPSC (U.S. Consumer Product Safety Commission). 2010. Review of Exposure Data and Assessments for Selected Dialkyl Ortho-Phthalates. Consumer Product Safety Commission, CPSC-D-06-0006, Bethesda, MD.

CPSC (U.S. Consumer Product Safety Commission). 2010b. Memorandum to Michael A. Babich, Ph.D., Project Manager for Phthalates, Phthalates Section 108 of CPSIA (Consumer Product Safety Improvement Act). Phthalate and Phthalate Substitutes in Children's Toys. U.S. Consumer Product Safety Commission, Bethesda, MD.

CPSC (U.S. Consumer Product Safety Commission). 2014. Appendix E1 Modeling Consumer Exposure to Phthalate Esters. Chronic Hazard Advisory Panel (CHAP) on Phthalates and Phthalate Alternatives. Bethesda, MD.

CSE (Center for Science and Environment), 2010. Phthalates in Toys. Center for Science and Environment. CSE/PML/PR-36/2010, New Delhi, India.

Danish EPA (Danish Environmental Protection Agency). 2011. Annex XV Restriction Report: Proposal for a Restriction of DEHP, BBP, DBP, DIBP. Danish Environmental Protection Agency, Copenhagen K, Denmark.

ECHA (European Chemicals Agency). 2013. Evaluation of new scientific evidence concerning DINP and DIDP in relation to entry 52 of Annex XVII to REACH Regulation (EC) No 1907/2006. Final review report. European Chemicals Agency Helsinki, Finland.

ECPI (European Council for Plasticisers and Intermediates). 2009. Review of Recent Scientific Data on Di-isononyl Phthalate (DINP) and Risk Characterisation for its use in Toys and Childcare articles. Technical report 2009-0601-DINP, European Council for Plasticisers and Intermediates (ECPI).

EU (European Union). 2003. 1,2-Benzene Dicarboxylic Acid, Di-C8-10-Branched Alkyl Esters, C9-Rich and Di-"Isononyl" Phthalate (DINP). Summary Risk Assessment Report- Final Report. European Commission- Joint Research Centre, Institute for Health and Consumer Protection, France.

EU (European Union). 2008. Opinion on phthalates in school supplies. European Commission. Health & Consumer Protection Director General, Scientific Committee on Health and Environmental Risks. Brussels.

ExxonMobil. 2001. High Production Volume (HPV) Chemical Challenge Test Program Test Plan For The Phthalate Esters Category. ExxonMobil Biomedical Sciences, Inc.

Fernandez, M. A., Gomara, B., Gonzalez, M. J., 2012. Occurrence of Phthalates and their metabolites in the environment and human health implications. Emerging Organic Contaminants and Human Health. The Handbook of Environmental Chemistry. 20, 307-336.

Fiala, F., Steiner, I., Kubesch, K., 1998. Migration of di-(2-ethylhexyl)phthalate (DEHP) and diisononyl phthalate (DINP) from PVC articles. Institute of Food Chemistry and Food Technology of Vienna University of Technology and Consumer Council of Austrian Standards Institute, Vienna. Available at: http://www.verbraucherrat.at/download/phthalates2.pdf. (As cited in ECHA, 2013).

Fiala, F., Steiner, I., Kubesch, K., 2000. Migration of di-(2-ethylhexyl)phthalate (DEHP) and diisononyl phthalate (DINP) from PVC articles. Deutsche Lebensmittel-Rundschau. 96, 51-57. (As cited in ECHA, 2013).

Gill, U.S., LaLonde, P.J., Chantal, P.D., Subramanian, K.S. 1999. Analysis of diisononyl phthalate in PVC consumer products used by children. Int J Injury Cont Safe Prom. 6, 223-234. (As cited in IFCS, 2006).

Grynkiewicz-Bylina, B. 2011. Dangerous phthalates in children's environment. Ecol Chem Eng S. 18, 456-463.

Harmon, M. E. 2001. This Vinyl House; Hazardous Additives in Vinyl Consumer Products and Home Furnishings Greenpeace U.S. Available at: http://www.greenpeace.org/raw/content/international/press/reports/chemical-additives-in-consumer.pdf; http://www.toysafety.net/2005/troubleintoyland2005.pdf. (As cited in IFCS, 2006).

Health Canada. 1998. Updated Risk Assessment On Diisononyl Phthalate In Vinyl Children's Products. Consumer Products Division, Product Safety Bureau, Environmental Health Directorate, Health Protection Branch. Ottawa, Ontario. (As cited in ECHA, 2013).

Hitchcock, L. 2008. 23rd Annual Toy Safety Surveys: Trouble in Toyland. U.S. PIRG, Educational Fund, Washington, D.C. (As cited in CSE, 2010).

HSDB (Hazardous Substances Data Bank). 2015. Hazardous Substances Data Bank online database, Toxnet Toxicology Data Network. U.S. National Library of Medicine. Available at: http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB.

IFCS (Intergovernmental Forum on Chemical Safety), 2006. Toys and Chemical Safety: A Thought Starter. Intergovernmental Forum on Chemical Safety. IFCS/Forum-V/03-TS, Budapest, Hungary.

Johnson, S., Saikia, N., Sahu, R., 2011. Phthalates in toys available in Indian market. Bull Environ Contam Toxicol. 86, 621–626.

Marcilla, A., Garcia, S., Garcia-Quesada, J. C., 2008. Migrability of PVC plasticizers. Polym Test. 27, 221–233.

NICNAS (National Industrial Chemicals Notification and Assessment Scheme). 2008. Phthalates Hazard Compendium. A summary of physicochemical and human health hazard data for 24 ortho-phthalate chemicals. Existing Chemical Hazard Assessment Report. Department of Health and Ageing. National Industrial Chemicals Notification and Assessment Scheme. Available at: http://www.nicnas.gov.au/__data/assets/pdf_file/0008/4958/Phthalate-Hazard-Compendium.pdf.

NICNAS (National Industrial Chemicals Notification and Assessment Scheme). 2012. Diisononyl Phthalate. Priority Existing Chemical Assessment Report No. 35. Department of Health and Ageing, National Industrial Chemicals Notification and Assessment Scheme.

Niino, T., Ishibashi, T., Itho, T., Sakai, S., Sugita, T., Ishiwata, H., Yamada, T., Onodera, S., 2001. Analysis of phthalate ester plasticizers in polyvinyl chloride children's toys, after 1998. Jpn. J. Food Chem. 8.

Niino, T., Ishibashi, T., Itoh, T., Sakai, S., Ishiwata, H., Yamada, T., Onodera, S., 2002a. Comparison of diisononyl phthalate migration from polyvinyl chloride products into human saliva in vivo and into saliva simulant in vitro. J Health Sci. 48, 277-281.

Niino, T., Asakura, T., Ishibashi, T., Itoh, T., Sakai, S., Ishiwata, H., Yamada, T., Onodera, S., 2002b. A simple and reproducible testing method for dialkyl phthalate migration from polyvinyl chloride products into saliva simulant. J Food Hyg Soc Japan. 44, 13-18. (As cited in ECHA, 2013).

NTP (National Toxicology Program). 2003 Center for the Evaluation of Risks to Human Reproduction (NTP-CERHR). NTP-CERHR Monograph on the Potential Human Reproductive and Developmental Effects of Di-isononyl Phthalate (DINP). NIH Publication No 03-4484.

Peters, R. J. B., 2003. Hazardous Chemicals in Consumer Products. TNO Netherlands Organisation for Applied Scientific Research. The Netherlands. (As cited in IFCS, 2006).

Peters, R. J. B., 2005. Chemical Additives in Consumer Products. TNO-report R&I=A R 2005/066. by TNO Environment and Geosciences: The Netherlands. (As cited in IFCS, 2006).

PIRG (U. S. Public Interest Research Group), Ridlington, E., Van Heeke, T., Frontier Group, 2014. Trouble in Toyland: The 29th Annual Survey of Toy Safety. Mierzwinski, U.S. PIRG Education Fund, (Ed.), Washington, D.C.

Pocas, M.F., Oliveira, J.C., Pereira, J.R., Hogg, T. 2010. Consumer exposure to phthalates from paper packaging: an integrated approach. Food Addit Contam. 27(10), 1451-1459.

RAPEX. 2015. Rapid Alert System for dangerous non-food products. Latest Reports Online database. European Commission. Available at: http://ec.europa.eu/consumers/safety/rapex/alerts/main/index.cfm?event=main.listNotifications.

Rijk, M. A. H., Telman, J., Ehrlert, K., 1999. Addendum to TNO Report V99.598. Validation of the Method Determination of Diisononylphthalate in Saliva Stimulant. TNO Nutrition and Food Research Institute, Ultrechtseweg, The Netherlands. (As cited in ECHA, 2013).

Sigma-Aldrich, 2015. Material Safety Data Sheet. Diisononyl Phthalate. 376663. Sigma-Aldrich. Available at: http://www.sigmaaldrich.com/catalog/product/aldrich/376663?lang=en&region=US.

Simoneau, C., Geiss, H., Roncari, A., Zocchi, P., Hannaert, P., 2001. Validation of methodologies for the release of di-isononylphthalate (DINP) in saliva simulant from toys. European Commission, DG-Joint Research Center, Food Products Unit, Institute for Health and Consumer Protection, Ispra, Italy. 2001 EUR 19826 EN. (As cited in CPSC 2010).

Simoneau, C., Rijk, C., 2001. Standard Operation Procedure for the determination of release of di-isononyl phthalate (DINP) in saliva simulant from toys and childcare articles using a head over heels dynamic agitation device". EUR Technical Report EUR 19899 EN. (As cited in ECHA, 2013).

Simoneau, C., Hannaert, P., Sarigiannis, D., (Ed). 2009. Effect of the nature and concentration of phthalates on their migration from PVC materials under dynamic simulated conditions of mouthing. European Commission. Joint Research Centre. Institute for Health and Consumer Protection. France. (As cited in ECHA, 2013).

SPIN (Substances in Preparation in Nordic Countries). 2015. SPIN Database. Danish Environmental Protection Agency. Available at: http://195.215.202.233/DotNetNuke/default.aspx.

Stringer, R., Labunska, I., Santillo, D., Johnston, P., Siddorn, J., Stephenson, A. 2000. Concentrations of phthalate esters and identification of other additives in PVC children's toys. Environ Sci Pollut Res Int. 7, 27-36. (As cited in IFCS, 2006).

Stringer, R., Johnson, P., Erry, B. 2001. Toxic chemicals in a child's world: an investigation of PVC plastics products. Greenpeace Research Laboratories, University of Exeter. Exeter, UK. (As cited in IFCS, 2006).

Sugita, T., Hirayama, K., Nino, R., Ishibashi, T., Yamada, T., 2001. Contents of phthalate in polyvinyl chloride toys. Shokuhin Eiseigaku Zasshi. 42, 48-55. (As cited in IFCS, 2006 and CSE, 2010).

Sugita, T., Kawamura, Y., Tanimura, M., Matsuda, R., Niino, T., Ishibashi, T., Hirabahashi, N. Matsuki, Y., Yamada, T., Maitani, T., 2003. Estimation of daily oral exposure to phthalates derived from soft polyvinyl chloride baby toys. Shokuhin Eiseigaku Zasshi. 44(2): 96-102. [Article in Japanese] Source National Institute of Health Sciences: 1-18-1, Kamiyoga, Setagaya-ku, Tokyo 158-8501, Japan. Reviewed by CPSC number V99.849. (As cited in ECHA, 2013).

TNO, 2010. Analytical Report Prepared for ExxonMobil Petroleum & Chemicals. Machelen, Belgium. (As cited in ECHA, 2013).

U.S. EPA (U.S. Environmental Protection Agency), 2015. Chemical Safety and Pollution Prevention: Pollution Prevention and Toxics. Vol. 2014. Chemical Data Access Tool (CDAT). Available at: http://java.epa.gov/oppt_chemical_search/.

Uththamawadu, D. P., Wijesekera, R. D., Rajasingham, S. L. 2010. A Study of Human Exposure to Selected Phthalates in Toys in Sri Lanka. Department of Chemistry, University of Colombo, Vauxhall St, Colombo.

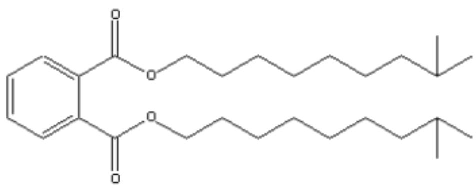
VWA, (Voedsel en Waren Autoriteit) 2009. Consumentenproducten in de eroticabranche. Fact sheet. Voedsel en Waren Autoriteit (VWA), Afdeling Signalering en Ontwikkeling, Regio Noord, Juni. (As cited in ECHA, 2013).

Wilkinson, C. F., Lamb, J. C., 1999. The potential health effects of phthalate esters in children's toys: A review and risk assessment. Regul Toxicol Pharmacol. 30(1), 140-155.

WSDE (Washington State Department of Ecology ECY). (2015). "Children's Safe Product Act Reported Data." Available at: https://fortress.wa.gov/ecy/cspareporting/.E

7 Diisodecyl phthalate (DIDP) CASRN: 26761-40-0, 68515-49-1

DIDP is a high molecular weight, dialkyl ortho phthalate (NICNAS, 2015; CPSC 2010). It is a mixture containing mostly C10 branched isomers including tri-methyl heptanols, di-methyl octanols, methyl nonanols, and octanols. The di-methyl octanols are the majority of the alcohol chains (ECHA, 2012). DIDP has two CAS numbers: the CASRN for DIDP is 26761-40-0, whereas the CASRN 68515-49-1 is for the mixture of C9-C11 branched phthalates. For market uses, the two phthalates are considered interchangeable; the EU does not distinguish between the two forms of DIDP (ECHA, 2013). One possible structure is as follows (CPSC, 2010):



7.1 Raw Materials Used in Production of DIDP

DIDP is manufactured by reaction of phthalic anhydride and isodecanol using an acid catalyst (HSDB, 2015).

The following chemicals are used as raw materials in the production of DIDP:

- phthalic anhydride
- isodecanol
- acid catalyst (not specified)

Commercially, DIDP is not a pure compound, but refers to a mixture of phthalates with an average side chain length of 10 (HSDB, 2015). Synonyms and trade names for DIDP are shown in the Table 7-1.

7.2 Chemical and Physical Properties of DIDP

DIDP is a clear, oily, viscous liquid with a mild odor and low flammability (ECHA, 2013). It has a low vapor pressure compared to other phthalates with lower molecular weights (NICNAS, 2015). It also has a long carbon chain resulting in a high octanol-water partition coefficient compared to other phthalates, meaning it is more soluble in lipophilic substances (NICNAS, 2015). Variations in physical and chemical properties are due to the difference in C10 branching between batches (ECHA, 2012).

Table 7-1. Physical/Chemical Characteristics of DIDP

Property	**Value**	**Source**
IUPAC Name	bis(8-methylnonyl) benzene-1,2-dicarboxylate	PubChem, 2015
CASRN	26761-40-0, 68515-49-1	ECHA, 2012
EC Number	247-977-1, 271-091-4	PubChem, 2015
Synonyms and Trade Names	Diisodecyl Phthalate; 26761-40-0; Bis (8-methylnonyl) phthalate; Plasticized ddp; Palatinol Z; Vestinol DZ; DIDP (plasticizer); Phthalic acid, diisodecyl ester; Bis(isodecyl)phthalate; Di(i-decyl) phthalate; Di-iso-decyl phthalate; Sicol 184; Bis(isodecyl) phthalate; 1,2-Benzenedicarboxylic acid, diisodecyl ester; Di-"isodecyl" phthalate; UNII-WF93T741QI; Phthalic acid,Bis(8-methylnonyl) ester; CCRIS 6194; HSDB 930; CHEBI:34709; ZVFDTKUVRCTHQE-UHFFFAOYSA-N; 1,2-Benzenedicarboxylic acid, di-C9-11-branched alkyl esters, C10-rich; EINECS 247-977-1; PX 120; BRN 2171889; 1,2-Benzenedicarboxylic acid, 1,2-diisodecyl ester; 1,2-Benzenedicarboxylic acid, bis(8-methylnonyl) ester; 89-16-7; di-isodecyl phthalate; 1,2-bis(8-methylnonyl) benzene-1,2-dicarboxylate; bis(8-methylnonyl) benzene-1,2-dicarboxylate; diisodecyl phthalate; diisodecyl phthalate; di-isodecyl phthalate; diisodecyl phthalate; di-i-decyl phthalate; diiso-decyl phthalate; di- i-decyl phthalate; di-i- decyl phthalate; (diisodecyl phthalate); di- isodecyl phthalate; di-iso decyl phthalate; di-iso-decyl phthalate; Di (isodecyl) phthalate; di (isodecyl) phthalate; Phthalsaurediisodecylester; Z (Diisodecyl phthalate); ACMC-1CQ9Z; AGN-PC-0JKN8W; DSSTox_CID_8666; C.) di-isodecyl phthalate; AC1L1PX5; Bis(8-methylnonyl)phthalate;	PubChem, 2015

	DSSTox_RID_78654; DSSTox_GSID_28666; SCHEMBL22307; 68515-49-1; KSC489Q5B; BIDD:ER0436; Phthalic Acid Diisodecyl Ester; WF93T741QI; CHEMBL3183266; 80135_FLUKA; CTK3I9850; MolPort-003-939-118; EINECS 201-884-2; Tox21_300530; ANW-41625; AKOS015888325; AG-E-40754; LS-1112; RTR-012077; Phthalic Acid Bis(8-methylnonyl) Ester; NCGC00248087-01; NCGC00248087-02; NCGC00254318-01; AJ-51825; AK114536; BD125130; CJ-12183; CAS-68515-49-1; KB-251092; ST2406706; TR-012077; FT-0606278; FT-0667182; FT-0667183; P0299; C14578; 1,2-Benzenedicarboxylic Acid Bis(8-methylnonyl) Ester; I01-10289; 3B1-003730; 3B1-007332; 3B1-008845; 1,2-Benzenedicarboxylic Acid 1,2-Bis(8-methylnonyl) Ester; 105009-98-1; 1341-39-5; 148384-02-5; 1H-Cyclohepta[a]naphthalene-8-carboxylic acid, 9-(2-carboxy-1,3,3-; trimethylcyclohexyl)tetradecahydro-4,4,6a,11b-tetramethyl-,dimethyl ester (7CI)	
Molecular Formula	$C_{28}H_{46}O_4$	CPSC, 2010
Molecular Weight	446.7 g/mol	CPSC, 2010
Physical Description	Oily, viscous, clear liquid	CPSC, 2010; HSDB, 2015; NICNAS 2015
Odor	Mild odor	CPSC, 2010; HSDB, 2015
Water solubility	0.2 µg/L at 20°C 2.0x10^{-4} mg/L 0.28 mg/L 3.81x10^{-5} mg/L <0.001 mg/L	ECHA, 2012; CPSC, 2010; HSDB, 2015; NICNAS 2015
Octanol-Water Partition Coefficient (Log K_{ow})	10.36 8.8 9.46	CPSC, 2010; ECHA, 2012; HSDB, 2015;

	~10	NICNAS 2015
Boiling point	> 400°C, 370°C, 250–257°C at 4 mm Hg	ECHA, 2012; HSDB, 2015; NICNAS 2015
Melting point	-53 to -39°C (av. -45°C), -48°C	ECHA, 2012; CPSC, 2010; HSDB, 2015; NICNAS 2015
Vapor pressure	5.1×10^{-5} Pa at 25°C, 7.04×10^{-5} Pa at 25°C 5.10×10^{-5} Pa at 25°C 1.84×10^{-6} Pa at 25°C	ECHA, 2012; CPSC, 2010
Flash point	> 200°C	CPSC, 2010; ECHA, 2012; NICNAS 2015

7.3 Worldwide Manufacturing of DIDP

DIDP is manufactured by a simple chemical synthesis. No additional information on worldwide manufacturing processes was available in the sources searched.

DIDP is manufactured by 12 companies in the U.S., two companies in Germany, two in Mexico, one in Hong Kong, one in Canada, one in China, one in the Czech Republic, one in Switzerland, and one in Japan (Chem Sources Online, 2015).

U.S. EPA CDAT (2015) reports four companies manufacture DIDP. Two companies report past production volumes of 17,637 lb/year and 370,000 lb/year while the other two companies either withheld or considered manufacturing information and production volume CBI.

DIDP manufacture has increased as a result of DIDP and DINP being used as alternatives to DEHP. Between 2001 and 2010, the market share of DEHP dropped and its alternatives, including DIDP, have increased (ECHA, 2012).

7.4 Annual Production of DIDP

Production of DIDP in the U.S. was estimated to be approximately 616,000.000 pounds in 1994 (CPSC, 2010). In 2002, DIDP annual production is approximately 270,000,000 pounds in the U.S. (CPSC, 2010). In 2012, the EPA reported U.S. production to be 500,000–1,000,000 lb/yr (U.S. EPA, 2015).

DIDP use in Nordic countries has decreased from 12,600,000 pounds in 2000 to 1,100,000 pounds in 2012 (SPIN, 2015).

Table 7-2. Production Volumes for DIDP Reported under the Inventory Update Rule*

Year	Production Range (pounds)
1986	>10,000,000–50,000,000
1990	>50,000,000–100,000,000
1994	>50,000,000–100,000,000
1998	>10,000,000–50,000,000
2002	>1,000,000–10,000,000
2012	500,000–1,000,000

Source: HSDB, 2015; U.S. EPA, 2015

7.5 Applications for DIDP in Materials, Consumer Products and Nonconsumer Products

DIDP is largely used in PVC and PVC/polyvinyl acetate co-polymers due to its high polymer affinity, good solvation during processing and the ability to maintain low temperature flexibility (NICNAS, 2015).

ECHA (2012) has indicated that DIDP is typically used as a plasticizer for heat-resistant electrical cords, leather for car interiors, and PVC flooring because of DIDP's volatility resistance, heat stability and electrical insulating properties. DIDP is also preferentially used in car interior trims in order to meet the low fogging thresholds set by car manufacturers. Furthermore, DIDP is preferably used in cables and wires and also in extruded and calendered articles (such as profiles, roofing sheets, ponds liners, etc.), and can also be blended into a paste (plastisol) that is used for coating (production of tarpaulins, synthetic leather, flooring, wall covering, etc.) and rotational molding (production of certain toys and sporting articles) (ECHA, 2012).

DIDP has been found in child care articles and toys as well as numerous other consumer and nonconsumer products. Concentration of DIDP in these materials is sometimes available.

7.5.1 Child Care Products

DIDP has been reported in children's products with several studies reporting concentrations found in toys and child care articles, including teethers.

DIDP is used children's toys and baby equipment. A maximum 20.1% DIDP found in a toy in Argentina and a maximum 20% DIDP concentration in toys in another study (CPSC, 2010). An Australian study found DIDP in inflatable water products, hoppers, and play and exercise balls, with a maximum concentration of 40% (NICNAS, 2015). A Danish study detected DIDP in four PVC toys (3 teethers and 1 doll) at concentrations ranging from 0.7 to 10.1% by weight (CPSC, 2010). In a study conducted by the U.K. Government, DIDP was found in six of 18 toys in 1990 and in four of 27 in 1991, but DIDP was not found in 16 toys in 1992 or in 29 toys in 1996 (CPSC, 2010). DIDP at 0.6% (6,247 ppm) has been reported in a bath toy and 1.1% (11455 ppm) in a doll (IFCS, 2006). Twenty-four toy samples from major brands were bought from market in Delhi, India, made in various world locations. Of these, 16.2% (w/w) DINP was found in toys from India, 6.0%, 7.1%, 6.2%, and 8.0% (w/w) in squeeze toys from China, 4.4% (w/w) from an inflatable toy from China, 4.5% (w/w) from a doll from China, 0.2% (w/w) from a doll from India, 0.2 % (w/w) from a pony toy from China, and less than 0.1% (w/w) in a "soft & hard biter" from Taiwan (Johnson et al., 2011[1]). A British study analyzed 72 toys that were purchased from 17 countries in which 20.1% (w/w) DIDP was found in a teether made in China, 15.7% (w/w) DIDP was found in a teether made in the U.S., and at an unknown concentration in an animal toy bought in India (Stringer, 2000). Another study of 228 children's products, including 172 toys, showed no DIDP concentrations above 0.05%, which was the lowest analytical limit of the study (Grynkiewicz-Bylina, 2011). A study of 27 PVC and non-PVC products from the Jordanian market were also found to have no DIDP above 0.001% (5 ppm), which was the study's lowest measureable limit (Al-Natsheh, 2015). A Sri Lankan study that quantitated DIDP in toys from a Colombo market found 0.004% DIDP concentration in the toys (Uththamawadu, 2010).

DIDP was reported at a maximum of 10.1% in a study of teethers; in another study, a maximum of 40% DIDP was found (CPSC 2010; NICNAS 2015). DIDP was found in two teethers containing PVC. The first teether, produced in China, contained 20% DIDP and the second teether, produced in the U.S., contained 15.7% DIDP (CPSC, 2010).

DIDP was assumed to also be in changing pad and playpens; concentration data were not presented (CPSC, 2014). RAPEX (2015) database reports DIDP in two bath toys (6 and 6.8%) and in two plastic doll sets (6.8 and 17%) during 2015.

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[1] In this study, the GC of DIDP and DINP was not distinguishable and this percentage is the total for both DIDP and DINP.

Table 7-3. DIDP in Children's Products

Use	Product	DIDP Concentration	Reference
Toy	Toy	40%	CPSC, 2010
Toy	Plastic waterproof pouch	26.4%	WSDE, 2015
Toy	Toy	20.1%	CPSC, 2010
Toy	Toy	16.2% (w/w) [DIDP/DINP]	Johnson et al., 2011
Toy	Toys	15.7%	CPSC, 2010; Stringer, 2000
Toy	Clear plastic front of pouch	14.8%	WSDE, 2015
Toy	Pink part of bag	12.8%	WSDE, 2015
Toy	Yellow vinyl side of basket	11.3–12.2%	WSDE, 2015
Toys	Bath toys	6 and 6.8%	RAPEX, 2015
Toys	Plastic doll set	6.8 and 17%	RAPEX, 2015
Toy	Squeeze toys	6.0%, 7.1%, 6.2%, and 8.0% (w/w) [DIDP/DINP]	Johnson et al., 2011
Toy	Clear plastic pouch	6.92%	WSDE, 2015
Toy	Plastic page of book	6.87%	WSDE, 2015
Toy	Doll	4.5% (w/w) [DIDP/DINP]	Johnson et al.,, 2011
Toy	Inflatable toy	4.4% (w/w) [DIDP/DINP]	Johnson et al., 2011
Toy	Clear plastic pouch	3.82%	WSDE, 2015
Toy	Component of colored aliens	2.5%	WSDE, 2015
Toy	Plastic zipper bag 1	1.81%	WSDE, 2015
Toy	Plastic zipper bag 2	1.79%	WSDE, 2015
Toy	Clear plastic pouch	1.66%	WSDE, 2015
Toy	Doll	1.1% (11,455 ppm)	IFCS 2006
Toy	Pink plastic edging from bag	0.64%	WSDE, 2015
Toy	Bath toy	0.62% (6,247 ppm)	IFCS, (2006
Toy	Pink/purple polka dot bag side fabric	0.55%	WSDE, 2015
Toy	Red plastic body	0.49%	WSDE, 2015

Use	Product	DIDP Concentration	Reference
Toy	Soft plastic worm body	0.47%	WSDE, 2015
Toy	Translucent red glittery plastic	0.45%	WSDE, 2015
Toy	Green flexible plastic outer body without inner liquid	0.44%	WSDE, 2015
Toy	Green soft plastic animal	0.41%	WSDE, 2015
Toy	Doll	0.2% (w/w) [DIDP/DINP]	Johnson et al., 2011
Toy	Pony toy	0.2% (w/w) [DIDP/DINP]	Johnson et al., 2011
Toy	Clear plastic packaging pouch	0.157%	WSDE, 2015
Toy	Clear structural liner from bottom of bag (toy packaging)	0.148%	WSDE, 2015
Toy	Toy	0.004%	Uththamawadu, 2010
Toy and child care article	3 teethers and 1 doll	0.7–10.1%	CPSC, 2010
Child care article	Teether	20.1%	Stringer , 2000
Child care article	Teether	20%	CPSC, 2010
Child care article	Body mist (for children)	0.28%	WSDE, 2015

*Concentrations < 0.1% are shaded.

The Washington State Department of Ecology (WSDE), under the 2008 Washington Children's Safe Product Act has been testing consumer products for toxic chemicals and receiving and posting data from manufacturers on children's products sold in Washington if their product contains a chemical of high concern, which includes phthalates. Of the 237 products tested for DIDP (CASRN 26761-40-0), 36 products contained DIDP over the analytical reporting limit with 24 of the 36 having concentrations greater than 0.1% (1000 ppm). The item of maximum concentration was 26.4% for a waterproof pouch.

From the manufacturers' testing results, the State of Washington has received a list of children's products that contain a "Chemical of High Concern" to children. There were a total of 217 items that contained DIDP. All of the 217 items contained <0.1% DIDP.

7.5.2 Other Products

DIDP is commonly used as a plasticizer in polyvinyl chloride for film, sheet and coated products including flooring, roofing, and wall covering. It is also used in medical films, hoses, wiring and cables, gloves and footwear, car undercoating and sealants, auto upholstery, building materials, furniture, artificial leather, carpet backing, and pool liners (ECHA, 2012; CPSC, 2010; NICNAS, 2015). It is used in other vinyl resins such as acrylic plastic resins, and other polymer-containing products, such as pressure sensitive adhesives and printing inks (ECHA, 2012). DIDP is applied in non-polymer applications, such as anti-corrosion and anti-fouling paints, sealing compounds, and textile inks (ECHA, 2012). DIDP is found in PVC and non-PVC products such as coatings, rubber, latex, mastics, sealants, inks, dyestuffs, lubricants, acrylic resins, personal care products, paints, pressure-sensitive adhesives, lacquers, varnishes, binding agents, coloring agents, construction materials, lubricants, additives, fillers, abrasives, textile inks, packaging materials, industrial flooring, paints, surfactants, adhesives, flame resistant plastics, polyurethane masonry and concrete sealants, interior and exterior caulk, and plumbing caulk (CPSC 2010; NICNAS 2015; SPIN 2015).

The typical DIDP concentration in PVC materials is approximately 30% (ECHA 2012). The maximum DIDP concentration differed for different product types, as follows: 17.1% (171,000 mg/kg) was found in plastic gloves, 5.5% (55,000 mg/kg) in paint, 0.3% (3,030 ppm) in adhesives, glues and sealing compounds (CPSC, 2010). A Danish study detected DIDP concentrations in half of the studied consumer goods made of PVC, such as shower curtains, bags, gloves, vinyl floor, carpet tiles, and vinyl wallpaper (CPSC, 2010). A minimum content of 10% plasticizer must be present in the PVC material to be effective (ECHA, 2013). The typical content of DIDP in PVC materials is 25–50% (w/w) (ECHA, 2013). DIDP can also be blended into a paste, or plastisol, used for coatings such as in the production of tarpaulins, synthetic leather, flooring, and wall covering (ECHA, 2012). DIDP can also be used in rotational molding in the production of certain toys and sporting articles (ECHA, 2012). Less than 1.9% (w/w) DIDP was found in 25 PVC flooring products sold in Germany (ECHA, 2012). It was also found in fitness balls with other phthalates (ECHA, 2012).

Table 7-4. DIDP Concentration in Consumer Child Care Products

Use	Product	DIDP Concentration	Child Use Potential?	Reference
Consumer Products	Eight Sex Toys	27% (w/w) average, 55% (w/w) maximum	No	ECHA, 2012
Consumer Product	Clear plastic bag	16.1%	NK	WSDE, 2015
Consumer Product	Clear plastic pouch	15.8%	NK	WSDE, 2015
Consumer Product	Plastic bag	12.9%	NK	WSDE, 2015
Consumer Product	Plastic bag	11.6%	NK	WSDE, 2015
Consumer Products	Plastic Gloves	17.1% (1,710 ppm)	NK	CPSC, 2010
Consumer Product	Clear plastic pouch	0.137%	NK	WSDE, 2015
Consumer Product	Bottle	0.0134%	NK	WSDE, 2015
Consumer Product	Plastic clear pouch	0.129%	NK	WSDE, 2015
Consumer Product	Clear plastic part of bag	0.107%	NK	WSDE, 2015
Consumer Product	Clear plastic pouch	0.105%	NK	WSDE, 2015
Consumer Product	Clear plastic pouch	0.101%	NK	WSDE, 2015
Home Maintenance	PVC Cable Sheathing	27% (w/w)	NK	ECHA, 2012
Home Maintenance	PVC wall papers	26% (w/w)	NK	ECHA, 2012
Home Maintenance	Polyurethane Concrete & Masonry Sealant	7–13%	NK	HPD, 2015
Home Maintenance	Paint	5.5% (550 ppm)	NK	CPSC, 2010
Home Maintenance (sold in	PVC Flooring products	<1.9% (w/w)	NK	ECHA, 2012

Use	Product	DIDP Concentration	Child Use Potential?	Reference
Germany)				
Home Maintenance	Paint roller	0.163%	NK	WSDE, 2015
Home Maintenance	Adhesives, glues and sealing compounds	0.3030003% (3.03 ppm)	NK	CPSC, 2010
Personal Care Product	Perfume	1.54%	NK	WSDE, 2015

*Concentrations < 0.1% are shaded.

7.6 Routes of Introduction of DIDP into Phthalate-free Material

DIDP is resistant to migration from polymers and is compatible with polar polymers and additives (HSDB, 2015). Its low vapor pressure and resistance to migration make it ideal for products that can be subjected to heat (ECHA, 2012). DIDP is also resistant to extraction with soapy water (ECHA, 2012). However, if it leaves the polymer structure, it may corrode some forms of plastics and will hydrolyze under acidic and basic conditions (HSDB, 2015). DIDP is soluble in most organic solvents but insoluble in glycerol, glycols and some amines (NICNAS, 2015).

DIDP is not covalently bound to the PVC matrix and stays within the polymer by electrostatic interactions with the polymer (ECHA, 2013). It can be released by volatization, extraction to a liquid, or by migration to a solid or semi-solid, depending on contact duration, temperature, concentration difference, and concentration (ECHA, 2013).

ECHA reported a migration rate for DIDP from mouthing toys for children in studies with a saliva stimulant (ECHA, 2012; ECHA, 2013). Some leaching studies of DIDP from toys to saliva showed leaching whereas others did not detect DIDP leaching (CPSC, 2010). Agitation, fluid, and heat enhance DIDP extraction (CPSC, 2010).

DIDP has a low vapor pressure making it unlikely to vaporize (CPSC, 2010). It may readily adhere to particles such as dust, soil and sediment (CPSC, 2010).

7.7 References

Al-Natsheh, M., Alawi, M., Fayyad, M., Tarawneh, I. 2015. Simultaneous GC–MS determination of eight phthalates in total and migrated portions of plasticized polymeric toys and childcare articles. J Chromat B. 985, 103-109.

Chem Sources Online. 2015. Chem Sources Online database. Chem Sources International, Inc. Available at: http://www.chemsources.com/chemonline.html.

CPSC (U.S. Consumer Product Safety Commission), 2010. Review of Exposure Data and Assessments for Selected Dialkyl Ortho-Phthalates. CPSC-D-06-0006, Consumer Product Safety Commission, Bethesda, MD.

CPSC (U.S. Consumer Product Safety Commission), 2014. Appendix E1. Modeling Consumer Exposure to Phthalate Esters. Chronic Hazard Advisory Panel, Consumer Product Safety Commission.

ECHA (European Chemicals Agency). 2012. Background Document to the Opinion on the Annex XV dossier proposing restrictions on four phthalates. Committee for Risk Assessment (RAC). Committee for Socio-Economic Analysis (SEAC). European Chemicals Agency.

ECHA (European Chemicals Agency). 2013. Evaluation of new scientific evidence concerning DINP and DIDP. Final Review Report in relation to entry 52 of Annex XVII to REACH Regulation (EC) No 1907/2006. European Chemicals Agency.

Grynkiewicz-Bylina, B. 2011. Dangerous phthalates in children's environment. Ecolog Chem Engineer. 18, 455-463.

HPD (Household Products Database). 2015. Household Products Database online. National Library of Medicine, National Institutes of Health. Available at: http://householdproducts.nlm.nih.gov/.

HSDB (Hazardous Substances Data Bank). 2015. Hazardous Substances Data Bank online database, Toxnet Toxicology Data Network. U.S. National Library of Medicine. Available at: http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB.

IFCS (Intergovernmental Forum on Chemical Safety), 2006. Toys and Chemical Safety: A Thought Starter. Intergovernmental Forum on Chemical Safety. IFCS/Forum-V/03-TS, Budapest, Hungary.

Johnson, S., Saikia, N., Sahu, R. 2011. Phthalates in toys available in Indian market. Bull Environ Contam Toxicol. 86, 621-626.

NICNAS (National Industrial Chemicals Notification and Assessment Scheme). 2015. Priority Existing Chemical Draft Assessment Report 39. Diisodecyl phthalate. Di-n-octyl phthalate. Department of Health, National Industrial Chemicals Notification and Assessment Scheme.

PubChem, 2015. The PubChem online database. National Library of Medicine. Available at: https://pubchem.ncbi.nlm.nih.gov/.

SPIN (Substances in Preparation in Nordic Countries). 2015. SPIN Database. Danish Environmental Protection Agency. Available at: http://195.215.202.233/DotNetNuke/default.aspx.

Stringer, R., Labunska, I., Santillo, D., Johnston, P., Siddorn, J., Stephenson, A. 2000. Concentrations of phthalate esters and identification of other additives in PVC children's toys. Environ Sci Pollut Res. 7, 1-10.

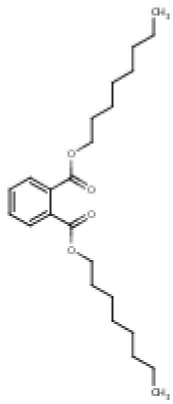
U.S. EPA (U.S. Environmental Protection Agency), 2015. Chemical Safety and Pollution Prevention: Pollution Prevention and Toxics. Vol. 2014. Chemical Data Access Tool (CDAT). Available at: http://java.epa.gov/oppt_chemical_search/.

Uththamawadu, D. P., Wijesekera, R. D., Rajasingham, S. L. 2010. A study of human exposure to selected phthalates in toys in Sri Lanka. Department of Chemistry, University of Colombo, Vauxhall St, Colombo.

WSDE (Washington State Department of Ecology ECY). (2015). "Children's Safe Product Act Reported Data." Available at: https://fortress.wa.gov/ecy/cspareporting/.

8 Di-n-Octyl Phthalate (DnOP) CASRN: 117-84-0

There is inconsistency in the technical literature regarding the chemical name di-n-octyl phthalate and associated chemical identity. The literature has on occasion referred to dioctylphthalate, DEHP, DIOP and DnOP as the same chemical (HSDB, 2015). This report addresses the linear (i.e., not branched-chain) di-n-octyl phthalate (CASRN 117-84-0), with the structure (HSDB, 2015) as follows:



DnOP is considered a high molecular weight phthalate (U.S. EPA, 2015; ACC 2001).

8.1 Raw Materials Used in Production of DnOP

DnOP is produced through simple chemical synthesis by the reaction of n-octylbromide or n-octanol with phthalic anhydride in the presence of a catalyst such as sulfuric acid or p-toluenesulfonic acid, or at high temperatures noncatalytically (PubChem, 2015; HSDB, 2015). Commercially, DnOP is produced as a component of straight-chain C6, C8, and Cl0 phthalate esters (U.S. EPA, 1993).

The following is a list of chemicals that are used as raw materials in the production of DnOp:

- n-octylbromide
- phthalic anhydride
- n-octanol
- catalyst (such as sulfuric acid or p-toluenesulfonic acid)

8.2 Chemical and Physical Properties of DnOP

DnOP is a clear, oily liquid at room temperature, with a low vapor pressure, and is essentially insoluble in water, but is soluble in many organic solvents and oils (HSDB, 2015).

DnOP must be stored to avoid contact with strong oxidizers (such as chlorine, bromine, or fluorine), strong acids (such as sulfuric acid, hydrochloric acid, or nitric acid), or alkylhalides, as violent reactions may occur (HSDB, 2015).

Table 8-1 Physical/Chemical Characteristics of DnOP

Characteristic	Value	Reference
IUPAC Name	Dioctyl benzene-1,2-dicarboxylate	PubChem, 2015
CASRN	117-84-0	PubChem, 2015
EC Number	204-14-7	SPIN, 2015
Synonyms and Trade Names	1,2-Benzenedicarbonic acid, dioctyl ester; 1,2-Benzenedicarboxylic acid, dioctyl ester; Benzenedicarboxylic acid di-n-octyl ester; Celluflex DOP; Di-n-octyl phthalate; Dicapryl phthalate; Dinopol NOP; Dioctyl 1,2-benzenedicarboxylate; Dioctyl o-benzenedicarboxylate; Dioctyl phthalate; Dioktylester kyseliny ftalove; Dioktylester kyseliny ftalove [Czech]; DNOP; n-Octyl phthalate; o-Benzenedicarboxylic acid, dioctyl ester; Octyl phthalate; Phthalic acid, dioctyl ester; Polycizer 162; PX-138; Vinicizer 85	HSDB, 2015: ChemIDPlus, 2015
Molecular Formula	$C_{24}H_{38}O_4$	HSDB, 2015
Molecular Weight	390.5 g/mol	HSDB, 2015
Physical description	Clear, oily liquid	HSDB, 2015
Odor	Odorless to slight odor	ATSDR, 1997; HSDB, 2015
Solubility in water	0.22 mg/L at 25°C	HSDB, 2015

Octanol/Water Partition Coefficient (Log K_{ow})	8.10	HSDB, 2015
Boiling Point	242°C	HSDB, 2015
Melting Point	25°C	HSDB, 2015
Vapor Pressure	5.5×10^{-6} mm Hg at 25°C; 1.0 mm Hg at 200°C 1.89×10^{-7} – 1.39×10^{-6} mm Hg (0.000000252 - 0.00000185) hPa) at 25°C (calculated)	HSDB, 2015
Flash Point	201°C; 215°C	HSDB, 2015

8.3 Worldwide Manufacturing Processes of DnOP

Manufacturing of DnOP occurs through simple chemical synthesis processes that are likely the same worldwide.

DnOP was considered a high-production volume chemical in 2005 with production of 10 to fewer than 50 million pounds (U.S. EPA, 2010; U.S. EPA, 2015). Two U.S. manufacturers for DnOP were reported by HSDB (2015), whereas Chem Sources Online (2015) reported seven manufacturers in the U.S. (U.S. EPA, 2015) lists one manufacturer in the U.S. for 2012. However, no production volume is reported as the company considers the information as Confidential Business Information (CBI).

The Canadian Environmental Protection Act (HC, 1993) states that there are no Canadian producers of DnOP.

In Europe, two manufacturers in Germany and one manufacturer in Switzerland were reported (Chem Sources Online, 2015). Use of DnOP in Nordic countries (SPIN, 2015) was 233,689 pounds (106 tonnes) in 2000, 85,980 pounds (39 tonnes) in 2006 and 158,732 pounds (72 tonnes) in 2013.

In Asia, Chem Sources Online (2015) reported one manufacturer each in China, Hong Kong, Japan, and Taiwan.

No phthalates are produced in Australia (NICNAS, 2012). According to NICNAS (2008), DnOP is imported for use as a plasticizer or for research purposes in Australia.

Production of DnOP by other countries was not located in the literature searched for this report.

8.4 Annual Production of DnOP

Table 8-2. Production Volumes for Non-Confidential Business Information (non-CBI) Chemicals Reported Under the U.S. EPA Inventory Update Rule

Year	Production Range (pounds)	Reference
1977	388,543,000	U.S. EPA, 1980
1978	>5,000	HSDB, 2015
1982	>5,000	HSDB, 2015
1985	275,000,000	HSDB, 2015
1986	290,000,000	HSDB, 2015
1987	350,000,000	HSDB, 2015
1986	>10,000,000–50,000,000	PubChem, 2015
1990	>1,000,000–10,000,000	PubChem, 2015
1990 & 1995	>1,000,000	HSDB, 2015
1994	>1,000,000–10,000,000	PubChem, 2015
1998	>1,000,000–10,000,000	PubChem, 2015
2002	>10,000,000–50,000,000	PubChem, 2015
2005	10,000,000 to <50,000,000	U.S. EPA, 2010

8.5 Application of DnOP in Materials, Consumer Products and Nonconsumer Products

DnOP is used as a plasticizer in plastics, cellulose ester, polystyrene and vinyl resins (HSDB, 2015). DnOP has uses other than as a plasticizer. It is also used as a chemical intermediate in the manufacture of adhesives and lacquer coatings (ATSDR, 1997). It is a dye carrier in PVCs, a carrier for catalysts or initiators, and a substitute for electrical capacitor fluid (HSDB, 2015).

8.5.1 Children's Products

DNOP use in children's products includes teethers and toys, changing pads, play pens, and furniture (CPSC, 2014). Items reported to contain DnOP include rainwear, shoes, notebook covers, dolls, and toys (ATSDR, 1997; HSDB, 2015).

In the United States, Cassidy (2005) reported DnOP was detected in a "cool teether" at a concentration of 5.4% (54,000 ppm) and a baby book at a concentration of 0.8% (8,000 ppm) (as referenced by Intergovernmental Forum on Chemical Safety (IFCS), 2006). DnOP was detected (concentration not specified) in a pacifier and baby bottle nipple (Sathyanarayana et al., 2008, as cited by CPSC, 2010). DnOP is reported to be present in boots from a child's Halloween costume at a concentration of 6.7% (CPSC, 2010). No detection of DnOP was reported in 30 samples of soft squeeze toys from the Colombo market in Sri Lanka (Uththamawadu et al., 2010).

Table 8-3 DnOP Concentrations in Children's Products

Use	Product	Concentration	Reference
Toy	Plastic doll	33.9%	RAPEX, 2015
Toy	Plastic toy set	24.68 %	RAPEX, 2015
Toy	Toys	0.28–15.4%	Al-Natsheh al., (2015)
Toy	Modeling clay	9.7–14%	Snedekar, 2014; CPSC, 2010
Toy	Toys	12.2%	Grynkiewicz-Bylina, 2011
Toy	Toy	2.2%	Grynkiewicz-Bylina, 2011
Toy	Book	0.8%	Cassidy, 2005 (as cited by IFCS, 2006)
Toy	Toys	<0.1%	WSDE, 2015
Toy	Toys	0.0004%	Ionas et al., 2014
Toy	Squeeze toys	ND	Uththamawadu et al., 2010
Toys and child care articles	Teether	5.4%	Cassidy, 2005 (as cited by IFCS, 2006)
Child care article	Articles used for relaxation and hygiene	1.45%	Grynkiewicz-Bylina, 2011
Children's product	Halloween costume	6.7%	CPSC, 2010

*Concentrations < 0.1% are shaded.

Concentrations of DnOP up to 14% by weight have been reported in modeling clay (Snedekar, 2014). Polymer modeling clay contained DnOP at 9.7% (97,500 ppm) (Stopford et al., 2003, cited by CPSC, 2010). In a recent study by Al-Natsheh al. (2015), phthalates were analyzed in toys to determine the migration rate into artificial saliva. DnOP was detected in 6 of 27 toys at the following average percentage concentrations: 15.4, 12.5, 0.28, 5.04, 0.72 and 2.13. In another study conducted in Belgium, DnOP was detected in 2 of 50 children's toys with an average concentration of 0.0004% (4 ppm) (Ionas et al., 2014). Grynkiewicz-Bylina (2011) reported DnOP in one of 10 toys at 2.2% DnOP by weight and in one of 10 articles for "children's relaxation and hygiene" at 1.45% DnOP by weight; however, the source-specific information and location are unreported.

The Washington State Department of Ecology (WSDE), under the 2008 Washington Children's Safe Product Act has been testing consumer products for toxic chemicals and receiving and posting data from manufacturers on children's products sold in Washington if their product contains phthalates. Of the 239 products tested for DnOP by WSDE, two products contained DnOP over the reporting limit but none of the concentrations were greater than 0.1% (1000 ppm). From the manufacturer's submissions, WSDE has received data for a total of 247 items that contained DnOP.

8.5.2 Other Products

As a plasticizer, DnOP is used for the manufacture of flooring and carpet tile, carpet backing, floor tile, wall coverings, canvas tarps, weather stripping, wire, cables, window shades, shower curtains, and tablecloths (ATSDR, 1997; HSDB, 2015). It is used in industrial processes for textiles, adhesives and glues (HazMap, 2015). In Nordic countries from 2000-2011, the majority use was for paints, lacquers, and varnishes; DnOP was also used in fillers, adhesives and binding agents in construction activities (SPIN 2015). DnOP was detected at less than 0.001% (0.08 mg/kg or ppm) in floorings in Germany (NTP, 2003). Other uses of DNOP in households include swimming pool liners and garden hoses (ATSDR, 1997; HSDB, 2015).

Personal use products that contained DnOP were laundry detergent, shaving cream, bar soap, soap packaging products, cosmetics (ATSDR, 1997; ECHA, 2010; HSDB, 2015). In adult sex toys, DnOP was detected in two of 15 samples with a maximum concentration of 23.9% (239,000 mg/kg, or ppm) (CPSC, 2010). Gao et al. (2014) did not detect DnOP in toiletries.

DnOP may be found in PVC products that have food applications such as seam cements, bottle cap liners, packaging films, and conveyor belts (HSDB, 2015; CPSC, 2010). DnOP has been found in catering gloves at a concentration of 6.2% (Schulz et al., 2015). Other items containing DnOP include traffic cones, automobile and furniture upholstery, vinyl gloves, medical tubing, blood storage bags and flea collars (ATSDR, 1997; HSDB, 2015) as well as coolants and pesticides (ECHA, 2010; ATSDR, 1997; HSDB, 2015).

8.6 Routes of Introduction of DnOP into Phthalate-free Material

Heating or baking of modeling clay results in airborne DnOP (Schettler, 2006, as cited by Snedakar, 2014).

DnOP is soluble in lipophilic substances, such as oils. This characteristic makes migration or partitioning from DnOP-containing materials into nearby oily substances likely.

8.7 References

ACC (American Chemistry Council). 2001. High Production Volume (HPV) Chemical Challenge Program Test Plan for the Phthalate Esters Category. Phthalate Esters Panel HPV Testing Group. American Chemistry Council.

Al-Natsheh, M., Alawi, M., Fayyad, M., Tarawneh, I. 2015. Simultaneous GC–MS determination of eight phthalates in total and migrated portions of plasticized polymeric toys and childcare articles. J Chromat B. 985, 103-109.

ATSDR (Agency for Toxic Substances and Disease Registry). 1997. Toxicological Profile for Di-*n*-Octyl Phthalate. U.S. Department of Health and Human Services. Public Health Service. Agency for Toxic Substances and Disease Registry. Available at: http://www.atsdr.cdc.gov/toxprofiles/tp95.pdf.

Cassidy A. 2005. 20th Annual Toy Safety Survey. Trouble in Toy Land. U.S. PIRG, Educational Fund, Washington DC. (As cited in IFCS, 2006).

ChemIDPlus, 2015. ChemID Plus, A Toxnet Database. U.S. National Library of Medicine. Available at: http://householdproducts.nlm.nih.gov/.

Chem Sources Online. 2015. Chem Sources Online database. Chem Sources International, Inc. Available at: http://www.chemsources.com/chemonline.html.

CPSC (U.S. Consumer Product Safety Commission), 2010. Review of Exposure Data and Assessments for Selected Dialkyl Ortho-Phthalates. Consumer Product Safety Commission, CPSC-D-06-0006, Bethesda, MD.

CPSC (U.S. Consumer Product Safety Commission), 2014. Appendix E1. Modeling Consumer Exposure to Phthalate Esters. Chronic Hazard Advisory Panel, Consumer Product Safety Commission.

ECHA (European Chemicals Agency). 2010. Review of new available information for Di-N-Octyl Phthalate (DNOP). Evaluation of New Scientific Evidence Concerning the Restrictions Contained in Annex XVII to Regulation (EC) No. 1907/2006 (REACH). European Chemicals Agency.

Grynkiewicz-Bylina, B. 2011. Dangerous phthalates in children's environment. Ecolog Chem Engineer. 18, 455-463.

HazMap, 2015. Haz-Map Information on Hazardous Chemicals and Occupational Diseases. U.S. National Library of Medicine. Available at: http://hazmap.nlm.nih.gov/index.php.

Health Canada. 1993. Di-n-Octyl Phthalate. Priority Substances List Assessment Report. Canadian Environmental Protection Act. Health Canada.

HSDB (Hazardous Substances Data Bank). 2015. Hazardous Substances Data Bank online database, Toxnet Toxicology Data Network. National Library of Medicine. Available at: http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB.

Ionas, A.C., Dirtu, A.C., Anthonissen, T., Neels, H., Covaci, A. 2014. Downsides of the recycling process: Harmful organic chemicals in children's toys. Environ Int. 65, 54-62.

NICNAS (National Industrial Chemicals Notification and Assessment Scheme). 2008. Phthalates Hazard Compendium. A summary of physicochemical and human health hazard data for 24 ortho-phthalate chemicals. Existing Chemical Hazard Assessment Report. Department of Health and Ageing. National Industrial Chemicals Notification and Assessment Scheme. Available at: http://www.nicnas.gov.au/__data/assets/pdf_file/0008/4958/Phthalate-Hazard-Compendium.pdf.

NICNAS (National Industrial Chemicals Notification and Assessment Scheme). 2012. Diisononyl Phthalate. Priority Existing Chemical Assessment Report No. 35. Department of Health and Ageing, National Industrial Chemicals Notification and Assessment Scheme.

NICNAS (National Industrial Chemicals Notification and Assessment Scheme). 2015. Priority Existing Chemical Draft Assessment Report 39. Diisodecyl phthalate. Di-n-octyl phthalate. Department of Health, National Industrial Chemicals Notification and Assessment Scheme. Available at: http://www.nicnas.gov.au/__data/assets/word_doc/0005/15764/PEC-39-Diisodecyl-phthalate-and-Di-n-octyl-phthalate-May-2015.docx.

NTP (National Toxicology Program). 2003. Center for the Evaluation of Risks to Human Reproduction (NTP-CERHR). NTP-CERHR Monograph on the Potential Human Reproductive and Developmental Effects of Di-n-Octyl Phthalate (DnOP).Center for the Evaluation of Risks to Human Reproduction, National Toxicology Program (NTP-CERHR).

PubChem, 2015. The PubChem online database. National Library of Medicine. Available at: https://pubchem.ncbi.nlm.nih.gov/.

RAPEX. 2015. Rapid Alert System for dangerous non-food products. Latest Reports Online database. European Commission. Available at: http://ec.europa.eu/consumers/safety/rapex/alerts/main/index.cfm?event=main.listNotifications.

Sathyanarayana, S. 2008. Phthalates and children's health. Curr Prob Pediat Adol Health Care. 38, 34-49.

Schettler, T. 2006. Human exposure to phthalates via consumer products. Int J Androl. 29, 134-139. As cited by Snedakar, 2014.

Schulz, S., Wagner, S., Gerbig, S., Wachter, H., Sielaff, D., Bohn, D., Spengler, B. 2015. DESI MS based screening method for phthalates in consumer goods. Analyst. 140, 3484-3491.

Snedekar, S.M. 2014. Toxicants in Food Packaging and Household Plastics. Exposure and Health Risks to Consumers. Humana Press, Springer-Verlag. London, United Kingdom.

SPIN (Substances in Preparation in Nordic Countries). 2015. SPIN Database. Danish Environmental Protection Agency. Available at: http://195.215.202.233/DotNetNuke/default.aspx.

Stopford, W., Turner, J., Cappellini, D. 2003. Determination of the magnitude of clay to skin and skin to mouth transfer of phthalates associated with the use of polymer clays. Department of Community & Family Medicine, Division of Occupational & Environmental Medicine, Duke University Medical Center. Durham, NC, 2003. (As cited in CPSC, 2010).

U.S. EPA (U.S. Environmental Protection Agency). 1980. Ambient Water Quality Criteria for Phthalate Esters. Office of Water Regulations and Standards. U.S. Environmental Protection Agency, Washington, D.C. Available at: http://water.epa.gov/scitech/swguidance/standards/criteria/upload/AWQC-for-Phthalate-Esters_1980.pdf.

U.S. EPA (U.S. Environmental Protection Agency). 1993. Di-n-octyl phthalate; toxic chemical release reporting; community right-to-know. U.S. Environmental Protection Agency. Federal Register 58(8), 4133-4137.

U.S. EPA (U.S. Environmental Protection Agency). 2010. Screening-Level Hazard Characterization. Phthalate Esters Category. Hazard Characterization Document. U.S. Environmental Protection Agency. Available at: http://www.epa.gov/hpvis/hazchar/Category_%20Phthalate%20Esters_March%202010.pdf.

U.S. EPA (U.S. Environmental Protection Agency), 2015. Chemical Safety and Pollution Prevention: Pollution Prevention and Toxics. Vol. 2014. Chemical Data Access Tool (CDAT). Available at: http://java.epa.gov/oppt_chemical_search/.

Uththamawadu, D. P., Wijesekera, R. D., Rajasingham, S. L. 2010. A study of human exposure to selected phthalates in toys in Sri Lanka. Department of Chemistry, University of Colombo, Vauxhall St, Colombo.

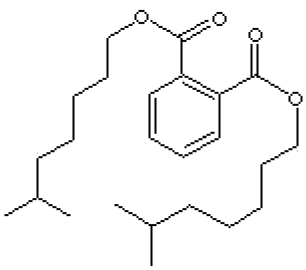
WSDE (Washington State Department of Ecology ECY). (2015). "Children's Safe Product Act Reported Data." Available at: https://fortress.wa.gov/ecy/cspareporting/.

9 Diisooctyl phthalate (DIOP) CASRN: 27554-26-3

Diisooctyl phthalate (DIOP) is comprised of a pair of eight-carbon side chains linked to a benzene-dicarboxylic acid ring. The branched ester side chains are in an ortho configuration (CPSC, 2010). DIOP belongs to the group of phthalates referred to as dioctyl phthalates (ATSDR, 2002); only CASRN 27554-26-3 will be discussed in this document.

U.S. EPA (2010) and NICNAS (2008) considered DIOP to be a high molecular weight phthalate ester. The European Chemicals Bureau (ECB, 2007; IUCLID, 2006) and the American Chemistry Council Phthalate Esters Panel HPV Testing Group (ACC, 2006) considered DIOP to be a transitional phthalate. The International Uniform Chemical Information Database (IUCLID, 2006) lists DIOP as a one of phthalates of the Transitional Phthalate Esters subcategory, due to the length of the carbon side chains.

The structure of DIOP (PubChem, 2015) is as follows:



9.1 Raw Materials Used in Production of DIOP

In general, DIOP is manufactured commercially in a closed system by catalytically esterifying phthalic anhydride with C8 oxo-alcohols (iso-octanol) (CPSC, 2010; (HSDB, 2015). Most of the iso-octyl alcohol raw materials used in the synthesis of DIOP are mixtures of octanol isomers (HSDB, 2015). The unreacted alcohols are recovered and reused, and the DIOP mixture is purified to approximately 99% by vacuum distillation or activated charcoal (CPSC, 2010). The remaining fraction of the DIOP commercial mixture contains ≤ 2% dioctyl phthalate esters other than DIOP (CPSC, 2010).

The following chemicals are used as raw materials in the production of DIOP:

- phthalic anhydride
- iso-octanol
- acid catalyst (not specified)

Synonyms and trade names for DIOP are shown in the Table 9-1.

9.2 Chemical and Physical Properties of DIOP

DIOP is a clear, viscous, oily liquid at room temperature with a mild or faint odor (CPSC, 2010; HSDB, 2015). It is almost insoluble in water but is compatible with vinyl chloride resins and some cellulosic resins (HSDB, 2015). DIOP is soluble to various extents in many common organic solvents and oils (HSDB, 2015).

The high boiling point and low vapor pressure contribute to DIOP's physical stability. DIOP has low volatility, as indicated by its vapor pressure. Although DIOP may be stable, there is the potential for it to volatilize when a material with DIOP is heated. Table 9-1 summarizes the chemical and physical characteristics of DIOP. The data for several of these characteristics varies depending on the source.

DIOP reacts with strong oxidants and decomposes (decomposition temperature not reported) on burning, producing irritating fumes (IPCS, 2012).

Table 9-1 Physical/Chemical Characteristics of DIOP

Characteristic	Value	Reference
IUPAC Name:	Bis(6-methylheptyl) benzene-1,2-dicarboxylate	PubChem, 2015
CASRN	27554-26-3	HSDB, 2015
EC Number	248-523-5	IUCLID, 2006; IPCS, 2012
Synonyms and Trade Names	DIOP; 1,2-Benzenedicarboxylic acid, diisooctylester; 1,2-Benzenedicarboxylic acid, 1,2-diisooctyl ester; 1,2-Benzenedicarboxylic acid, diisooctyl ester; diisooctyl ester; Corflex 880; Diisooctyl 1; Diisooctyl 1,2-benzenedicarboxylate; Di-iso-octyl phthalate; di-"isoalkyl" phthalates; Diisooctyl 1,2-benzene dicarboxyl acid; Diisooctyl ester 1,2-Benzenedicarboxylic acid; Diisooctyl ester of 1,2-benzenedicarboxylic acid;	U.S. EPA, 2010; HSDB, 2015; NICNAS, 2013; IUCLID, 2006; CCOHS, 2015

	Diisooktylftalat; EINECS 248-523-5; Flexol Plasticizer DIOP; Genomoll 100; Hexaflex Diop; Hexaplas M/O; phthalic acid, bis(6-methylheptyl)ester; phthalic acid, diisooctyl ester; AI3-27697-X(USDA); Staflex Diop Morflex 100; Palatinol D10; Witcizer 313; Bis(6-methylheptyl) phthalate	
Molecular Formula	$C_{24}H_{38}O_4$ C8H17COO)2C6H4	HSDB, 2015; IPCS, 2012; CPSC, 2010
Molecular Weight	390.557g/mol	HSDB, 2015; IPCS, 2012; IUCLID, 2006; CPSC, 2010
Physical description	Clear or nearly colorless, viscous, oily liquid	HSDB, 2015; CPSC, 2010
Odor	Mild or faint odor	HSDB, 2015; CPSC, 2010
Solubility in water	9.0×10^{-2} mg/L at 25°C $2.4 \times 10^{-4} – 2.49 \times 10^{-3}$ mg/L at 25°C	HSDB, 2015 IUCLID, 2006
Octanol/Water Partition Coefficient (Log K_{ow})	8.39 (est) 3.4 (estimated) 7.73 – 8.39 at 25°C (calculated)	HSDB, 2015 IPCS, 2012; CDC, 2014 IUCLID, 2006; ECB, 2007
Boiling Point	230°C (0.53 kPa) 370°C 417°C at 1013 hPa (estimated)	NICNAS , 2013 HSDB, 2015; IPCS, 2012; CDC, 2014 IUCLID, 2006
Melting Point	-4°C -45°C -46°C -50°C(measured)	HSDB, 2015 IPCS, 2012; CDC, 2014; CPSC, 2010 IUCLID, 2006 U.S. EPA, 2010
Vapor Pressure	5.5×10^{-6} mm Hg at 25°C; 1.0 mm Hg at 200°C $1.89 \times 10^{-7} – 1.39 \times 10^{-6}$ at 25°C (calculated)	HSDB, 2015 IUCLID, 2006

Flash Point	450°F; 232°C (method not specified) 450°F(232°C) (Closed cup) Flash point: 227°C (Closed cup)	HSDB, 2015 IPCS, 2012; CDC, 2014

9.3 Worldwide Manufacturing Processes for DIOP

Synthesis of DIOP is by a simple chemical process; it is likely that the same process is used throughout the world, although there is no information available in the sources searched describing worldwide manufacturing processes.

In the U.S., one manufacturer is reported by HSDB (2015) and IUCLID (2006), whereas Chem Sources Online (2015) reports seven other manufactures that were not reported by the other sources.

In Europe, Chem Sources Online (2015) reports one manufacturer in Germany. In the Nordic countries (Sweden, Norway, Finland, and Denmark), 2,205 pounds (1 tonne) or less have been used since 2003 and none between 2009 and 2012, the last year these data were available (SPIN, 2015).

Chem Sources Online (2015) reports three manufacturers, one each in Hong Kong, China, and India.

There is no information available in the sources searched for manufacturers in other countries.

9.4 Annual Production of DIOP

The Australian Competition and Consumer Commission (ACCC, 2015) indicates that around 4,000,000,000 pounds of phthalates are produced across the world each year and that more than 20 types of phthalates are in common use, including DIOP. However, the contribution of DIOP to the worldwide volume is not available.

DIOP is listed as a High Production Volume (HPV) chemical since it was produced or imported into the U.S. at greater than 1,000,000 pounds (>500 tons) in 1990 and/or 1994. The HPV list is based on the 1990 Inventory Update Rule (IUR) (CFR, 2015; HSDB, 2015).

Recent production in the U.S. declined from 24,300,000 pounds (2005) to 22,300,000 pounds (NICNAS 2008; Bizzari et al., 2007, 2009, as cited by CPSC, 2010). These data from 2005 were the most current obtained.

Table 9-2 U.S. Production Volumes for DIOP from Non-confidential Chemicals Reported under the Inventory Update Rule

Year	Production Range (pounds)	
1986	>10,000,000–50,000,000	HSDB, 2015
1990	>10,000,000–50,000,000	
1994	>10,000,000–50,000,000	
1998	>50,000,000–100,000,000	
2002	>10,000,000–50,000,000	

According to CPSC (2010), production and consumption trends for Western Europe are similar to those in the U.S. with consumption of DIOP declining from a high of 92,600,000 pounds (1988) to 33,100,000 pounds (NICNAS, 2008; CPSC, 2010).

Data on the production and consumption of DIOP in other countries either are not available or have been combined into multi-phthalate groups, and so are not specific to DIOP and relevant for this report.

9.5 Application of DIOP in Materials, Consumer Products, and Nonconsumer Products

DIOP is used as a plasticizer for vinyl, cellulosic and acrylate resins, and synthetic rubber (HSDB, 2015). The use of DIOP has also been reported in teethers (10.2%) and pacifiers (17.1%) and toys (>10%) (Stringer, 2000).

No other information as to the concentration of DIOP in products has been reported in the literature searched, including the HPD (2015) or the State of Washington's Department of Ecology database (WSDE, 2015).

The high molecular weight phthalate esters are used primarily as industrial chemicals that are added to impart flexibility to polyvinyl chloride (PVC) resins (CPSC, 2010). They are also used as synthetic base stocks for lubricating oils (NICNAS, 2008, as cited by CPSC, 2010). DIOP is generally used for insulation in building wire (HSDB, 2015). NICNAS (2008) reported that in Australia, DIOP is imported in rubber compounds for the manufacture of automotive hoses and parts (including truck bed linings at 5–20% v/v) and is distributed to various institutions and laboratories for biotechnological and pharmaceutical research. They are also used in inks, perfumes and lubricants (Stringer et al., 2000; SPIN, 2015).

The U.S. FDA has approved DIOP for use in adhesives (CFR, 2014) or surface resin and polymer coatings (CFR, 2014) for products that have contact with food (products intended to be used in production, manufacturing, packing, transport, or holding of food). The use of DIOP as an additive in plastics which will come into contact with food is also permitted in Italy as in the U.S. by the FDA (HSDB, 2015).

The Washington State Department of Ecology (WSDE, 2015), under the 2008 Washington Children's Safe Product Act has tested consumer products for toxic chemicals and has received and posted data from manufacturers on children's products sold in Washington if their product contains chemicals of high concern, which includes phthalates. It is not clear whether WSDE has or has not tested for DIOP in any of the products as it has not reported on this phthalate in their database.

9.6 Routes of Introduction of DIOP into Phthalate-free Material

Specific information as to migration of DIOP into phthalate-free material was not located in the sources searched for this report. However, general information on phthalates may shed some light on the potential of DIOP to migrate from PVC materials. Stringer et al. (2000) indicates that phthalates in soft PVC products are not tightly bound to the plastic, but are present as mobile components of the plastic matrix. Therefore, the phthalates from soft PVC can be lost by volatilization over time. Additionally, they can be released from soft PVC by surface contact, especially where mechanical pressure is applied (e.g., during chewing of a PVC teether) (Stringer et al., 2000).

Phthalates in recycled materials could represent a source of contamination for phthalate-free materials. They can be exempted from REACH (Registration, Evaluation, Authorization and Restriction of Chemicals) when they comprise less than 20% of the recyclate (Lee et al., 2014), indicating that they could be present as a source of contamination for phthalate-free materials.

9.7 References

ACC (American Chemistry Council). 2006. High Production Volume (HPV) Chemical Challenge Program Test Plan for the Phthalate Esters Category. American Chemistry Council.

ACCC (Australian Competition & Consumer Commission). 2015. Phthalates in Consumer Products. Product Safety in Australia. Australian Competition & Consumer Commission. Available at: https://www.productsafety.gov.au/content/index.phtml/itemId/972486#h3_281.

ATSDR (Agency for Toxic Substances and Disease Registry). 2002. Toxicological Profile for Di (2-Ethylhexyl) Phthalate. U.S. Department of Health and Human Services. Public Health Service. Agency for Toxic Substances and Disease Registry.

Bizzari, S.N., Blagoev, M., Kishi, A. 2007. CEH Marketing Research Report. Plasticizers. SRI Consulting. 148 pp. (As cited in CPSC, 2010).

Bizzari, S.N., Blagoev, M., Kishi, A. 2009. CEH Marketing Research Report. Plasticizers. SRI Consulting. 148 pp. (As cited in CPSC, 2010).

CCOHS (Canadian Centre for Occupational Health and Safety). 2015. Web search for 27554-26-3. Canadian Centre for Occupational Health and Safety. Available at: http://search.ccinfoweb.ccohs.ca/ccohs/jsp/search/search.jsp?QueryText=27554-26-3&MaxDocs=500&ResultStart=1&SortSpec=Score+desc&hTab=7&vTab=1.

CDC (Centers for Disease Control and Prevention). 2014. International Chemical Safety Cards (ICSC) 0876. Diisooctyl Phthalate. Centers for Disease Control and Prevention. Available at: http://www.cdc.gov/niosh/ipcsneng/neng0876.html.

Chem Sources Online. 2015. Chem Sources Online database. Chem Sources International, Inc. Available at: http://www.chemsources.com/chemonline.html.

CFR (Code of Federation Regulations). 2014. Title 21, Subchapter B, Part 175 Indirect Food Additives; Adhesives and Components of Coatings. Code of Federal Regulations, Washington, D.C., Available at: http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/cfrsearch.cfm?fr=175.105.

CFR (Code of Federation Regulations). 2015. Title 40, Part 710 subpart B Compilation of the TSCA Chemical Substance Inventory. Code of Federal Regulations, Washington, D.C., Available at: http://www.ecfr.gov/cgi-bin/text-idx?SID=1a45f84adbf028c202e5062cd73db5f9&mc=true&node=se40.31.710_11&rgn=div8.

CPSC (U.S. Consumer Product Safety Commission). 2010. Toxicity Review for Diisooctyl Phthalate (DIOP). Contract No. CPSC-D-06-0006. U.S. Consumer Product Safety Commission, Bethesda, MD. Available at: https://www.cpsc.gov/PageFiles/125782/diop.pdf.

ECB (European Chemicals Bureau). 2007. Substance ID: 27554-26-3. Diisooctyl phthalate. IUCLID Dataset. European Chemicals Bureau. European Commission. 30pp.

HPD (Household Products Database), 2015. Household Products Database. U.S. Department of Health and Human Services. National Library of Medicine. Available at: http://householdproducts.nlm.nih.gov/.

HSDB (Hazardous Substances Data Bank). 2015. Diisooctyl Phthalate. Hazardous Substances Data Bank, National Library of Medicine. Available at: http://toxnet.nlm.nih.gov/cgi-bin/sis/search/a?dbs+hsdb:@term+@DOCNO+588.

IPCS (International Programme on Chemical Safety). 2012. Diisooctyl Phthalate. ICSC 0876. International Programme on Chemical Safety, European Commission. Available at: http://www.inchem.org/documents/icsc/icsc/eics0876.htm.

IUCLID (International Uniform Chemical Information Database). 2006. Substance ID: 27554-26-3. Diisooctyl phthalate. IUCLID Dataset. European Chemicals Bureau. European Commission. Available at: http://www.epa.gov/HPV/pubs/summaries/benzene/c13467rr3p.pdf.

Lee, J., Lee, J-H., Kim, C-K., Thomsen, M. 2014. Childhood exposure to DEHP, DBP, and BBP under existing chemical management systems: A comparative study of sources of childhood exposure in Korea and in Denmark. Environ Int. 63, 77-91.

NICNAS (National Industrial Chemicals Notification and Assessment Scheme). 2008. Diisooctyl phthalate. Existing Chemical Hazard Assessment Report. National Industrial Chemicals Notification and Assessment Scheme. (As cited in CPSC, 2010).

NICNAS (National Industrial Chemicals Notification and Assessment Scheme). 2013. AICS Listing. 1,2-Benzenedicarboxylic acid, diisooctyl ester. National Industrial Chemicals Notification and Assessment Scheme. Available at: http://www.nicnas.gov.au/regulation-and-compliance/aics/aics-search-page/chemical?id=17004.

PubChem, 2015. The Pubchem online database. National Library of Medicine. Available at: https://pubchem.ncbi.nlm.nih.gov/.

RAPEX. 2015. Rapid Alert System for dangerous non-food products. Latest Reports Online database. European Commission. Available at: http://ec.europa.eu/consumers/safety/rapex/alerts/main/index.cfm?event=main.listNotifications.

SPIN (Substances in Preparation in Nordic Countries). 2015. SPIN Database. Danish Environmental Protection Agency. Available at: http://195.215.202.233/DotNetNuke/default.aspx.

Stringer, R., Labunska, I., Santillo, D., Johnston, P., Siddorn, J., Stephenson, A. 2000. Concentrations of phthalate esters and identification of other additives in PVC children's toys. Environ Sci Pollut Res. 7, 1-10.

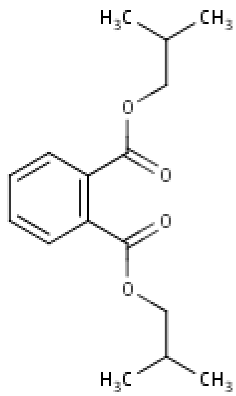
U.S. EPA (U.S. Environmental Protection Agency). 2010. Screening-Level Hazard Characterization. Phthalate Esters Category. Hazard Characterization Document. U.S. Environmental Protection Agency. Available at: http://www.epa.gov/hpvis/hazchar/Category_%20Phthalate%20Esters_March%202010.pdf.

WSDE (Washington State Department of Ecology ECY). (2015). "Children's Safe Product Act Reported Data." Available at: https://fortress.wa.gov/ecy/cspareporting/.

10 Diisobutyl phthalate (DIBP) CASRN: 84-69-5

Diisobutyl phthalate (DIBP) is an ortho-phthalate with branched alkyl side chains of length C3, and is considered a low molecular weight phthalate (Danish EPA, 2011; ECHA, 2012; CPSC, 2010).

The structure of DIBP (PubChem, 2015) is as follows:



10.1 Raw Materials Used in Production of DIBP

Synthesis of DIBP generally occurs by esterification of phthalic anhydride with i-butyl alcohol (isobutanol) in a closed system, followed by purification using vacuum distillation or activated charcoal (HSDB, 2015; CPSC, 2010).

The following chemicals are used as raw materials in the production of DIBP:

- iso-butyl alcohols
- phthalic anhydride

Synonyms and trade names for DIBP are shown in the Table 10-1.

10.2 Chemical and Physical Properties of DIBP

Diisobutyl phthalate (DIBP) is a liquid at room temperature that is almost insoluble in water and soluble in organic solvents, such as carbon tetrachloride, and in oils (HSDB, 2015).

The high boiling point and low vapor pressure contributes to DIBP's physical stability (HSDB, 2015). DIBP has low volatility, as indicated by its vapor pressure (HSDB, 2015). Volatilization from water and moist surfaces containing dissolved DIBP (based on data from soil) is expected based on the vapor pressure and water solubility, but volatilization is not expected from dry surfaces (HSDB, 2015; U.S. EPA, 2014). However, only a small amount of DIBP can dissolve in water.

DIBP reacts with strong oxidants and should be stored separately (HSDB, 2015). When heated to decomposition (temperature not specified), DIBP emits irritating and acrid toxic gases and fumes (HSDB, 2015). Table 10-1 summarizes the chemical and physical characteristics of DIBP (HSDB, 2015; Danish EPA, 2011; ECHA, 2012; CPSC, 2010). The data for several of these characteristics varies depending on the source.

Table 10-1. Physical/Chemical Characteristics of DIBP

Characteristic	Value	Reference
IUPAC Name	1,2-Benzenedicarboxylic Acid, Bis(2-methylpropyl) Ester	HSDB, 2015
CASRN	84-69-5	HSDB, 2015
EC Number	201-553-2	Danish EPA, 2011
Synonyms and Trade Names	1,2-Benzoldicarbonsaeure-bis(2-methylpropyl)ester; Bisoflex DIBA; Bisoflex DIBP; Diisobutilftalato; Di(isobutyl) 1,2-benzenedicarboxylate; Di-Iso-Butyl Phthalate; Diplast B; Ftatato di isobutile; HEXAPLAS M/1B; Hexaplas MIB; Isobutyl Phthalate; Mollan L; PALATINOL IC; Phthalic Acid, Diisobutyl Ester; Phthalsaeure-diisobutylester; Phthalsaurediisobutylester; Vestinol IB; AI3-04278 (USDA); Hatol DIBP; Kodaflex DIBP; Palatinol IC; DiBP; Phthalic acid, diisobutyl ester; Diisobutyl phthalate; Diisobutylester kyseliny ftalove; 1,2-Benzenedicarboxylic acid, di(2-methylpropyl) ester; Bis(2-methylpropyl) phthalate; NSC 15316; Isobutyl-o-phthalate; di-2-methylpropyl phthalate	HSDB, 2015; NIST Webbook, 2015
Molecular Formula	$C_{16}H_{22}O_4$	HSDB, 2015
Molecular Weight	278.344 g/mol	HSDB, 2015; CPSC, 2010

Physical description	Colorless, clear, viscous liquid	HSDB, 2015; Danish EPA, 2011; CPSC, 2010
Odor	Mostly odorless	CPSC, 2010
Solubility in water	6.2 mg/L at 24°C 20 mg/L at 20°C 1.1 x 10^{-3} g/L (temperature not specified)	HSDB, 2015 Danish EPA, 2011 CPSC, 2010
Octanol/Water Partition Coefficient (log K_{ow})	4.11	HSDB, 2015; Danish EPA, 2011
Boiling Point	296.5°C; 159°Cat 4 mm Hg 320°C	HSDB, 2015 Danish EPA, 2011
Melting Point	-64°C -37°Cat 1,013 hPa	HSDB, 2015 Danish EPA, 2011
Vapor Pressure	4.76x10^{-5} mm Hg at 25°C 0.01 Pa at 20°C 1.0 x 10^{-5} kPa	HSDB, 2015; CPSC, 2010 Danish EPA, 2011 CPSC, 2010
Flash Point	185°C 161–185°C	HSDB, 2015 CPSC, 2010

10.3 Worldwide Manufacturing Processes for DIBP

DIBP is produced through a relatively simple synthesis reaction that would be very similar throughout the world. In the United States, two manufacturers were reported in 2006 by HSDB (2015). U.S. EPA (2015) shows at least two U.S. companies as manufacturing DIBP. A Chem Sources Online search (2015) identified at least 12 U.S. manufacturers, three Chinese manufacturers, and one each in Switzerland, Germany, Hong Kong, Japan, and the United Kingdom. Available sources did not present information for other countries.

10.4 Annual Production of DIBP

Annual production data are available for the U.S. and Europe. While there are manufacturers in Asia, the sources searched did not report production volume data for other countries.
In the United States, DIBP is listed as a HPV chemical (HSDB, 2015). Chemicals listed as HPV were produced in or imported into the U.S. in >1,000,000 pounds in 1990 and/or 1994. The HPV list is based on the 1990 Inventory Update Rule (IUR) (CFR, 2015).

Table 10-2. U.S. Production Volumes for DIBP from Non-confidential Chemicals Reported under the Inventory Update Rule*

Year	Production Range (pounds)
1986	>1,000,000–10,000,000
1990	>1,000,000–10,000,000
1994	>1,000,000–10,000,000
1998	>1,000,000–10,000,000
2002	>500,000–1,000,000
2012	500,000

*Source: HSDB, 2015; U.S. EPA, 2014

CPSC (2010) reported that U.S. production of DIBP is low, and combined production estimates with nine other phthalates was 28,660,094 pounds (13,000 metric tonnes). The U.S. EPA (2015) reports that past production volumes were near 453,710 lb/yr by at least one company, but shows at least two companies listed as manufacturing DIBP.

The Danish EPA (2011) reported information was available from manufacture and/or use in Europe in the range of 20,000,000–50,000,000 pounds/year (10,000–50,000 tons/year) (Danish EPA, 2011; ECHA, 2012; CPSC, 2010). They present data on EU production and import of DIBP used for production in 2007 at 38,000,000 pounds (19,000 tons) and in 2009/2010 at 6,000,000 pounds (3,000 tons) (Danish EPA, 2011).

In Nordic countries, up to 50,706 pounds (23 tonnes) of DIBP was used in 2012 (SPIN, 2015). Total DIBP use, however, has shown a mostly decreasing trend since peak usage in 2007 (at 104.9 tonnes or 231,264 pounds). Overall, use has steadily declined in Sweden since 2002, in Finland since 2003, and in Norway and Denmark since 2007 (SPIN, 2015).

10.5 Application of DIBP in Materials, Consumer Products and Non-consumer Products

DIBP has been found in children's products both in toys and child care articles, as well as numerous other consumer and non-consumer products. Concentrations of DIBP in some of these materials are available.

DIBP is typically combined with other phthalates for use in PVC (CPSC, 2010). DIBP can also be found industrially in paints, lacquers, varnishes, paper, pulp and boards, adhesives, binding agents, “softeners”, and viscosity adjusters; in Australia similar uses are reported along with additional use as a catalyst (HSDB, 2015; U.S. EPA, 2014). DIBP has been registered for use in multiple product categories, including: crayons, erasers (type not specified), school bags, plastic cutlery and dishware, and milk packaging, among others (Danish EPA, 2014). The sources providing this information did not specify how or why DIBP was used in these products. DIBP can also be present in products as a contaminant (Danish EPA, 2014).

10.5.1 Child Care Products

In a survey of DIBP occurrence in toys and child care articles, DIBP was found in 2% of the articles tested (Danish EPA, 2011), but no information on concentrations was reported. In another assessment, 27 plastic samples from plasticized toys and child care articles were tested for concentrations of DIBP and other phthalate ester plasticizers. Reported values of DIBP in PVC products ranged from 0.05– 29.0% (w/w), and was detected twice at 0.01 % (w/w) in non-PVC products (Al-Natsheh et al., 2015).

In an assessment looking at DIBP concentrations in toys, child care articles, children’s sandals and similar articles, DIBP was detected in 4% of the samples (total 252 samples), with a mean concentration of 15.4% (w/w) (range 0.4% to 35%) (Biedermann-Brem et al., 2008). DIBP was specifically detected in children’s articles with a mean concentration of 22% (Biedermann-Brem et al., 2008). DIBP was detected in children’s cored block (not wooden blocks) toys at 0.9% (Korfali et al., 2013). DIBP has also been detected in a number of additional children’s products including: plastic shoes/sandals, dinner mats/oilcloths, water wings, and in a swimming pool (ECHA, 2012). While the WSDE reports other phthalates (DPP, DHEXP, DEHP, DnOP, DIDP, and DINP) in childcare articles and toys, DPENP is not reported (WSDE, 2015).

In 2014, the CPSC Chronic Hazard Advisory Panel (CHAP) recommended a permanent ban for DIBP at levels >0.1% in children’s toys and child care articles. A similar ban was proposed in 2011 by the Danish EPA for articles intended for use indoors or that may come into direct contact with the skin or mucous membranes containing DIBP in a concentration greater than 0.1% by weight (Danish EPA, 2011).

Table 10-3 shows DIBP concentrations in various children’s products or products that have the potential to be used by children. Consistent with the CPSC CHAP report (2014), DIBP is not frequently found in toys and child care articles. However, when found, it may be present in concentrations that exceed 0.1%.

Table 10-3. DIBP Concentrations in Children's Products

Use	Product	DIBP Concentration	Reference
Toy	Various toys	27% (w/w)	Biedermann-Brem et al., 2008
Toy	Water toys	5% (w/w)	Biedermann-Brem et al., 2008
Toy	Modeling materials	0.02% (196 ppm)	IFCS, 2006
Toy	Bath toy	0.004% (37 ppm)	IFCS, 2006
Toys	Swimming pool	0.002% (18 ppm)	ECHA, 2012
Toy	Play putty	0.002% (16 ppm)	IFCS, 2006
Toy	Action figure	<0.001% (1.6 ppm)	IFCS, 2006
Toys	Water wing	ND	ECHA, 2012
Toys and child care articles	Plasticized (PVC) toys and child care articles	29.00 ± 0.40 % (w/w)	Al-Natsheh et al., 2015
Toys and child care articles	Plasticized (PVC) toys and child care articles	21.20 ± 0.50 % (w/w)	Al-Natsheh et al., 2015
Toys and Child care articles	Plasticized (PVC) toys and child care articles	21.10 ± 0.40 % (w/w)	Al-Natsheh et al., 2015
Toys and child care articles	Plasticized (PVC) toys and child care articles	8.48 ± 0.66 % (w/w)	Al-Natsheh et al., 2015
Toys and child care articles	Plasticized (PVC) toys and child care articles	8.31 ± 0.21 % (w/w)	Al-Natsheh et al., 2015
Toys and child care articles	Plasticized (PVC) toys and child care articles	7.06 ± 0.15 % (w/w)	Al-Natsheh et al., 2015
Toys and child care articles	Plasticized (PVC) toys and child care articles	2.42 ± 0.13 % (w/w)	Al-Natsheh et al., 2015
Toys and child care articles	Plasticized (PVC) toys and child care articles	0.32 ± 0.03 % (w/w)	Al-Natsheh et al., 2015
Toys and child care articles	Plasticized (PVC) toys and child care articles	0.18 ± 0.05 % (w/w)	Al-Natsheh et al., 2015
Toys and child care articles	Plasticized (PVC) toys and child care articles	0.07 ± 0.00 % (w/w)	Al-Natsheh et al., 2015
Toys and child care articles	Plasticized (PVC) toys and child care articles	0.05 ± 0.00 % (w/w)	Al-Natsheh et al., 2015

Use	Product	DIBP Concentration	Reference
Toys and child care articles	Plasticized (non-PVC) toys and child care articles	0.01 ± 0.00 % (w/w)	Al-Natsheh et al., 2015
Toys and child care articles	Plasticized (non-PVC) toys and child care articles	0.01 ± 0.00 % (w/w)	Al-Natsheh et al., 2015
Clothing, Footwear	Pinafores, shoes	24% (w/w)	Biedermann-Brem et al., 2008
Clothing, Footwear	Plastic sandals Shoes - 6/7-year old	3.9% (12–38,650 ppm)	ECHA, 2012
Clothing, Footwear	Plastic sandals Shoes - 2-year old	0.001–12% (12–121,000 ppm)	ECHA, 2012
Children's Products	Toys, child care articles, sandals for children and similar articles	15.4 % (w/w)	Biedermann-Brem et al., 2008
Children's Products	Selected toys and child care products produced from foam plastic	<0.001–0.18% (2.8–1800 ppm)	CPSC, 2010
Children's Products	Oilcloth and dinner mat	0.001–0.006% (8.9–56.2 ppm)	ECHA, 2012
Children's Products	Suckers, plastic spoons and forks, boxes for microwave ovens, milk package bags, disposable cups, plates, bowls	<0.001% (0.01–7.8 ppm)	CPSC, 2010

*Concentrations < 0.1% are shaded.

10.5.2 Other Products

DIBP has been used as a plasticizer for a number of cellulosic applications. It is also used in consumer products such as nail polish, cosmetics, lubricants, carpets, tapestries, clothing, and some dentistry settings (CPSC, 2010; HSDB, 2015). DIBP is also used as a fuel stabilizer, in concrete, in explosives, and for printing inks in paper and packaging (HSDB, 2015; U.S. EPA, 2014). DIBP can also be used as a substitute for dibutyl phthalate (DBP) based on similar physical/chemical properties (HSDB, 2015; CPSC, 2010).

DIBP has been detected in paper and packaging materials, including in paper towels ranging from 0.00033-0.00103% (3.3 to 10.3 ppm) and in paper and boxboard packaging ranging from 0.003–0.05% (30 to 450 ppm) (Cao, 2010). Other packaging samples were found to contain 0.000015–0.0021% (0.15 to 21 ppm) DIBP (Pocas et al., 2010). In another study investigating phthalate concentrations in packaging materials (including cardboard, tetra brick, plastic, multi-layer packing material, wax, and paper) DIBP ranged from 'not detected' to 523 ng/cm² (median 7.5 ng/cm²) (conversion to ppm or % not specified) (Van Holderbeke et al., 2014). Cao (2010) suggests that most of the phthalates in packaging and paper materials comes from printing inks and adhesives, and that recycled paper materials could be carried over from previous materials. DIBP has also been detected in the nonstick coatings on cookware (Cao, 2010).

The European Industry reports DIBP concentration in three types of PVC flooring heterogeneous PVC (1.59%), PVC with foam backing (0.65%) and cushioned PVC (5.71%) (Danish EPA, 2011). Analysis of 8 PVC floorings detected DIBP at 7.4% and another analysis of 25 PVC floorings reported DIBP ≤6.9% (Danish EPA, 2011). European trends for flooring and related products are moving away from DIBP use (Danish EPA, 2011). HSDB (2015) reported that water-based adhesives may contain DIBP at concentration up to 15%. In handbags, shoulder bags, sponge bags, rucksacks, trolleys and plastic bags for consoles, DIBP was found at concentrations below 0.1% (Danish EPA, 2011).

Analysis of DIBP concentrations in 12 oilcloths and dinner mats tested were below 0.1% (Danish EPA, 2011). In 8 carpet tiles tested, only one contained DIBP (at a concentration of 0.016%) (Danish EPA, 2011). In 13 tested air mattresses, only one contained DIBP (below 0.1%) (Danish EPA, 2011). In 15 tested wallpapers, DIBP was detected below 0.1% (Danish EPA, 2011). DIBP was detected in swimming pools but the concentration was not quantified (Danish EPA, 2011). Two of 10 sampled fitness balls had levels of DIBP above 1% (exact amount not reported) (Danish EPA, 2011). Levels in a balance ball and a training ball were reported in ECHA (2012), and in bags, adult plastic sandals, and shower curtains.

From 2000-2012, industrial uses of DIBP in Nordic countries included: adhesives; binding agents; coloring agents; construction materials; fillers; intermediates; paints, lacquers, and varnishes; process regulators; and others (SPIN, 2015); no additional or specific information was available from this source. The volume of use remained relatively constant from 2008-2012, and no other specific use trends were identified (SPIN, 2015).

Table 10-4 shows the concentrations of DIBP reported in various consumer products.

Table 10-4 DIBP Concentrations in Consumer Products

Use	Product	DIBP Concentration	Reference
Personal Care Product	Perfumes	0.01% (0.2–38 ppm)	CPSC, 2010
Clothing, Footwear	Plastic sandals Shoes - adults	<0.001–21.2% (3–212,000 ppm)	ECHA, 2012
Food packaging	Food packaging material	0.7% (7055.3 ppm, max value)	CPSC, 2010
Food packaging	Paper wraps on sugar packets	<0.01% (95 to 98 ppm)	Cao, 2010
Food packaging	Food packaging samples	<0.01% (0.15 to 21 ppm)	Pocas et al., 2010
Consumer Products	Training ball	36% (355,000 ppm)	ECHA, 2012
Consumer Products	Cushioned PVC flooring	5.71%	Danish EPA, 2011
Consumer Products (flooring)	Heterogeneous PVC flooring	1.59%	Danish EPA, 2011
Consumer Products	PVC with foam Backing flooring	0.65%	Danish EPA, 2011
Consumer Products	Bag	0.5% (10–509 ppm)	ECHA, 2012
Consumer Products	Balance ball	0.01–0.07% (115–693 ppm)	ECHA, 2012
Consumer Products	Paper towels	0.001% (3.3 to 10.3 ppm)	Cao, 2010
Consumer Products	Paper and boxboard packaging	<0.001–0.05% (30 to 450 ppm)	Cao, 2010
Consumer Products	Air freshener, liquid	<0.001% (0.24 – 1.6 μg/kg)	CPSC, 2014
Consumer Products	Laminated PVC	None	Danish EPA, 2011
Consumer Products	Shower curtain	ND	ECHA, 2012

*Concentrations < 0.1% are shaded.
NK= not known
ND= not detected

10.6 Routes of Introduction of DIBP into Phthalate-free Material

Phthalates used as plasticizers are not chemically bound to the polymer matrix. Therefore, they are expected to be leachable and may migrate out of plastics, particularly when children handle and chew on phthalate-containing products (Al-Natsheh et al., 2015; U.S. EPA, 2014). DIBP was shown to migrate from PVC and non-PVC plasticized toys and child care articles into a number of solvents and artificial saliva (Al-Natsheh et al., 2015). Migration data are available showing DIBP migration out of plastic baby bottles (Simoneau et al., 2012). There are also migration data of DIBP into artificial saliva from bags, shower curtains, oilcloths/dinner mats, a swimming pool, balance balls, training balls, and erasers (type not specified) (ECHA, 2012). The migration rate for DIBP was reported in the range of less than 0.1–1% per year (Danish EPA, 2014).

Migration data are available showing DIBP migration from training balls and sandals into sweat (ECHA, 2012). Other migration data into sweat were reported for bags, shower curtains, oilcloths, water wings, swimming pools, and sex toys (ECHA, 2012).

There are also migration data available suggesting that DIBP can migrate from plastic polyethylene terephthalate (PET) or polylactic acid (PLA) based water bottles into water (CalRecycle, 2013), consistent with the limited solubility of DIBP in water. Two hypotheses have emerged regarding DIBP in bottled water: that the concentrations of DIBP in the water were due to migration from DIBP in the PET material used to make the water bottle, or that because water bottles are expected to be rigid and not contain high levels of phthalates, that DIBP in bottled water is strictly related to environmental contamination of the water itself (Cao, 2010).

Phthalate migration from PVC gloves was generally increased in gloves sterilized with alcohol (Cao, 2010), consistent with the higher solubility of DIBP in non-aqueous solvents.

The prevalence of DIBP in house and office dust suggests that DIBP may adsorb onto the surface of the dust particles (HSDB, 2015). It was also suggested that environmental concentrations of DIBP are due to the slow release from plastics over time (U.S. EPA, 2014; Danish EPA, 2011).

10.7 References

Al-Natsheh, M., Alawi, M., Fayyad, M., Tarawneh, I., 2015. Simultaneous GC-MS determination of eight phthalates in total and migrated portions of plasticized polymeric toys and childcare articles. J Chromatogr B Analyt Technol Biomed Life Sci. 985, 103–109.

Biedermann-Brem, S., Biedermann, M., Pfenninger, S., Bauer, M., Altkofer, W., Rieger, K., Hauri, U., Droz, C., Grob, K., 2008. Plasticizers in PVC toys and childcare products: What succeeds the phthalates? Market Survey 2007. Chromatographia. 68, 227-234.

CalRecycle (California Department of Resources Recycling and Recovery). 2013. Experimental Comparison of Chemical Migration from Petrochemical Plastic and Bioplastic Bottles into Drinking Water. Department of Resources Recycling and Recovery. DRRR-2013-1486. California Department of Resources Recycling and Recovery Sacramento, CA.

Cao, X-L. 2010. Phthalate esters in foods: sources, occurrence, and analytical methods. Compr Rev Food Sci F. 9, 21-43.

CFR (Code of Federation Regulations). 2015. Title 40, Part 710 subpart B Compilation of the TSCA Chemical Substance Inventory. Code of Federal Regulations, Washington, D.C., Available at: http://www.ecfr.gov/cgi-bin/text-idx?SID=1a45f84adbf028c202e5062cd73db5f9&mc=true&node=se40.31.710_11&rgn=div8.

Chem Sources Online. 2015. Chem Sources Online database. Chem Sources International, Inc. Available at: http://www.chemsources.com/chemonline.html.

CPSC (U.S. Consumer Product Safety Commission). 2010. Review of Exposure Data and Assessments for Selected Dialkyl Ortho-Phthalates. CPSC-D-06-0006. Consumer Product Safety Commission, Bethesda, MD.

CPSC (U.S. Consumer Product Safety Commission). 2014. Chronic Hazard Advisory Panel on Phthalates and Phthalate Alternatives. Report to the U.S. Consumer Product Safety Commission. Directorate for Health Sciences. Bethesda, MD.

Danish EPA (Danish Environmental Protection Agency). 2011. Annex XV Restriction Report: Proposal for a Restriction. Substance Name: Bis(2-Ehtylhexyl) Phthalate, Bis(2-Ethylhexyl) Phthalate (DEHP), Benzyl Butyl Phthalate (BBP), Dibutyl Phthalate (DBP), Diisobutyl Phthalate (DIBP). Danish Environmental Protection Agency, Copenhagen K, Denmark.

Danish EPA (Danish Environmental Protection Agency). 2014. Hazardous substances in plastics. Survey of chemical substances in consumer products No. 132, 2014. Danish Environmental Protection Agency, Copenhagen K, Denmark.

ECHA (European Chemicals Agency). 2012. Evaluation of new scientific evidence concerning DINP and DIDP in relation to entry 52 of Annex XVII to REACH Regulation (EC). No 1907/2006. Final review report. European Chemicals Agency.

HSDB (Hazardous Substances Data Bank). 2015. Hazardous Substances Data Bank online database, Toxnet Toxicology Data Network. U.S. National Library of Medicine. Available at: http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB.

IFCS (Intergovernmental Forum on Chemical Safety), 2006. Toys and Chemical Safety: A Thought Starter. Intergovernmental Forum on Chemical Safety. IFCS/Forum-V/03-TS, Budapest, Hungary. Available at: http://www.who.int/ifcs/documents/forums/forum5/intro_shea.pdf.

Korfali, S. I., Sabra, R., Jurdi, M., Taleb, R. I., 2013. Assessment of toxic metals and phthalates in children's toys and clays. Arch Environ Contam Toxicol. 65, 368-381.

NIST (National Institute of Standards and Technology). 2015. NIST WebBook. NIST Standard Reference Database Number 69. Available at: http://webbook.nist.gov/.

Poças, M. F., Oliveira, J. C., Pereira, J. R., Hogg, T., 2010. Consumer exposure to phthalates from paper packaging: an integrated approach. Food Addit Contam Part A. 27, 1451–1459.

Simoneau, C., Van den Eede, L., Valzacchi, S. 2012. Identification and quantification of the migration of chemicals from plastic baby bottles used as substitutes for polycarbonate. Food Addit Contam Part A Chem Anal Control Expo Risk Assess. 29, 469-480.

SPIN (Substances in Preparation in Nordic Countries). 2015. SPIN Database. Danish Environmental Protection Agency. Available at: http://195.215.202.233/DotNetNuke/default.aspx.

U.S. EPA (U.S. Environmental Protection Agency). 2014. Preliminary Materials for the Integrated Risk Information System (IRIS) Toxicological Review of Diisobutyl Phthalate (DIBP) (CASRN 84-69-5). Office of Research and Development. U.S. Environmental Protection Agency. EPA/635/R-14/333. Washington, DC. Available at: http://www.epa.gov/iris/publicmeeting/iris_bimonthly-feb2015/DIBP_PreliminaryMaterials-upd.pdf.

U.S. EPA (U.S. Environmental Protection Agency). 2015. Chemical Safety and Pollution Prevention: Pollution Prevention and Toxics. Vol. 2014. Chemical Data Access Tool (CDAT). Available at: http://java.epa.gov/oppt_chemical_search/.

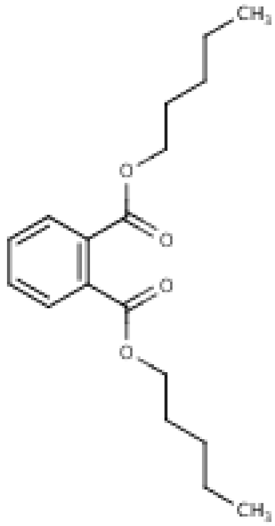
Van Holderbeke, M., Geerts, L., Vanermen, G., Servaes, K., Sioen, I., De Henauw, S., Fierens, T., 2014. Determination of contamination pathways of phthalates in food products sold on the Belgian market. Environ Res. 134, 345-352.

WSDE (Washington State Department of Ecology ECY). (2015). "Children's Safe Product Act Reported Data." Available at: https://fortress.wa.gov/ecy/cspareporting/.

11 Di-n-pentyl phthalate (DPENP) CASRN: 131-18-0

DPENP is an ortho-phthalate with two linear five-carbon side chains (CPSC, 2010). The five-carbon chains place DPENP in the transitional phthalate group (U.S. EPA, 2010).

The structure of DPENP (PubChem, 2015) is as follows:



11.1 Raw Materials Used in Production of DPENP

DPENP is produced through the esterification of phthalic anhydride with amyl alcohol in the presence of sulfuric acid as catalyst (HSDB, 2015; PubChem, 2015).

The following are used as raw materials in the production of DPENP:

- phthalic anhydride
- amyl alcohol (1-pentanol)
- catalyst (sulfuric acid)

Synonyms and trade names for DPENP are shown in Table 11-1 below.

11.2 Chemical and Physical Properties of DPENP

DPENP is a colorless, oily liquid that is nearly odorless. It has a similar density to water, but has a low solubility in water. It has a relatively low flash point, which makes it less stable than other phthalates (HSDB, 2015).

Table 11-1 summarizes the chemical and physical characteristics of DPENP.

Table 11-1 Physical/Chemical Characteristics of DPENP

Characteristic	Value	Source
IUPAC Name	Dipentyl benzene-1,2-dicarboxylate; dipentyl phthalate	PubChem, 2015; ECHA, 2013
CASRN	131-18-0	HSDB, 2015; ECHA, 2013
EC Number	205-017-9	PubChem, 2015; ECHA, 2013
Synonyms and Trade Names	DPP; DPeP;Dipentyl phthalate; DAP; Diamyl phthalate; DnPP; Di-n-pentyl phthalate; Amyl phthalate; Amoil; Di-n-pentylphthalate; Di-n-amyl phthalate;1,2-Benzenedicarboxylic acid, dipentyl ester; dipentyl benzene-1, 2-dicarboxylate; Phthalic acid, diamyl ester; Phthalic acid, dipentyl ester; NSC 4720; Dipentyl 1,2-benzenedicarboxylate; 1,2-Benzenedicarboxylic acid 1,2-dipentyl ester	HSDB, 2015; PubChem, 2015; U.S. EPA, 2012; NIST, 2015
Molecular Formula	$C_{18}H_{26}O_4$	HSDB, 2015; PubChem, 2015
Molecular Weight	306.4 g/mol	HSDB, 2015; PubChem, 2015
Physical description	Colorless, oily liquid	HSDB, 2015; PubChem, 2015
Specific Gravity/ Density	1.022 at 20°C, 1.03 g/cm^3	HSDB, 2015; PubChem, 2015; ECHA, 2013
Odor	Nearly odorless	HSDB, 2015; PubChem, 2015
Solubility in water	0.8 mg/L at 25°C	HSDB, 2015; PubChem, 2015; ECHA, 2013
Octanol/Water Partition Coefficient (Log K_{ow})	5.62	HSDB, 2015; PubChem, 2015; ECHA, 2013

Boiling Point	342°C	HSDB, 2015; PubChem, 2015
Melting Point	-55°C	HSDB, 2015; PubChem, 2015
Vapor Pressure	Extremely low, 1.96 $x10^{-4}$ mm Hg at 25°C	HSDB 2015; ECHA, 2013
Flash Point	357°F (180°C) /245°F (118°C), 118–180°C	PubChem, 2015; ECHA, 2013

11.3 Worldwide Manufacturing of DPENP

HSDB (2015) identified two companies that manufacture DPENP, one in India and one in Brazil (HSDB, 2015). Chem Sources Online (2015) reports the following number of manufacturers: seven in the United States, two in Germany, two in Japan, two in India, one in Switzerland, one in China, and one in Hong Kong. While Europe (specific countries not specified) does not manufacture DPENP, reported use of DPENP was at less than 2000 pounds per year (Danish EPA, 2014).

11.4 Annual Production of DPENP

DPENP production does not exceed 1,000,000 pounds per year and therefore does not qualify as a HPV phthalate in the U.S. (U.S. EPA, 2010; CPSC, 2010). Production data for DPENP in the U.S. are limited as production range is often not reported, as shown in Table 11-2. In 1990, the only year information for DPENP manufacture information was available, it was estimated at 10,000–500,000 pounds in the U.S.

Table 11-2 Production volumes for non-confidential chemicals reported under the Inventory Update Rule or National Production Volume

Year	Production Range (pounds)
1986	No Reports
1990	10,000 – 500,000
1994	No Reports
1998	No Reports
2002	No Reports
2006	No Reports
2012	No Reports

*Source: HSDB, 2015; U.S. EPA, 2015

In 1997, European manufacture was less than 2,200,000 lbs. per year. In Sweden, approximately 11,000 lbs. of DPENP was used in 2011, a decrease from approximately 24,000 lbs. in 2008 (SPIN, 2015).

Worldwide production data were not found in the sources searched for this project. There were no production volume data reported for DPENP in 2006, according to the 2006 Inventory Update Reporting database of the Toxic Substances Control Act (U.S. EPA, 2012). Manufacturers and producers are required to report DPENP production to the EPA, and there are no reports of DPENP being produced or imported into the U.S. (U.S. EPA, 2012). Therefore, any uses of DPENP would be new uses (U.S. EPA, 2012).

11.5 Applications for DPENP in Materials, Consumer Products and Nonconsumer Products

DPENP is used as a plasticizer in nitrocellulose and in polyvinyl chloride (PVC) (HSDB, 2015; CPSC, 2010; CPSC, 2014; U.S. EPA, 2014). DPENP is widely used as a solvent and can be found in personal care products, inks, dyes, nitrocellulose, resin lacquer, in the manufacture of glue and rubber cements to prevent foam, and in membrane electrodes (from PVC use), air fresheners and pharmaceutical devices (CPSC, 2010).

DPENP was not reported in the databases (WSDE, HPD, RAPEX) that report on phthalates in children's toys or child care articles searched for this report, nor is it widely found in the environment (CPSC, 2014; U.S. EPA, 2014). A British study analyzed 72 toys that were purchased from 17 countries and DPENP was not found in any of the products tested (Stringer et al., 2000). Two other studies (one with eight and another with 68 toys) also did not detect any DPENP (CPSC, 2010). An EU study did not detect DPENP leaching from two PVC teething toys (CPSC, 2010).

11.6 Routes of Introduction of DPENP into Phthalate-free Material

While DPENP appears to resist migration from polymers, migration might be possible at higher temperatures (specific temperatures not specified) (HSDB, 2015). DPENP is compatible with polar polymers and additives over a wide range of compositions (HSDB, 2015). It is soluble to various extents in many common organic solvents, such as carbon tetrachloride and carbon disulfide and oils, but has a relatively low solubility in water (HSDB, 2015). When heated to decomposition (temperature not specified) it emits acrid smoke and irritating fumes (PubChem, 2015). No other data on migration to phthalate-free materials were found in the sources searched for this project.

11.7 References

Chem Sources Online, 2015. Di-n-Pentyl Phthalate (DPENP), CASRN: 131-18-0. Chemical Source International, Inc. Available at: http://www.chemsources.com/chemonline.html.

CPSC (U.S. Consumer Product Safety Commission). 2010. Review of Exposure Data and Assessments for Selected Dialkyl Ortho-Phthalates. CPSC-D-06-0006. U.S. Consumer Product Safety Commission, Bethesda, MD.

CPSC (U.S. Consumer Product Safety Commission). 2014. Chronic Hazard Advisory Panel on Phthalates and Phthalate Alternatives. Report to the U.S. Consumer Product Safety Commission. Directorate for Health Sciences. Bethesda, MD.

Danish EPA (Danish Environmental Protection Agency). 2014. Hazardous substances in plastics. Survey of chemical substances in consumer products No. 132, 2014. Danish Environmental Protection Agency, Copenhagen K, Denmark. Available at: http://www2.mst.dk/Udgiv/publications/2014/12/978-87-93283-31-2.pdf.

ECHA (European Chemicals Agency). 2013. Annex XV Dossier - Identification of Dipentyl Phthalate. Proposal for identification of a substance as a CMR 1A or 1B, PBT, vPvB or a substance of an equivalent level on concern. European Chemical Agency. Available at: http://echa.europa.eu/documents/10162/d55c182b-f063-4955-969d-5684584d17b2.

HSDB (Hazardous Substances Data Bank). 2015. Hazardous Substances Data Bank online database, Toxnet Toxicology Data Network. U.S. National Library of Medicine. Available at: http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB.

NIST (National Institute of Standards and Technology). 2015. NIST WebBook. NIST Standard Reference Database Number 69. Available at: http://webbook.nist.gov/.

PubChem, 2015. The PubChem online database. National Library of Medicine. Available at: https://pubchem.ncbi.nlm.nih.gov/.

SPIN (Substances in Preparation in Nordic Countries). 2015. SPIN Database. Danish Environmental Protection Agency. Available at: http://195.215.202.233/DotNetNuke/default.aspx.

U.S. EPA (U.S. Environmental Protection Agency). 2010. Screening-Level Hazard Characterization. Phthalate Esters Category. Hazard Characterization Document. U.S. Environmental Protection Agency.

U.S. EPA (U.S. Environmental Protection Agency). 2012. Phthalates Action Plan. U.S. Environmental Protection Agency. Available at: http://www.epa.gov/oppt/existingchemicals/pubs/actionplans/phthalates_actionplan_revised_2012-03-14.pdf.

U.S. EPA (U.S. Environmental Protection Agency). 2014. Toxics Release Inventory Program. U.S. Environmental Protection Agency). Available at: http://www2.epa.gov/toxics-release-inventory-tri-program .

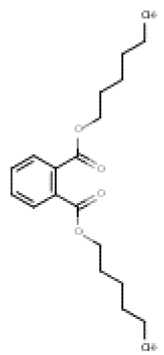
U.S. EPA (U.S. Environmental Protection Agency). 2015. Chemical Safety and Pollution Prevention: Pollution Prevention and Toxics. Vol. 2014. Chemical Data Access Tool (CDAT). Available at: http://java.epa.gov/oppt_chemical_search/.

WSDE (Washington State Department of Ecology ECY). (2015). "Children's Safe Product Act Reported Data." Available at: https://fortress.wa.gov/ecy/cspareporting/.

12 Dihexyl phthalate (DHEXP) CASRN: 84-75-3

Dihexyl phthalate (DHEXP) is a linear ortho-phthalate diester comprised of two six-carbon backbones and is considered a medium-weight, or transitional, phthalate ester (CPSC, 2010).

The structure of DHEXP (PubChem, 2015) is as follows:



12.1 Raw Materials Used in Production of DHEXP

DHEXP is manufactured commercially by esterifying phthalic anhydride with hexanol in the presence of a sulfuric acid catalyst (HSDB, 2015). DHEXP may be found as a minor component (less than 1%) of C6-10- phthalate mixtures and as an isomer (less than 25%) in mixtures of diisohexyl phthalates (DIHP) (CASRN 68515-50-4) (HSDB, 2015).

The following chemicals are used as raw materials in the production of DHEXP:

- phthalic anhydride
- hexanol
- acid catalyst (sulfuric acid)

Synonyms and trade names for DHEXP are shown in the Table 12-1 below.

12.2 Chemical and Physical Properties of DHEXP

DHEXP is a clear, oily liquid with a slightly aromatic odor (HSDB, 2015; Chemicalland21, 2015; CPSC, 2010). It is slightly soluble in water.

Table 12-1 summarizes the chemical and physical characteristics of DHEXP. The data for several of these characteristics varies depending on the source.

Table 12-1 Physical/Chemical Characteristics of DHEXP

Characteristic	Value	Reference
IUPAC Name	Dihexyl phthalate; dihexyl benzene-1,2-dicarboxylate	ECHA, 2013; PubChem, 2015
CASRN	84-75-3	HSDB, 2015; NICNAS, 2015
EC Number	201-559-5	ECHA, 2013;
Synonyms and Trade Names	DHEXP; DnHP; 1,2-Benzenedicarboxylic acid, dihexylylester; 1,2-Benzenedicarboxylic acid dihexyl ester; 1,2-Benzenedicarboxylic acid, dihexyl ester (9CI); Bis(n-hexyl) phthalate; 1,2-Benzenedioic acid dihexyl ester; Dihexyl 1,2-benzenecarboxylate; 1,2-Benzenedioic acid dihexyl ester; Dihexylester Kyseliny Ftalove (Czech); Dihexyl ester phthalic acid; Dihexyl phthalate; Di-n-hexyl phthalate; DnC6P; Hexyl phthalate, 1,2-; N-Dihexyl phthalate; Phthalic acid, dihexyl ester; Phthalic Acid Di-n-hexyl Ester; AI3-04274 (USDA); BRN 1886839; CCRIS 6192; DNHP; NSC 4817; Jayflex DHP; UNII-42MAH1QFG5 Phthalic Acid, Bis-Hexyl Ester; TIMTEC-BB SBB007740; 1,2-Benzenedicarboxylicacid,dihexylester; 1,2-benzenedioicaciddihexylester; 1,2-hexylphthalate; di-1-hexylphthalate	CPSC, 2010; HSDB, 2015; NICNAS, 2015; ECHA, 2013; PubChem, 2015; Chemical Book, 2015
Molecular Formula	$C_{30}H_{20}O_4$	HSDB, 2015; NICNAS, 2015

Molecular Weight	334.450 g/mol 334.46 g/mol	HSDB, 2015; NICNAS, 2005 ECHA, 2013; Chemicalland21, 2015
Physical description	Clear, oily liquid Clear liquid	HSDB, 2015; CPSC, 2010; Chemicalland21, 2015
Odor	Slightly aromatic; slight odor	HSDB, 2015; Chemicalland21, 2015
Solubility in water	0.05 mg/L at 25°C Slightly soluble	HSDB, 2015; CPSC, 2010 Chemicalland21, 2015
Octanol/Water Partition Coefficient (log K_{ow})	6.82	HSDB, 2015; CPSC, 2010
Boiling Point	210°C at 5 mm Hg 345°C 350°C	HSDB, 2015; CPSC, 2010 OSHA, 2015 Chemicalland21, 2015
Melting Point	-58°C < -58°C -28°C; ~-27°C	HSDB, 2015 CPSC, 2010 Chemicalland21, 2015
Vapor Pressure	1.4×10^{-5} mm Hg at 25°C 5 mm Hg at 20°C	HSDB, 2015; CPSC, 2010 OSHA, 2015
Flash Point	193°C 381°F; 193°C (method not specified)	CPSC, 2010; OSHA, 2015 HSDB, 2015

12.3 Worldwide Manufacturing Processes for DHEXP

Synthesis of DHEXP is by a simple chemical process. There is no information available in the sources searched describing worldwide manufacturing processes.

In the U.S., two manufacturers are reported by HSDB (2015) and another by U.S. EPA (2015). However, Chem Sources Online (2015) reports seven manufactures in the U.S. that are not reported by HSDB (2015) or U.S. EPA (2015). Chem Sources Online (2015) reports two manufacturers in Germany and one manufacturer in Japan.

12.4 Annual Production of DHEXP

DHEXP is listed as an Extended High Production Volume (EHPV) (HSDB, 2015). Chemicals listed as EHPV were produced in or imported into the U.S. in greater than 1,000,000 pounds according to the 2002 Toxic Substances Control Act (TSCA) Inventory Update (HSDB, 2015). The EHPV program is a voluntary initiative that allows companies to demonstrate that adequate screening data exist for organic HPV chemicals. U.S. EPA (2015) reports a U.S. production volume of 48,000 lb/year.

DHEXP is listed on the ECHA Candidate List of Substances of Very High Concern for authorization (ECHA, 2013).

Table 12-2 U.S. Production Volumes for DHEXP from Non-confidential Chemicals Reported under the Inventory Update Rule

Year	Production Range (lb)	
1986	>500,000–1,000,000	HSDB, 2015
1990	>10,000–500,000	HSDB, 2015
1994	>10,000–500,000	HSDB, 2015
1998	>10,000–500,000	
2002	>1,000,000–10,000,000	
2012	48,000	U.S. EPA, 2015

CPSC (2010) indicates that DHEXP is produced primarily to be a component of other industrially important phthalates such as diisohexyl phthalate (up to 25 percent) and C6-10 phthalates (up to 1 percent). The NTP Center for Evaluation of Risks to Human Reproductive Phthalates Expert Panel estimated that up to 1,000,000 lbs. of DHEXP could be consumed annually as a component of other phthalates (NTP, 2003; CPSC, 2010).

SPIN (2015) shows from 1999-2002 in Nordic countries only 2200 – 4400 pounds were used; data are not reported after 2003. DHEXP was used in consumer preparations until 2003 but data were considered confidential and not reported after that time. There are no records for industrial use of DHEXP on SPIN (2015).

No information on the use of DHEXP in Australia was available from 2004 and 2006 industrial surveys (NICNAS, 2008) and are not likely as phthalates are no longer manufactured in Australia (ACCC, 2015).

No information regarding the production trends in Europe or other countries has been identified from the sources searched.

12.5 Application of DHEXP in Materials, Consumer Products and Nonconsumer Products

DHEXP is used in the making of plastisols and as a plasticizer for cellulose ester and vinyl plastics (HSDB, 2015).

DHEXP or DHEXP-containing compounds are currently not found in children's toys or child care products, and they are not widely found in the environment (CPSC, 2010; 2014). In a survey of 72 toys (64 of which were made of PVC) from 17 different countries, no DHEXP was detected (CPSC, 2010; Stringer et al., 2000).

The Washington State Department of Ecology (WSDE), under the 2008 Washington Children's Safe Product Act has been testing children's products and packaging from consumer and children's products. Data from manufacturers on children's products sold in Washington WSDE are posted if their product contains chemicals of high concern, including phthalates (WSDE, 2015). Of the 238 products tested by WSDE for DHEXP, DHEXP was not detected above the method reporting limit in any of the products. From the manufacturers' testing results, the State of Washington has received data containing a total of 163 items that contained DHEXP. All concentrations for these 163 items were less than 0.1% (1000 ppm).

Plastisols containing DHEXP are used in the manufacture of automobile parts (air filters, battery covers) and dip-molded products (tool handles, dishwasher baskets) (HSDB, 2015).

PVC used in the manufacture of flooring, canvas tarps, and notebook covers may have added DHEXP (HSDB, 2015). Substances containing DHEXP may also be used in manufacture of a variety of items, including traffic cones, toys, vinyl gloves, and weather stripping, flea collars, shoes, and conveyor belts used in food packaging operations, although concentration data were not located to confirm these uses. It is also used as a partial replacement for di-(2-ethyl hexyl) phthalate (DEHP) (CPSC, 2014). Neither DHEXP nor DHEXP -containing compounds are used in medical devices (CPSC, 2010).

12.6 Routes of Introduction of DHEXP into Phthalate-free Material

Phthalates are abundant in the global environment because of their releases during manufacture, use and disposal of PVC products (Stringer et al., 2000). Stringer et al. (2000) indicates that phthalates in soft PVC products are not tightly bound to the plastic, but are present as mobile components of the plastic matrix. Therefore, the phthalates from soft PVC can be lost by volatilization over time. Additionally, they can be released from soft PVC by surface contact, especially where mechanical pressure is applied (e.g., during chewing of a PVC teether) (Stringer et al., 2000).

Phthalates in recycled materials could represent a source of contamination for phthalate-free materials; however, they can be exempted from REACH (Registration, Evaluation, Authorization and Restriction of Chemicals) when they comprise less than 20% of the recyclate (Lee et al., 2014).

CPSC (2010) indicated that DHEXP can leach from plastic consumer goods during their processing, use, or disposal.

12.7 References

ACCC (Australian Competition and Consumer Commission). 2015. Phthalates in consumer products. Australian Competition and Consumer Commission. Canberra, Australia. Available at: http://www.productsafety.gov.au/content/index.phtml/itemId/972486.

Chemical Book. 2015. Di-N-Hexyl Phthalate. 84-75-3. Chemical Book Online Database. Available at: http://www.chemicalbook.com/CASEN_84-75-3.htm.

Chemicalland21. 2015. Dihexyl Phthalate. Chemicalland21. Available at: http://www.chemicalland21.com/industrialchem/plasticizer/DIHEXYL%20PHTHALATE.htm.

Chem Sources Online. 2015. Chem Sources Online database. Chem Sources International, Inc. Available at: http://www.chemsources.com/chemonline.html.

CPSC (U.S. Consumer Product Safety Commission). 2010. Review of Exposure Data and Assessments for Selected Dialkyl Ortho-Phthalates. CPSC-D-06-0006. U.S. Consumer Product Safety Commission, Bethesda, MD. Available at: http://www.cpsc.gov/pagefiles/126552/pthalexp.pdf.

CPSC (U.S. Consumer Product Safety Commission). 2014. Chronic Hazard Advisory Panel (CHAP) on Phthalates and Phthalate Alternatives. U.S. Consumer Product Safety Commission, Bethesda, MD. Available at: https://www.cpsc.gov/PageFiles/169876/CHAP-REPORT-FINAL.pdf.

ECHA (European Chemicals Agency). 2013. Support Document for Identification of Dihexyl Phthalate as a Substance of Very High Concern Because of its CMR Properties. Member State Committee. European Chemicals Agency. Available at: http://echa.europa.eu/documents/10162/19377756/supdoc_dihexyl_phthalate_en.pdf.

HSDB (Hazardous Substances Data Bank). 2015. Hazardous Substances Data Bank online database, Toxnet Toxicology Data Network. U.S. National Library of Medicine. Available at: http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB.

Lee, J., Lee, J-H., Kim, C-K., Thomsen, M. 2014. Childhood exposure to DEHP, DBP, and BBP under existing chemical management systems: A comparative study of sources of childhood exposure in Korea and in Denmark. Environ Int. 63, 77-91.

NICNAS (National Industrial Chemicals Notification and Assessment Scheme). 2008. Phthalates hazard compendium. A summary of physicochemical and human health hazard data for 24 ortho-phthalate chemicals. Existing Chemical Hazard Assessment Report. Department of Health and Ageing. National Industrial Chemicals Notification and Assessment Scheme. Available at: http://www.nicnas.gov.au/__data/assets/pdf_file/0008/4958/Phthalate-Hazard-Compendium.pdf.

NICNAS (National Industrial Chemicals Notification and Assessment Scheme). 2015. Inventory Multi-Tiered Assessment and Prioritisation (IMAP). Human Health Tier II Assessment for C4-6 Side Chain Transitional Phthalates. Australian Department of Health, National Industrial Chemicals Notification and Assessment Scheme. Available at: http://www.nicnas.gov.au/chemical-information/imap-assessments/imap-group-assessment-report?assessment_id=1126.

NTP (National Toxicology Program). 2003. Center for the Evaluation of Risks to Human Reproduction (NTP-CERHR). NTP-CERHR Monograph on the Potential Human Reproductive and Developmental Effects of Di-n-Hexyl Phthalate (DnHP). NIH Publication No 03-4489.

OSHA (Occupational Safety and Health Administration). 2015. Di-n-hexyl Phthalate. Chemical Sampling Information (CSI). U.S. Department of Labor, Occupational Safety and Health Administration. Available at: https://www.osha.gov/dts/chemicalsampling/data/CH_236585.html.

PubChem, 2015. The PubChem online database. National Library of Medicine. Available at: https://pubchem.ncbi.nlm.nih.gov/.

SPIN (Substances in Preparation in Nordic Countries). 2015. SPIN Database. Danish Environmental Protection Agency. Available at: http://195.215.202.233/DotNetNuke/default.aspx.

Stringer, R., Labunska, I., Santillo, D., Johnston, P., Siddorn, J., Stephenson, A. 2000. Concentrations of phthalate esters and identification of other additives in PVC children's toys. Environ Sci Pollut Res. 7, 1-10.

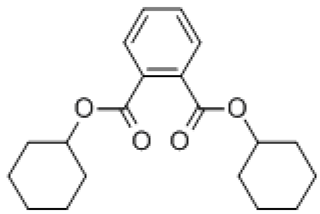
U.S. EPA (U.S. Environmental Protection Agency), 2015. Chemical Safety and Pollution Prevention: Pollution Prevention and Toxics. Vol. 2014. Chemical Data Access Tool (CDAT). Available at: http://java.epa.gov/oppt_chemical_search/.

WSDE (Washington State Department of Ecology ECY). (2015). "Children's Safe Product Act Reported Data." Available at: https://fortress.wa.gov/ecy/cspareporting/.

13 Dicyclohexyl Phthalate (DCHP) CASRN: 84-61-7

DCHP is listed as a HPV chemical by U.S. EPA (HSDB, 2015). It can be considered a "transitional" phthalate, defined as those phthalates produced from alcohols with straight-chain carbon backbones of C4-6 (NICNAS, 2008).

The structure of DCHP (PubChem, 2015) is as follows:



13.1 Raw Materials Used in Production of DCHP

DCHP can be produced from an esterification reaction of phthalic anhydride with cyclohexanol in an inert solvent like toluene at approximately 130°C (HSDB, 2015).

The following are used as raw materials in the production of DCHP (HSDB, 2015):

- phthalic anhydride
- cyclohexanol
- inert solvent such as toluene

Synonyms and trade names for DCHP are shown in Table 13-1 below.

13.2 Chemical and Physical Properties of DCHP

DCHP is a white solid at room temperature. It has a low solubility in water and a high octanol to water partition coefficient (PubChem, 2015). It has a relatively high melting point and low vapor pressure compared to the other specified phthalates. Table 13-1 summarizes the chemical and physical characteristics of DCHP.

Table 13-1 Physical/Chemical Characteristics of DCHP

Characteristic	Value	Reference
IUPAC Name	Dicyclohexyl benzene-1,2-dicarboxylate	PubChem, 2015
CASRN	84-61-7	PubChem, 2015
EC Number	201-545-9	PubChem, 2015
Synonyms and Trade Names	1,2-Benzenedicarboxylic acid, dicyclohexyl ester; Dicyclohexyl 1,2-benzenedicarboxylate; Ergoplast FDC; ErgoplastFDC; Ergoplast f.d.c.; HF 191; Howflex CP; KP 201; Phthalic acid, dicyclohexyl ester; Unimoll 66; DCHP; Dicyclohexyl benzene-1,2-dicarboxylate; Morflex 150; Unimoll 66 M; Uniplex 250; 1,2-Benzenedicarboxylic acid, 1,2-dicyclohexyl ester; NSC 6101	Haz-Map, 2015
Molecular Formula	$C_{20}H_{26}O_4$	HSDB, 2015
Molecular Weight	330.42 g/mol	HSDB, 2015
Physical description	White granular solid; White, crystalline solid; Prisms from alcohol	HSDB, 2015
Density	1.383 g/cm^3 (20°C)	NICNAS, 2008
Odor	Mildly aromatic odor	HSDB, 2015
Solubility in water	4.0 mg/L at 24°C; negligible	HSDB, 2015; NIOSH 2005
Octanol/Water Partition Coefficient (log Kow)	6.20 (est); 5.6 (calculated)	HSDB, 2015; NIOSH 2005
Boiling Point	224°C at 4 mm Hg; 222–228°C at 0.5 kPa	HSDB, 2015;

		NIOSH 2005
Melting Point	66°C	HSDB, 2015; NIOSH 2005
Vapor Pressure	8.69 X 10^{-7} mm Hg at 25°C, negligible	HSDB, 2015; PubChem, 2015
Flash Point	180–190°C	PubChem, 2015

13.3 Worldwide Manufacturing of DCHP

The 1977 TSCA inventory listed four companies which manufactured DCHP with a total production volume of 12,200,000 pounds. HSDB (2015) identified two companies that manufacture DCHP in the United States.

Chem Sources Online (2015) reports the following numbers of manufacturers: six in the United States, three in China, two in each of Canada, Switzerland, and one in each in Germany, Japan, Hong Kong, and the United Kingdom.

13.4 Annual Production of DCHP

Production volume for DCHP in the United States is 500,000–1,000,000 lb/yr (U.S. EPA, 2015). U.S. EPA (2015) reports three companies that responded to Chemical Data Reporting information on the production and use of DCHP manufactured or imported into the United States in 2012. However, the manufacture and production volume was either considered CBI or withheld by these companies.

Production volumes for non-confidential chemicals reported under the Inventory Update Rule or National Production Volume (HSDB, 2015; U.S. EPA, 2015) were as follows:

Table 13-2. U.S. Production Volumes for DIOP from Non-confidential Chemicals Reported under the Inventory Update Rule*

Year	Production Range (pounds)
1986	>1,000,000–10,000,000
1990	>1,000,000–10,000,000
1994	>1,000,000–10,000,000
1998	>500,000–1,000,000
2002	>500,000–1,000,000
2011	>500,000–1,000,000

Source: HSDB, 2015

In Nordic countries, over 62,000 lb of DCHP was used in 2012, an increase from approximately 42,000 lb in 2005 (SPIN, 2015).

Worldwide production data were not found in the sources searched for this project.

13.5 Applications for DCHP in Materials, Consumer Products and Nonconsumer Products

DCHP is used as a plasticizer in nitrocellulose, ethyl cellulose, chlorinated rubber, polyvinyl acetate, polyvinyl chloride, and other polymers. It improves the heat and light stability of synthetic resins, in alkyd resins and cellulose nitrate. It is used in paper finishes, paints, lacquers and varnishes because it creates a glossy, water resistant finish. It is also used as a heat sealant for cellulose (HSDB, 2015; ECHA, 2014).

According to SPIN, in Nordic countries DCHP is used in civil engineering, construction, printing, reproduction of printed media, chemical and chemical products, plastics, and rubbers (SPIN, 2015). In Sweden, from 2007-2009 DCHP was a component of at least 18 products (ECHA, 2014).

In Australia, DCHP is used in the manufacture of adhesives and screen printing inks. It is also used for research and product development (NICNAS, 2008).

Based on a review of numerous databases (Haz-Map, 2015; HSDB, 2015; SPIN, 2015; NICNAS, 2008; OECD, 2015), it was found that DCHP is used in the manufacture of:

- Plastics
- Rubbers
- Pulp and paper processing
- Heat sealer for cellulose

- Paper finishes
- Paint, lacquers and varnishes
- Printers ink
- Printed media
- Adhesives
- Construction material
- Clay
- Chemical products
- Headphones and hearing protection aids

It was not stated in the above sources how DCHP was specifically used in the manufacture of these materials.

13.5.1 Children's Products

Data regarding the concentration of DCHP in materials are very limited. IFCS (2006) reported concentrations of 0.0003% (3.4 ppm) in dolls and 0.04% (388 ppm) in modeling material (toys). HPD (2015) reported less than 3% DCHP in cement tube and cement bottle. No other concentration information was available in the sources searched for this report. While the WSDE (2015) reports other phthalates in child care articles and toys, DCHP is not reported.

13.6 Routes of Introduction of DCHP into Phthalate-free Material

Data regarding the migration of DCHP into phthalate-free materials was difficult to locate in the sources searched for this report.

Due to the low solubility in water and high octanol to water partition coefficient of DCHP, it is unlikely that DCHP would leach or move into water-based liquids. However, these physical properties suggest that DCHP could leach or move into oily hydrophobic materials, particularly when temperatures are above 66°C (~150°F) and free DCHP would be in liquid form.

Some studies have shown that DCHP is resistant to migration from polymers and is compatible with polar polymers and additives over a wide range of composition (HSDB, 2015). This characteristic would inhibit DCHP migration to other materials.

DCHP stays in the polymer despite being surrounded by solvents both hydrophilic (such as acetone and acetonitrile) and hydrophobic (such as hexane). DCHP concentration was reported to be below 0.002% (20 ppm) in an extensive review of many food products, which offer complex combinations of hydrophobic and hydrophilic surroundings (Cao, 2010). The highest reported migration of DCHP in Belgian food products was less than 0.001% (42 ppb) in milk and dairy products (Van Holderbeke, 2014). DCHP migration was not detected in a study number of baby bottles (Ozaki, 2002).

When heated to decomposition (temperature not specified), DCHP emits acrid smoke and irritating vapors (HSDB, 2015). Heating of materials containing DCHP could result in the release of DCHP vapor; however, this is unlikely due to its negligible vapor pressure. Accidents causing DCHP plastic materials to burn above its boiling point would result in DCHP byproducts.

DCHP is used in PVC materials, which can be recycled, and could result in DCHP release depending on the recycling process.

13.7 References

Cao, X-L. 2010. Phthalate esters in foods: Sources, occurrence, and analytical methods. Comp Rev Food Sci Food Safe. 9, 21-43.

Chem Sources Online. 2015. Chem Sources Online database. Chem Sources International, Inc. Available at: http://www.chemsources.com/chemonline.html.

ECHA (European Chemicals Agency). 2014. CLH Report for Dicyclohexyl Phthalate. Proposal for Harmonised Classification and Labelling. European Chemicals Agency. Available at: http://echa.europa.eu/documents/10162/13626/clh_report_dicyclohexyl_phthalate_en.pdf

HazMap, 2015. Haz-Map Information on Hazardous Chemicals and Occupational Diseases. U.S. National Library of Medicine. Available at: http://hazmap.nlm.nih.gov/index.php.

HPD (Household Products Database). 2015. Household Products Database online. National Library of Medicine, National Institutes of Health. Available at: http://householdproducts.nlm.nih.gov/.

HSDB (Hazardous Substances Data Bank). 2015. Hazardous Substances Data Bank online database, Toxnet Toxicology Data Network. U.S. National Library of Medicine. Available at: http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB.

IFCS (Intergovernmental Forum on Chemical Safety), 2006. Toys and Chemical Safety: A Thought Starter. Intergovernmental Forum on Chemical Safety. IFCS/Forum-V/03-TS, Budapest, Hungary. Available at: http://www.who.int/ifcs/documents/forums/forum5/03_ts_en.pdf.

NICNAS (National Industrial Chemicals Notification and Assessment Scheme). 2008. Existing Chemical Hazard Assessment Report. Dicyclohexyl Phthalate. Department of Health and

Ageing, National Industrial Chemicals Notification and Assessment Scheme. Available at: http://www.nicnas.gov.au/__data/assets/pdf_file/0003/4962/DCHP-hazard-assessment.pdf.

OECD (Organisation for Economic Cooperation and Development). 2015. eChemPortal online database. Organisation for Economic Cooperation and Development. Available at: http://www.echemportal.org/echemportal/substancesearch/page.action?pageID=0.

Ozaki, A., Yamaguchi, Y., Okamoto, A., Kawai, N. 2002. Determination of alkylphenols, bisphenol A, benzophenone, and phthalates in containers of baby food, and migration into food simulants. Shokuhin Eiseigaku Zasshi. 43(4), 260-266.

PubChem, 2015. The PubChem online database. National Library of Medicine. Available at: https://pubchem.ncbi.nlm.nih.gov/.

SPIN (Substances in Preparation in Nordic Countries). 2015. SPIN Database. Danish Environmental Protection Agency. Available at: http://195.215.202.233/DotNetNuke/default.aspx.

U.S. EPA (U.S. Environmental Protection Agency), 2015. Chemical Safety and Pollution Prevention: Pollution Prevention and Toxics. Vol. 2014. Chemical Data Access Tool (CDAT). Available at: http://java.epa.gov/oppt_chemical_search/.

Van Holderbeke, M., Geerts, L., Vanerman, G., Servaes, K., Sioen, I., De Henauw, S., Fierens, T. 2014. Determination of contamination pathways of phthalates in food products sold on the Belgian market. Environ Res. 134, 345-352.

14 Summary

The tiered approach used to research the six factors for the 11 specified phthalates is an effective and efficient way to identify relevant information (or data) sources. In Tier 1, secondary sources were used to narrow the field of possible information for further investigation. Overlap or redundancy in information between authoritative sources increased our confidence that we had identified the most relevant information. The tiered approach also assisted us in identifying what information was *not* available and what gaps existed to better focus further efforts on specific phthalates and specific factors, such as migration of phthalates into phthalate-free material.

The volume of information available among the 11 phthalates differed, as did the volume of information on the six factors. The reasons for this may be attributed to:

- the phthalate may be produced in larger volumes (i.e., are HPV chemicals) and therefore may be more widely used and more information available;
- the phthalate may have been more widely studied (such as for health effects), and more research may be available from which to draw information about the six factors;
- the phthalate may be a recent alternative to a more established-use phthalate, making information more sparse; or
- the phthalate may have been banned in the U.S. or in other countries, limiting recent information that is available.

As anticipated, the largest information gap was for migration information; how do phthalates move from one material to another, or how do they move out of one material into the environment? While there were some studies about migration of phthalates from PVC plastic to saliva from simulated chewing, physical movement between materials was difficult to find in the sources searched for this project. Conjecture of how the specified phthalates might move was based on their physical and chemical characteristics.

Despite the research limitations, some generalizations can be derived from the research conducted for this report on the 11 specified phthalates, and their exposure, use and occurrence in materials, consumer products and nonconsumer products.

The 11 specified phthalates vary from low to high molecular weight phthalates, are soluble in organic solvents and fats (lipophilic), and are generally water insoluble (hydrophobic). They are synthesized by relatively simple chemical reactions, likely by the same processes throughout the world; and most of them are produced in large quantities, making them HPV chemicals. Their movement between materials is dependent on several factors: their molecular weight, lipophilicity, environmental temperature, physical environment (agitation, movement), and time of contact between the materials.

Eight of the 11 specified phthalates are found widely in consumer products, including those made for children, as shown in Table 14-1. Some children's products, such as toys, modeling materials, teethers and rattles, child care articles and children's clothing and footwear were found to contain the specified phthalates at concentrations greater than 0.1%, with the exception of DPENP, DHEXP and DCHP.

Table 14-1. Overview of the Products Containing the 11 Specified Phthalates

Phthalate	Toys & Modeling Material	Teethers & Rattles	Child Care Articles	Clothing & Footwear	School supplies	Household	Personal Care Products	Medical Care Products & Devices	Building Materials	Other Products
DEHP	√	√	√	√	√	√	√	√	√	√
DBP	√		√	√		√	√			
BBP	√		√			√	√			
DINP	√		√	√	√	√	√		√	
DIDP	√	√	√	√		√	√	√	√	√
DnOP	√	√	√	√		√	√	√		√
DIOP	√	√								√
DIBP	√		√	√	√	√	√			
DPENP							√	√		
DHEXP					√	√				√
DCHP								√	√	√

Child Care Article: other than teethers and rattles
School Supplies: erasers, backpacks
Household: flooring, curtains, table clothes, wall coverings
Personal Care Products: nail polish, perfumes, hair products
Building materials: insulation, “construction materials”
Other Products: aerosol propellants, flame retardant, pesticide, explosives

An overview of the materials that may contain one of the 11 specified phthalates is presented in Table 14-2. These phthalates are used as plasticizers to soften and make materials such as PVC more flexible. They are most frequently found in PVC plastics. However, several may be found (and therefore likely used in manufacture) in other types of plastics. Their purpose in other plastics is likely to be the same, i.e., to soften the material.

Most of these phthalates may be used in adhesives, sealers, binding agents, fillers, paints, lacquers, varnishes, inks and coloring agents. While these uses are consistently reported, the role of the phthalate in these materials was not within the scope of this research. Similarly, several of these phthalates were used in soaps, detergents, perfumes and textiles, although the reason for their use in these materials was not specifically stated in the sources available.

Four of the specified phthalates (BBP, DINP, DIBP, DCHP) were reported to be used in paper and DBP was reported in glass. It is not clear whether these phthalates are used directly in the manufacture of paper or glass or whether they are present there due to an indirect use such as in ink or as a colorant or adhesive. DBP is used in safety glass in an inner layer for shatter resistance; however, it is not clear if that is the only use of this phthalate in glass. Further information as to the use of these phthalates in paper or glass was not specified in the sources searched for this project.

While the research provided information on where the 11 specified phthalates could be found, materials where they may not be found can be gleaned from the data. The 11 specified phthalates were not reported in metals, natural wood, or ceramic materials.

Table 14-2. Overview of Various Materials That May Contain the 11 Specified Phthalates

Phthalate	Materials											
	PVC	**Non-PVC plastics**	**Adhesives, Sealers, Binding Agents, Fillers**	**Paints, Lacquers, Varnishes**	**Inks, Coloring**	**Soaps, Detergent, Perfumes**	**Textiles**	**Metals**	**Wood**	**Paper**	**Glass**	**Ceramics**
DEHP	√		√	√	√		√					
DBP	√	√	√	√	√	√	√				√	
BBP	√		√	√	√					√		
DINP	√		√	√			√			√		
DIDP	√	√	√	√	√	√	√					
DnOP	√	√	√	√		√	√					
DIOP	√	√	√		√	√						
DIBP	√		√	√	√		√			√		
DPENP	√			√	√							
DHEXP	√											
DCHP	√	√	√	√	√					√		