Office of Environmental Health Hazard Assessment

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Matthew Rodriquez
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May 26, 2016

Jeffrey Margulies
Norton Rose Fulbright
Fulbright & Jaworski LLP
555 South Flower Street, 41st Floor
Los Angeles, California 90071

Dear Mr. Margulies:

In response to your request on behalf of Tandus Centiva, Inc., the Office of Environmental Health Hazard Assessment (OEHHA) is issuing the following safe use determinations for diisononyl phthalate (DINP) in Tandus Centiva ER3® modular vinyl carpet tiles, pursuant to our authority under Title 27 of the Cal. Code of Regs., section 25204(h)(1):

1. OEHHA is issuing a safe use determination for DINP exposures to residents of homes and other facilities from Tandus Centiva ER3® modular vinyl carpet tiles with a DINP content in the secondary backing layer of 9% by weight, or less, with no DINP present in other parts of the product.

2. OEHHA is issuing a safe use determination for DINP exposures to professional carpet installers from Tandus Centiva ER3® modular vinyl carpet tiles with a DINP content in the secondary backing layer of 8.7% by weight, or less, with no DINP present in other parts of the product.

Please find enclosed copies of our document supporting these determinations and the notice as it will appear on the OEHHA website at www.oehha.ca.gov, and in the *California Regulatory Notice Registry*, dated June 10, 2016. If you would like to discuss any issue concerning the safe use determination further, please call Dr. Martha Sandy, of my staff, at (510) 622-3190.

Sincerely,

Allan Hirsch
Chief Deputy Director

Enclosures

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CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF ENVIRONMENTAL HEALTH HAZARD ASSESSMENT

SAFE DRINKING WATER AND TOXIC ENFORCEMENT ACT OF 1986
(PROPOSITION 65)

NOTICE TO INTERESTED PARTIES
June 10, 2016

ISSUANCE OF SAFE USE DETERMINATIONS FOR DIISONONYL PHTHALATE IN TANDUS CENTIVA ER3® MODULAR VINYL CARPET TILES

The California Environmental Protection Agency's Office of Environmental Health Hazard Assessment (OEHHA) is the lead agency for the implementation of the Safe Drinking Water and Toxic Enforcement Act of 1986[1]. OEHHA received a request from Tandus Centiva, Inc. that OEHHA issue a Safe Use Determination (SUD) for the use of diisononyl phthalate (DINP) in Tandus Centiva ER3® modular vinyl carpet tiles, pursuant to OEHHA's authority under Section 25204(a) of Title 27 of the California Code of Regulations[2]. The carpet tile products that are the subject of this request are used as indoor carpet for commercial and residential applications and are installed by professional carpet installers. DINP was listed under Proposition 65 as a chemical known to the state to cause cancer effective December 20, 2013.

In accordance with the process set forth in Section 25204(f), OEHHA held a written public-comment period on this request from January 16 to February 25, 2015. OEHHA also held a public hearing on February 19, 2015, in Sacramento, California. No public comments were received.

As provided in Sections 25204(a) and (k), OEHHA is issuing the following SUDs only to Tandus Centiva, Inc. for DINP in certain Tandus Centiva ER3® modular vinyl carpet tiles:

1. OEHHA is issuing a safe use determination for *DINP exposures to residents* of homes and other facilities from Tandus Centiva ER3® modular vinyl carpet tiles *with a DINP content in the secondary backing layer of 9% by weight, or less, with no DINP present in other parts of the product.*
2. OEHHA is issuing a safe use determination for *DINP exposures to professional carpet installers* from Tandus Centiva ER3® modular vinyl carpet tiles *with a DINP content in the secondary backing layer of 8.7% by weight, or less, with no DINP present in other parts of the product.*

The essential elements and results of OEHHA's assessment are described in the supporting document available at: http://oehha.ca.gov/proposition-65/notices.

Based on the screening level exposure analyses described in the supporting documentation, upper-end estimates of DINP exposure to residents and to professional carpet installers from Tandus Centiva ER3® modular vinyl carpet tiles were made for professional flooring installers and residents and compared to the No Significant Risk Level (NSRL) for DINP of 146 micrograms/day. The estimated exposure to DINP from Tandus Centiva ER3® modular vinyl carpet tiles:

- Corresponds to a calculated excess cancer risk of less than one in 100,000 for exposures to residents with Tandus Centiva ER3® modular vinyl carpet tiles installed in their homes, when the tiles contain up to 9% DINP by weight in the secondary backing layer, with no DINP present in other parts of the product. Thus OEHHA determined that exposure of residents to DINP from Tandus Centiva ER3® modular vinyl carpet tiles containing up to 9% DINP by weight in the secondary backing layer, with no DINP present in other parts of the product, is below the NSRL. A warning for DINP is not required for residents in buildings where these products are installed.

- Corresponds to a calculated excess cancer risk of one in 100,000 for professional installers as a result of installing Tandus Centiva ER3® modular vinyl carpet tiles, when the tiles contain 8.7% DINP by weight in the secondary backing layer, with no DINP present in other parts of the product. Thus OEHHA determined that exposure of professional installers to DINP is at or below the NSRL where DINP content is 8.7% by weight, or less, in the secondary backing layer, with no DINP present in other parts of the product. A warning would not be required for workers (i.e., professional installers) for products meeting this DINP concentration limit.

Supporting documentation for these Safe Use Determinations are available on OEHHA's web site.

Questions regarding this notice should be directed to:

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Supporting Materials for a Safe Use Determination for Diisononyl Phthalate (DINP) in Tandus Centiva ER3® Modular Vinyl Carpet Tiles

Office of Environmental Health Hazard Assessment
May 2016

Summary

This document presents an evaluation of a request from Fulbright and Jaworski LLP and Norton Rose Fulbright US LLP on behalf of Tandus Centiva, Inc. for a Safe Use Determination (SUD) for diisononyl phthalate (DINP) in Tandus Centiva ER3® modular vinyl carpet tiles.

The Office of Environmental Health Hazard Assessment (OEHHA) utilized a screening level approach to evaluate this request. In this approach, upper-end estimates of the level of exposure to DINP were determined based on the available data on measured dermal exposures to DINP from Tandus Centiva ER3® modular vinyl carpet tiles, DINP air emissions from related materials, indoor air quality models, and several assumptions. OEHHA compared these upper-end estimates of DINP exposure for professional installers and residents to the estimate of exposure associated with a one in 100,000 excess cancer risk, i.e., the No Significant Risk Level (NSRL) of 146 µg/day.

Based on the screening level analyses discussed in this document, and the NSRL of 146 µg/day, the estimated exposure to DINP from Tandus Centiva ER3® modular vinyl carpet tiles:

- Corresponds to a calculated excess cancer risk of less than one in 100,000 for exposures to residents with Tandus Centiva ER3® modular vinyl carpet tiles installed in their homes, when the tiles contain up to 9% DINP by weight in the secondary backing layer, with no DINP present in other parts of the product. Thus OEHHA determined that exposure of residents to DINP from Tandus Centiva ER3® modular vinyl carpet tiles containing up to 9% DINP by weight in the secondary backing layer, with no DINP present in other parts of the product, is below the NSRL. A warning for DINP is not required for residents in buildings where these products are installed.

- Corresponds to a calculated excess cancer risk of one in 100,000 for professional installers as a result of installing Tandus Centiva ER3® modular vinyl carpet tiles, when the tiles contain 8.7% DINP by weight in the secondary backing layer, with no DINP present in other parts of the product. Thus OEHHA determined that exposure of professional installers to DINP is at or below the

NSRL where DINP content is 8.7% by weight, or less, in the secondary backing layer, with no DINP present in other parts of the product. A warning would not be required for workers (i.e., professional installers) for products meeting this DINP concentration limit.

A number of factors may tend to increase or decrease estimates of exposure relative to the approach used to develop the exposure levels described above. We believe, on the whole, that the assumptions made are likely to have resulted in overestimates of exposure levels from the average installation or use of Tandus Centiva ER3® modular vinyl carpet tiles. As discussed in detail below, these analyses only apply to the exposure scenarios discussed in this document.

This SUD request was limited to exposures to DINP from Tandus Centiva ER3® modular vinyl carpet tiles (see Section 1.1 below for a description of the products covered). Exposures to other listed substances, if any, that may result from the installation and use of Tandus Centiva ER3® modular vinyl carpet tiles were not reviewed by OEHHA in the context of this request.

1. Introduction

The California Environmental Protection Agency's Office of Environmental Health Hazard Assessment (OEHHA) is the lead agency for the implementation of Proposition 65[1]. On January 16, 2015, OEHHA announced that it had received a request from Fulbright and Jaworski LLP and Norton Rose Fulbright US LLP on behalf of Tandus Centiva, Inc. for a Safe Use Determination (SUD) for the use of diisononyl phthalate (DINP) in Tandus Centiva ER3® modular vinyl carpet tiles, pursuant to Title 27 of the California Code of Regulations, section 25204[2].

DINP is on the Proposition 65 list of chemicals known to the state to cause cancer. For chemicals that are listed as causing cancer, the "No Significant Risk Level (NSRL)" is defined as the level of exposure that would result in no more than one excess case of cancer in 100,000 individuals exposed to the chemical over a 70-year lifetime. The NSRL for DINP is 146 micrograms per day (µg/day) [3].

[1] The Safe Drinking Water and Toxic Enforcement Act of 1986, codified at Health and Safety Code section 25249.5 *et seq*, is commonly known as Proposition 65 and is hereafter referred to as Proposition 65.
[2] All further references are to sections of Title 27 of the Cal. Code of Regulations.
[3] The NSRL for DINP was adopted April 1, 2016 in Section 25705(b)(1).

A public comment period on this SUD request was held from January 16 to February 25, 2015, and a public hearing was held on February 19, 2015. No public comments were received.

Based on information provided in the SUD request, OEHHA has identified the DINP exposures for analysis to be those to professional installers participating in the installation of Tandus Centiva ER3® modular vinyl carpet tiles, and residents of homes and other facilities that have these carpet tile products installed.

This document first provides a brief description of Tandus Centiva ER3® modular carpet tile products covered by the SUD request and how they are used and installed, followed by a brief summary of the Fulbright & Jaworski LLP and Norton Rose Fulbright US LLP exposure analyses (referred to hereafter as the NRF analyses) of professional installer and resident exposures to DINP which accompanied the SUD request. OEHHA's analyses of professional installer and resident exposures to DINP from Tandus Centiva ER3® modular vinyl carpet tiles are then presented.

1.1 Product Description

The following information was supplied by the requestor. Tandus Centiva ER3® modular vinyl carpet tiles are used as indoor flooring for commercial and residential applications. The tiles may be square or rectangular, measuring 1.5 to 3 feet on each side, and each tile has a surface area of between 2.25 and 9 square feet. The tiles are available either with or without a pre-applied adhesive (covered with a protective film that is removed before installation). The tiles are packaged in stacks of 15 tiles, stacked one on top of the other (i.e., with the bottom of one tile in contact with the top of another).

Tandus Centiva ER3® modular vinyl carpet tiles are composed of several layers of differing composition, including recycled carpet and vinyl. The top layer of Tandus Centiva ER3® modular vinyl carpet tile is called the wear layer, and is comprised of nylon yarn. The wear layer is needled into a primary backing layer that is made of polyester/nylon nonwoven fabric. Beneath the primary backing layer is a pre-coat layer comprised of ethylene vinyl acetate copolymer, calcium carbonate, and aluminum trihydrate. Next is the intermediate layer, comprised of a non-woven sheet of continuous glass filament that includes polyvinyl chloride (PVC) and non-phthalate plasticizer. The bottom layer, which contacts the floor, is referred to as the secondary backing layer, and is comprised of 100% reclaimed or recycled content pre- and post-consumer carpet. Altogether, Tandus Centiva ER3® modular vinyl carpet tile contains between 44% - 65% recycled content, and 12% - 20% post-consumer recycled content.

According to information provided by NRF, DINP is present in Tandus Centiva ER3® modular vinyl carpet tiles solely as a result of the use of recycled content containing DINP, and is present only in the secondary backing layer of the tile (i.e., the bottom layer of the tile). The concentration of DINP in the secondary backing ranges from 6.2% - 9% by weight. This is equivalent to DINP concentrations in the whole tile ranging from 2.2% - 3.2% (average 2.7%) by weight, as calculated by OEHHA by using the mass fraction of the secondary backing layer of 35.2%, provided by NRF in the SUD application.

1.2 Product Use and Installation

Tandus Centiva recommends that certified professionals install ER3® modular vinyl carpet tiles. According to the information provided in the SUD request, these ER3® tiles are installed only by professional installers.

As noted above, Tandus Centiva ER3® modular vinyl carpet tiles are manufactured both with and without pre-applied adhesive. Tiles with pre-applied adhesive have an easily removable protective film covering the adhesive on the entire back of the tile. For a tile with pre-applied adhesive, installers remove the protective film covering and then place the tile into position on the sub-floor. After placing all of the tiles into position, the installer then rolls a 75 to 100 pound roller across the tiles to secure them to the sub-floor. For tiles without pre-applied adhesive, installers first apply adhesive to the sub-floor, then after the adhesive has dried sufficiently the tiles are placed into position.

1.3 Exposure Analyses Provided by NRF

NRF assessed DINP exposure from Tandus Centiva ER3® modular vinyl carpet tiles and concluded that professional installers and residents may be exposed to DINP by inhalation, incidental ingestion via hand-to-mouth (HTM) activities, and dermal absorption. Exposure to DINP was assessed separately for professional installers and residents.

NRF submitted technical data, including wipe samples from the tops and bottoms of three Tandus Centiva ER3® modular vinyl carpet tiles with pre-applied adhesive, wipe samples from the tops and bottoms of three Tandus Centiva ER3® modular vinyl carpet tiles without pre-applied adhesive, hand-wipe samples (i.e., wipes of five fingertips, wipes of the palmer surface of the hand) from two volunteers simulating (i) installers' exposures and (ii) residents' exposures, and air emission data from a chamber study. The air emission study was conducted with one Tandus Centiva ER3® modular vinyl carpet tile in a Micro-Chamber with a sampling duration of three days, and a DINP detection limit of 0.5 $\mu g/m^3$. All tests were conducted in carpet tiles containing 9% DINP in the secondary backing layer (NRF, 2016).

1.3.1 NRF exposure analysis for professional installers

NRF assessed DINP exposure during installation of Tandus Centiva ER3® modular vinyl carpet tiles and concluded that the expected exposure of a professional installer to DINP is 2.2 µg/day.

The potential exposure pathways identified in the NRF analysis for professional installers are:

- Inhalation of DINP.
- Dermal absorption of DINP through direct contact with the vinyl carpet tiles.
- Incidental ingestion of DINP via hand-to-mouth (HTM) activities.

NRF used the emission parameter (Y_0) from Liang and Xu (2014) and a box model to estimate the gas-phase DINP concentration that a professional installer is exposed to during installation of these vinyl carpet tiles. However, NRF used an incorrect Y_0 value (0.52 µg/cubic meter [m^3]), instead of the correct value of 0.42 µg/m^3 from the Liang and Xu (2014) publication.

NRF used hand-wipe samples from two volunteers simulating professional installers' exposures to Tandus Centiva ER3® modular vinyl carpet tiles (with and without pre-applied adhesive) to estimate the dermal loading of DINP on the hands. Hand wipes were taken from each volunteer after simulated installation of 15, 30, and 45 tiles. Two types of wipe samples were collected and used for estimating exposures by two different pathways: wipes of the palmer surface of the hand were used to estimate exposure by the dermal absorption pathway, and wipes of five fingertips were used to estimate exposure by the HTM ingestion pathway. Maximum DINP concentrations were measured from wipes of the palmer surface of the hand after handling 45 tiles, and from wipes of the fingertips after handling 30 tiles.

Based on the hand wipe data, NRF predicted that a "steady-state (maximum)" DINP hand wipe concentration of 144.4 µg would be reached during the course of handling more than 165 tiles, assuming that the additional amount of DINP transferred to the hands decreased by about 50% for every consecutive installation of 15 tiles, based on the results of three data points (results of hand wipe samples after handling 15, 30 and 45 tiles). Specific adjustment factors were calculated based on the ratios of estimated steady-state (maximum) concentration and the predicted concentration after handling 45 tiles for the dermal route and 30 tiles for the HTM route. These adjustment factors were 1.13 (Line E, Table 1) for dermal exposure, and 1.31 (Line J, Table 1) for HTM exposure.

Table 1 lists the exposure factors used in the NRF analysis for estimating DINP exposures to professional installers by each of these pathways, and the adjustment factors employed in the NRF analysis to derive the adjusted lifetime average daily dose of 2.2 μg/day.

Table 1. Summary of NRF evaluation of professional installer exposure to DINP during installation of Tandus Centiva ER3® modular vinyl carpet tiles

Exposure Factor	Unit	Value	Basis
Inhalation			
A. DINP air concentration	μg/m^3	0.085	Box model using an emission parameter (Y_0) from Liang and Xu (2014)[a]
B. Breathing rate	m^3/day	10	Proposition 65 default for workers
C. Daily inhalation dose	μg/day	0.85	= A x B
Dermal absorption			
D. Hand (palmar surface) DINP loading	μg/day	278	= (139 μg/hand) x (two hands), maximum measured @ 45 tiles, NRF
E. Adjustment factor for number of tiles handled	unitless	1.13	Ratio of estimated maximum hand loading to the predicted wipe data @ 45 tiles
F. Dermal absorption coefficient	unitless	1.72%	Deisinger *et al.* (1998, Table 2); Elsisi *et al.* (1989)
G. Dermal dose	μg/day	5.4	= D x E x F
Hand-to-Mouth (HTM) ingestion			
H. Five fingertip DINP loading	μg/event	86.5	Maximum measured @ 30 tiles, NRF
I. Adjustment factor for number of fingers	unitless	0.6	= 3/5, OEHHA (2008)
J. Adjustment factor for number of tiles handled	unitless	1.31	Ratio of estimated maximum hand loading to the predicted wipe data @ 30 tiles
K. HTM transfer efficiency	unitless	6.5%	Gorman Ng *et al.* (2014)
L. HTM contact frequency	events/hr	2.8	Gorman Ng *et al.* (2016, Table 4, mean manual task)
M. HTM contact duration	hr/day	6.5	Assumed by NRF
N. Daily ingestion dose	μg/day	80.4	= H x I x J x K x L x M
Total uptake by all pathways			
O. Daily dose from all exposure pathways	μg/day	86.7	= C + G + N
P. Lifetime averaging adjustment factor	unitless	23.5%	= 5 day/7 day x 48 wk/52 wk x 25 yr/70 yr
Q. Lifetime average daily dose	μg/day	20.4	= O x P
R. Market share	unitless	11%	USA 2013 market survey
S. Adjusted lifetime average daily dose	μg/day	2.2	= Q x R

[a] NRF used an incorrect Y_0 value of 0.52 μg/m^3. Using the correct Y_0 value of 0.42 μg/m^3 (Liang and Xu, 2014) would raise the DINP air concentration to 0.101 μg/m^3; however, the adjusted lifetime average daily dose is unchanged at 2.2 μg/day.

1.3.2 NRF exposure analysis for residents

NRF's approach to assessing DINP exposures to residents did not involve pathway-specific analyses. Instead, a simplified approach was taken, based on the assumption that potential exposure of residents to DINP is limited to the amount of DINP that is present on the surface of new Tandus Centiva ER3® modular vinyl carpet tiles (without pre-applied adhesive). NRF assumed that DINP remains in the bottom layer of the tile, and does not migrate out of that layer through the upper layers to the tile surface. NRF used the data from wipe samples taken from the top surface of three replicate Tandus Centiva ER3® modular vinyl carpet tiles (without pre-applied adhesive) to derive an "upper bound" estimate of the total DINP available to the resident of a home, office, or other facility. NRF used the arithmetic mean of the three replicate wipe samples, 416 µg DINP/square meter [m^2] (Footnote 17 on page 20 in the material submitted with the SUD request), to represent the maximum amount of DINP available to the resident. In calculating the resident's exposure, NRF assumed that the area with Tandus Centiva ER3® modular vinyl carpet tile was 3000 square feet (279 m^2) and that the entire mass of available DINP (416 µg/m^2 multiplied by 279 m^2) is absorbed by a single resident over a 70 year lifetime, yielding an estimated lifetime average daily dosage of DINP of $(416 \times 279) / (70 \times 365) = 4.5$ µg/day.

This analysis is based on the questionable premise that the amount of DINP measured by wiping the top surface of a new tile, 416 µg/m^2, represents the total available DINP content in one square meter of carpet over the lifetime of the product. OEHHA disagrees with this analysis because with the slow rate of DINP volatilization from the carpet tiles, the DINP emission will continue throughout the time that the source materials/carpet tiles are present in the indoor environment (Weschler and Nazaroff, 2008) and allow continuous exposure from various pathways (inhalation, dermal uptake and incidental ingestion) to occur.

2. OEHHA Analyses of DINP Exposures from Tandus Centiva ER3® Modular Vinyl Carpet Tiles

OEHHA conducted screening-level exposure analyses to derive upper-end estimates of DINP exposure to professional installers (151 µg/day; Table 2) and residents (32.8 µg/day; Table 3).

The potential exposure pathways included in the analysis are:

- Inhalation of DINP in the air (residents only).
- Dermal absorption of DINP:
  - Via direct contact with the vinyl carpet tiles for installers;
  - Via dust-to-dermal and air-to-dermal absorption for residents (direct contact with the vinyl carpet tiles is considered negligible relative to dust-to-dermal absorption for residents).
- Incidental ingestion of DINP:
  - Via HTM activities for installers;
  - Via incidental ingestion of dust for residents.

The models used, assumptions made, and exposure parameter values applied by OEHHA in these screening level exposure analyses are discussed below. In addition, differences between OEHHA's analyses and those of NRF are noted.

2.1 OEHHA Exposure Analysis for Professional Installers

The upper-end estimate of DINP exposures to professional carpet installers during the installation of Tandus Centiva ER3® modular vinyl carpet tiles containing 9% DINP by weight in the secondary backing layer is 151 µg/day.

Inhalation of DINP by professional installers during carpet installation is considered to be negligible because the degree to which DINP, a semi-volatile organic compound (SVOC), will volatilize from brand-new carpet tiles is expected to be minimal during the first few days after a package of tiles is opened. The slow rate of DINP volatilization from the new tiles is not expected to result in significant air concentrations of DINP during the installation period.

Table 2 summarizes the exposure parameters OEHHA used to estimate DINP exposures to professional carpet installers by the dermal absorption and HTM incidental ingestion pathways, the adjustment factor used to derive the lifetime average daily dose of DINP, and the results of this analysis.

Table 2. Parameters used in and results of the OEHHA analysis of DINP exposures during installation of Tandus Centiva ER3® modular vinyl carpet tiles

Parameter	Unit	Value	Basis
Dermal absorption			
A. Hand (palmar surface) DINP loading	μg/day	278	= (139 μg/hand) x (two hands), maximum, measured @ 45 tiles, NRF
B. Human dermal absorption coefficient	unitless	0.15%	McKee *et al.* (2002); Scott *et al.* (1987) (see below)
C. Dermal dose	μg/day	0.4	= A x B
Hand-to-Mouth (HTM) ingestion			
D. HTM fingertip DINP loading	μg/event	51.9	Calculated by OEHHA, see text
E. HTM transfer efficiency	unitless	50%	OEHHA (2008)
F. HTM contact frequency	events/hr	2.28	Calculated by OEHHA based on Gorman Ng *et al.* (2016), see text
G. HTM activity duration	hr/day	6.5	Same as NRF's assumption
H. HTM ingestion dose	μg/day	384.6	= D x E x F x G
Total exposure by all pathways			
I. Total daily dose (all pathways)	μg/day	385	= C + H
J. Lifetime averaging factor	unitless	39.2%	= 5 day/7 day x 50 wk/52 wk x 40 yr/70 yr [a]
K. Lifetime average daily dose	μg/day	151	= I x J

[a] Section 25721 (d)(3) provides a number of assumptions to be used in calculating the reasonably anticipated rate of exposure to carcinogens in the workplace, unless more specific and scientifically appropriate data are available. These include assumptions that workers breathe 10 m^3 of air per 8 hour work day, and that the exposure duration for a worker is 50 weeks per year for 40 years.

2.1.1 Dermal absorption pathway

Installers are exposed to DINP via direct dermal contact with the carpet tiles. Dermal dose is the product of dermal loading and dermal absorption. Dermal dose for professional installers is estimated to be 0.4 μg per working day (Line C, Table 2). This dermal absorption dose is less than that estimated by NRF (5.4 μg/day), due primarily to the use of different information to estimate dermal absorption of DINP in humans. In estimating the DINP dose by the dermal absorption pathway, the following assumptions were made:

1. Dermal exposure of the professional carpet installer to DINP occurs only during the time spent laying and attaching the carpet tiles to the sub-floor.
2. Dermal exposure is limited to the palmar surface of both hands (data on DINP loading on other parts of the body during carpet installation are not available).
3. Based on the results of single-hand wipe samples from two volunteers handling 15 - 45 new carpet tiles, NRF and OEHHA used the reported maximum palmar

concentration (139 µg/hand) to estimate the dermal dose from two DINP-loaded hands (139 µg/hand x 2 hands = 278 µg; Table 2, Line A). While NRF used an additional adjustment of 1.13 (Table 1, Line E) based on assumptions about steady-state DINP loading on the hands, OEHHA did not.

4. Since there are no data regarding DINP absorption by human skin, we based our absorption estimate on dermal DINP absorption in rats, adjusted by the ratio of human to rat dermal absorption from studies of di-(2-ethylhexyl) phthalate (DEHP), as summarized below.
   i. McKee *et al.* (2002) reported that 0.3% to 0.6% of the applied dose of DINP was absorbed over a 24-hour period in dermal absorption studies in male and female F344 rats. We used the upper end of this range (0.6%).
   ii. A study by Scott *et al.* (1987) suggests that human skin is less permeable to phthalates than rat skin. In this study, the authors measured the *in vitro* permeability coefficient of DEHP in abdominal skin from human cadavers and dorsal skin removed from Wistar-derived AL/pk rats. The study reported a four-fold higher dermal permeability coefficient for DEHP in rat skin as compared to human skin. Since the molecular weight of DEHP (390.6 g/mol) is reasonably similar to that of DINP (418.6 g/mol), the DEHP dermal permeability coefficient ratio for humans to rats (0.25) was applied as a surrogate value for the DINP permeability coefficient ratio.
   iii. The human dermal absorption coefficient for DINP is estimated as follows:

      DINP dermal absorption coefficient for humans
      = DINP dermal absorption coefficient for rats x dermal permeability coefficient ratio for humans to rats
      = 0.6% x 0.25
      = 0.15% (Table 2, Line B)

   iv. NRF used a higher dermal absorption coefficient, 1.72% (Table 1, Line F).

2.1.2 HTM ingestion pathway

OEHHA estimated the dose of DINP to the professional carpet installer by the HTM ingestion pathway as 384.6 µg per working day (Line H, Table 2), higher than that estimated by NRF (80.4 µg/d), due to selection of different exposure parameters. In estimating the DINP dose by the HTM ingestion pathway, the following assumptions were made:

1. All direct HTM contact for professional carpet installers is assumed to occur during the portion of the workday when the installer is handling the new carpet tiles, and involves contact of the fingertips with the perioral area. Each contact with the perioral area is assumed to involve three fingertips. It is judged unlikely for carpet installers to have direct contact of the fingertips in the mouth (i.e., hand-to-oral contact) when working.

2. Indirect HTM exposure (e.g., via food consumption) is not estimated due to data limitations. We assume implicitly that professional carpet installers wash their hands before eating and at the end of the work day, completely removing DINP from the hands/fingertips.
3. Based on the results of five-fingertip wipe samples from two volunteers handling 15 - 45 new carpet tiles, NRF and OEHHA used the reported maximum fingertip concentration of DINP (86.5 µg/five fingertips) to estimate the loading on three fingertips. The fingertip loading used for HTM exposure is 51.9 µg (= 86.5 µg × 3/5; Table 2, Line D). While NRF used an additional adjustment factor of 1.31 (Line J, Table 1) based on assumptions about steady-state DINP loading on the fingertips, OEHHA did not. The DINP concentration in the secondary backing layer of the carpet tiles used to generate the five-fingertip wipe samples was reported by NRF (2016) to be 9%.
4. In the absence of data on the HTM transfer efficiency of DINP, OEHHA applied the same direct HTM transfer efficiency of 50% (Table 2, Line E) used in OEHHA (2008), based on empirical data of transfer efficiencies of three pesticides (technical mixtures of chlorpyrifos, pyrethrin I, and piperonyl butoxide) in three volunteers (Camann *et al.*, 2000). NRF based the hand-to-perioral transfer efficiency estimate on Gorman Ng *et al.* (2014), which reported a hand-to-perioral transfer efficiency of 6.5% for acetic acid. DINP is a sticky substance and may not behave exactly like the three pesticides studied by Camann *et al.* (2000) or acetic acid. In the absence of DINP-specific transfer efficiency data, OEHHA chose a more conservative estimate of 50% for HTM transfer efficiency.
5. In the absence of data on the frequency of HTM activity by professional installers of vinyl carpet tile, data on HTM activity frequency from a study in workers by Gorman Ng *et al.* (2016) were used. OEHHA selected the average HTM activity frequency (which included hand-to-oral and hand-to-perioral contacts) reported for all industrial workers, 7.6 events per hour. NRF used 2.8/hr, the mean number of direct HTM contacts for "manual" tasks, as reported in Gorman Ng *et al.* (2016). As carpet installation is not one of the job categories surveyed in Gorman Ng *et al.* (2016), we chose the higher value reported for all industrial workers, to be conservative. Gorman Ng *et al.* (2016) defined the perioral area as "the lips and the area within 2 cm of the lips." In the absence of information on the fraction of hand-to-perioral contacts that involve the lips, OEHHA applied a factor of 0.3 (based on the estimated ratio of the surface area of the lips to the entire perioral region) to estimate the "hand-to-lip" frequency. This frequency was used in the calculation of HTM intake. The adjusted hand-to-lip contact frequency is 2.28 events per hour (= 7.6 × 0.3; Table 2, Line F).
6. OEHHA used the same 6.5 hr per work day HTM activity duration as was assumed by NRF (Table 2, Line G). This is a reasonable estimate of the time spent working

with new carpet tiles per 8-hr workday, after deducting for preparation time and breaks.

2.1.3 Total exposure by all pathways to professional installers

The total exposure to DINP via all pathways (151 µg/day, Table 2, Line K) was calculated as the product of the sum of the daily doses for the two exposure routes (385 µg/day, Table 2, Line I) and the lifetime adjustment factor appropriate for the worker scenario (39.2%, Table 2, Line J). The lifetime average adjustment factor was calculated as: 5/7 days x 50/52 weeks x 40/70 years = 39.2%

The lifetime average adjustment factor is consistent with Section 25721(d)(3), which provides a number of assumptions to be used in calculating the reasonably anticipated rate of exposure to carcinogens in the workplace, unless more specific and scientifically appropriate data are available. These include assumptions that the exposure duration for a worker is 50 weeks per year for 40 years.

The estimated DINP intake for installers via all pathways adjusted by the lifetime averaging factor (39.2%) is 151 µg/day, exceeding the NSRL for DINP of 146 µg/day. As indicated by NRF, DINP exists only in the secondary backing layer of the carpet tiles at concentrations in that layer ranging from 6.2% to 9%. The DINP content of the carpet tiles used in the simulated installation scenario from which the five-fingertip wipe data was generated was 9% DINP by weight in the secondary backing layer. The maximum allowable DINP content in the secondary backing layer of the carpet tiles to reach 146 µg/day for professional installers is 8.7% (= (146/151) × 9%) by weight, assuming a linear relationship between total exposures of installers and DINP content in the secondary backing layer.

2.1.4 Uncertainties associated with professional installers' exposure estimate

1. The HTM pathway dominates installers' exposure. A number of factors contribute to uncertainty in the estimate of exposure via the HTM pathway.
   i. The HTM intake estimate is only for direct hand-to-mouth contact, i.e., not including indirect hand-to-mouth contact (e.g., via food consumption or smoking with contaminated hands) due to data limitations. This could underestimate DINP exposure.
   ii. Five-fingertip wipe data:
      - Five-fingertip wipe samples were collected in a limited number of subjects (n = 2).
      - Intra- and inter-individual variability was apparent from the wipe sample data.
      - Actual installers' contact with the carpet tiles may differ from that of the two volunteer subjects.

Thus, use of the wipe sample data could under- or over-estimate DINP exposure. OEHHA did not apply additional adjustment factors to account for the possibility that fingertip loading differs when more than 45 tiles are handled consecutively. The adjustment factors applied by NRF relied on only three data points and we did not view the adjustment factors as reducing uncertainty associated with the wipe data.

iii. We used 50% as the HTM transfer efficiency for DINP, based on pesticide data and assumed that only three fingertips were in contact with the mouth or perioral area, based on the best scientific judgement as no empirical data are available for carpet installers. This could under- or over-estimate DINP exposure.

iv. We did not adjust for higher HTM contact frequency evident in the data from Gorman Ng *et al.* (2016) for smokers and for between-task periods because to do so would require additional assumptions. This could underestimate DINP exposure.

2. Regarding the dermal exposure pathway:
    i. Dermal dose estimates include only the palmar surface of the hands, ignoring other body parts due to data limitations. This could underestimate DINP exposure.
    ii. The palmar surface hand wipe samples were collected in a limited number of subjects (n = 2). Intra- and inter -individual variability was apparent from the wipe sample data, and actual installers' contact with the carpet tiles may differ from that of the two volunteer subjects.
3. Additional potential exposure pathways not evaluated in this analysis include worker exposure to contaminated clothing after work and exposure during removal of the old carpet if it contains DINP. This could underestimate DINP exposure.
4. NRF adjusted workers' DINP exposure according to their 11% market share of carpet tiles. OEHHA conservatively assumed that carpet installers work full-time installing the ER3® brand of carpet tiles. This could overestimate DINP exposure if workers also install carpet tiles that do not contain DINP.
5. OEHHA conservatively assumed that carpet installers work for 40 years[4]; workers may install ER3® carpet tiles less than 40 years. This could overestimate DINP exposure for workers with less than 40 working years.

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[4] Section 25721(d)(3)

2.2 OEHHA Exposure Analysis for Residents

The upper-end estimate of DINP exposures to residents of homes, offices, and other facilities that have Tandus Centiva ER3® modular vinyl carpet tiles containing 9% DINP by weight in the secondary backing layer is 32.8 μg/day.

OEHHA evaluated the lifetime daily DINP exposure for residents in homes carpeted with Tandus Centiva ER3® modular vinyl carpet tiles. DINP, an SVOC, is commonly found in gas and condensed phases, redistributing from the emission source to indoor air and interior surfaces, including airborne particles, dust and skin. DINP will release from the carpet tiles over time. Over the typical use duration of carpet tiles, DINP is released from the product and sorbed onto airborne-particles and dust, and onto other indoor surfaces. Thus residents' exposure to DINP occurs following emission from the source into air and subsequent migration into different media and re-emission / desorption from these media as indoor conditions (e.g., temperature) change (Xu and Zhang, 2011).

Residents' exposure to DINP was estimated using the screening model proposed by Little *et al.* (2012), which includes inhalation of DINP in the gas phase, inhalation of DINP sorbed to airborne particles, dermal sorption of DINP from the air and dust, and ingestion of DINP sorbed to dust. Table 3 summarizes the exposure parameters OEHHA used to estimate DINP exposures by the inhalation, dermal absorption, and incidental ingestion pathways and the results of OEHHA's exposure assessment for residents. Age-adjusted exposure parameters were calculated based on age-specific values specified in Section 25721(d)(2)(A) (inhalation rate), the OEHHA Air Toxics Exposure Assessment Guidelines (2012) (body surface area), and the US Environmental Protection Agency (US EPA) Exposure Factors Handbook (2011) (time spent indoors, dust adherence to skin, dust ingestion rate). Table 4 shows the calculation of indoor air gas-phase DINP concentration that is used to calculate the inhalation, dermal, and incidental ingestion doses (Table 3).

Table 3. Parameters used in and results of the OEHHA analysis of DINP exposures to residents of homes with Tandus Centiva ER3® modular vinyl carpet tiles

Parameter	Unit	Value	Basis
Inhalation			
A. Airborne gas-phase concentration	μg/m^3	0.044	From Table 4, Line L
B. Particle-air partition coefficient	m^3/μg	0.023	Weschler and Nazaroff, (2010); Liang and Xu (2014)
C. Total suspended particles	μg/m^3	20	Little *et al.* (2012)
D. Airborne particle-phase concentration	μg/m^3	0.020	= A × B × C
E. Total DINP air concentration	μg/m^3	0.064	= A + D
F. Breathing rate	m^3/day	19	Age-weighted value calculated based on Section 25721(d)(2)(A)
G. Time spent indoors	unitless	82.4%	Age-weighted value calculated based on US EPA (2011; Table 16-1)
H. DINP inhalation dose	μg/day	1.0	= E x F x G
Dermal absorption			
I. Dermal contact surface	m^2	0.44	= 25% of total body surface (age-weighted value calculated based on OEHHA (2012; Table 6.4))
J. Mass of dust adhered to skin	g/m^2-day	7.1	US EPA (2011; Table 7-23)
K. Human dermal absorption coefficient	unitless	0.15%	McKee *et al.* (2002); Scott *et al.* (1987)
L. Skin permeability coefficient	μg/m^2-hr/(μg/m^3)	1.12	Weschler and Nazaroff (2012); Liang and Xu (2014)
M. Dermal intake from dust	μg/day	3.4	= I x J x K × Q
N. Dermal intake from gas	μg/day	0.4	= A x G x I x L x 24 h/d
O. Dermal absorption dose	μg/day	3.8	= M + N
Incidental ingestion			
P. Dust-air partition coefficient	m^3/μg	0.0165	Liang and Xu (2014); Weschler and Nazaroff (2010)
Q. DINP in dust	μg/g	726	= A × P × 10^6 μg/g
R. Dust ingestion rate	g/day	0.03857	Age-weighted value calculated based on US EPA (2011; Table 5-1)
S. DINP ingestion dose	μg/day	28.0	= Q x R
Total exposure by all pathways			
T. Lifetime daily dose	μg/day	32.8	= H + O + S

2.2.1 Inhalation pathway

The inhalation dose for residents with Tandus Centiva ER3® modular vinyl carpet tiles installed in their home is estimated to be 1.0 µg/day (Table 3, Line H), based on the assumptions listed below:

1. OEHHA assumed that 100% of the indoor floor area is carpeted with Tandus Centiva ER3® modular vinyl carpet tiles.
2. OEHHA used the Liang and Xu (2014) chamber study to estimate the gas-phase DINP concentration (details in Table 4 and Appendix A). The authors reported a DINP emission parameter (Y_0) of 0.42 µg/m^3, based on emissions from a single PVC tile containing 20% DINP. OEHHA adjusted the Y_0 downward by a factor of 0.16, the ratio of the maximum DINP concentration in the carpet tile (3.2%) to that in the PVC tile (20%) tested by Liang and Xu (2014) (i.e., 0.42 µg/m^3 × 3.2% ÷ 20% = 0.067 µg/m^3; Line A in Table 4). This adjustment assumes that Y_0 is linearly related to DINP concentration in the flooring materials, and that the DINP emission parameter (i.e., Y_0) is the same for vinyl carpet tile and PVC tile containing equivalent concentrations of DINP.
3. The concentration of DINP in airborne particles (Line D, Table 3) was calculated from the gas-phase DINP concentration by multiplying the total suspended particle concentration (TSP; Table 3, Line C) and the particle-air partition coefficient (Table 3, Line B). This coefficient (0.023 m^3/µg) is estimated from the octanol-air partition coefficient (K_{oa}, Weschler and Nazaroff, 2010) and adjusted by particle size distribution (Liang and Xu, 2014) (See Appendix A).
4. The age-weighted breathing rate is calculated based on the age-specific values in Section 25721(d)(2)(A) as 19 m^3/d (Line F, Table 3).
5. Time activity data were obtained from US EPA (2011; Table 16-1) for total time spent indoors. An age-weighted average of time spent indoors of 82.4% (Line G, Table 3) is used for the inhalation dose calculation.

Table 4. OEHHA's calculation of indoor gas-phase DINP concentration

Parameter	Unit	Value	Basis
A. Emission parameter	μg/m³	0.067	Modified from Liang and Xu (2014) (see text)
B. Convective mass-transfer coefficient	m/s	0.00047	1.7 m/h conversion; Liang and Xu (2014)
C. Convective mass-transfer coefficient near sorption surface	m/s	9.6×10^{-5}	Liang and Xu (2014)
D. Sorption surface partition coefficient	m	2100	Liang and Xu (2014)
E. Particle-air partition coefficient	m³/μg	0.023	Weschler and Nazaroff (2010), Liang and Xu (2014) (see text)
F. Floor surface area	m²	279	3000 ft², assumed
G. Room height	m	2.6	8.5 ft, standard ceiling height
H. Room volume	m³	725	= F × G
I. Air changes per hour	/hr	0.23	CDPH EHLB (2010) default
J. Ventilation rate	m³/s	0.0046	= H × I × (1/3600 h/s)
K. Total suspended particles	μg/m³	20	Little *et al.* (2012)
L. Gas-phase DINP concentration	μg/m³	0.044	= (A × B × F) / [B × F + (1 + E × K) × J]

2.2.2 Dermal absorption pathway

The dose of DINP to residents by the dermal absorption pathway is estimated to be 3.8 μg/day (Table 3, Line O) via dermal contact with DINP-containing dust and direct air-to-dermal absorption (Weschler and Nazaroff, 2012). Dermal exposure from direct dermal contact with vinyl carpet tiles (approximately 0.04 μg/day) is considered negligible relative to dust-to-dermal absorption (3.4 μg/day).

The dermal dose from dust (Table 3, Line M) is estimated as the product of dermal dust loading, contact surface area, the DINP concentration in the dust, and the human dermal absorption coefficient. The dermal dose from gas-phase DINP (Table 3, Line N) is the product of the gas-phase concentration, exposed skin surface area, and the dermal permeability coefficient, adjusted by the time spent indoors.

In estimating the DINP dose by the dermal absorption pathway for residents, the following assumptions were made:

1. Skin contact surface area is 0.44 m², about one-fourth of the age-weighted body surface area calculated from age-specific values presented in OEHHA (2012) (Table 3, Line I)
2. Dermal dust loading is 7.1 g/m²-day (Table 3, Line J; US EPA, 2011)
3. Since there are no DINP-specific absorption data for human skin, we used 0.15% (Line K in Table 3) as the human dermal absorption coefficient, as discussed above in Section 2.1.1. NRF used a higher dermal absorption estimate of 1.72%.

4. The skin permeability coefficient for direct air-to-dermal absorption is 1.12 µg/m^2-hr/(µg/m^3) (Table 3, Line L), based on the model proposed by Weschler and Nazaroff (2012), as calculated by Liang and Xu (2014).
5. The DINP concentration in dust is calculated as the product of the dust-air partition coefficient and the gas-phase concentration (Table 3, Line Q, see Section 2.2.3 for details).

2.2.3 Incidental ingestion pathway

Residents' DINP intake from incidental ingestion is estimated to be 28 µg/day (Line S, Table 3). It is calculated as the product of the gas-phase DINP concentration, the dust-air partition coefficient, and the daily dust ingestion rate.

In estimating the DINP dose by the incidental ingestion pathway for residents, the following assumptions were made:

1. The gas-phase concentration (Line A, Table 3) calculation is the same as presented in Section 2.2.1 above for the inhalation calculations.
2. Calculation of the concentration of DINP in airborne particles (Line D, Table 3) is the same as presented in Section 2.2.1 above for the inhalation calculations.
3. The concentration of DINP in dust (Table 3, Line Q) is calculated from the gas-phase DINP concentration using the dust-air partition coefficient (Table 3, Line P). The dust-air partition coefficient is estimated as 0.0165 m^3/µg, using the octanol-air partition coefficient (Weschler and Nazaroff, 2010) adjusted by the particle size distribution (Liang and Xu, 2014) (See Appendix A).
4. OEHHA calculated an age-weighted dust ingestion rate of 0.03857 g/d (Table 3, Line R) based on age-specific values reported in the US EPA Exposure Factors Handbook (US EPA, 2011; Table 5-1). According to US EPA (2011), this rate accounts for ingestion of indoor settled dust only.

2.2.4 Total exposure by all pathways to residents

The total lifetime daily exposure to DINP via all pathways for residents was 32.8 µg/day (Line T, Table 3), and was calculated as the sum of the inhalation, dermal absorption (via direct air-to-dermal and dust absorption), and incidental ingestion pathways. This calculated exposure for residents is below the NSRL of 146 µg/day. Therefore residential exposure to DINP from these specific carpet tiles is calculated to fall below the level posing significant risk.

2.2.5 Uncertainties associated with residents' exposure estimate

There are many uncertainties associated with the indoor air quality (IAQ) models and parameter inputs used in the exposure assessment for residents. DINP is an SVOC that is difficult to measure, which makes it a challenge to develop and validate IAQ models for this chemical. For the same reason, many of the IAQ model parameters, such as the partition coefficients, are not well characterized for DINP. The submitted chamber results (non-detected with a detection limit of 0.5 μg/m^3) from NRF, conducted in three days in a Micro Chamber, illustrate the difficulty in quantifying DINP emissions.

Because SVOCs are released from sources at a slow rate and because of their propensity to sorb onto materials, SVOCs can persist indoors for years after they are introduced. Parallels can be drawn between indoor persistent SVOCs and outdoor persistent organic pollutants (Weschler and Nazaroff, 2008). Even if the SVOC source is removed, SVOC will persist indoors for weeks or years because all indoor surfaces have become coated with SVOC (LBNL IAQ Resources Bank). Though we do not have good quantification of the DINP emission from Tandus Centiva ER3® modular vinyl carpet tiles, we do know from studies on other SVOCs that over time DINP is likely to slowly release from the carpet tiles which, more often than not, will be present in residents' homes for decades. Once DINP is released from the carpet tiles, it will be sorbed onto indoor surfaces, airborne particles, and dust.

There are only two published studies reporting the emission parameter Y_0 for DINP, Liang and Xu (2014) and Liang *et al.* (2015). OEHHA used the Y_0 for DINP reported by Liang and Xu (2014) which is based on data from PVC tile containing 20% DINP, and adjusted it to account for the lower DINP concentration present in Tandus Centiva ER3® modular vinyl carpet tiles. The adjustment was made by assuming linearity between Y_0 and DINP concentration in the flooring materials. This was based on the observation that Y_0 for DEHP is linearly related to DEHP concentrations in the flooring materials at concentrations less than 13% from the same chamber study (Liang and Xu, 2014). It is not ideal to use the Y_0 measured from PVC tile and apply it to vinyl carpet tiles (with adjustment for differences in DINP concentration), but there are no better data available. OEHHA assumes that DINP behaves similarly to DEHP and that vinyl carpet tile will have the same emission pattern as PVC tile at the same DINP concentration. This is likely to be a conservative assumption, as DINP may volatilize more slowly from the vinyl carpet tiles, which have multiple layers of non-DINP containing material above the secondary backing layer, than from PVC tiles, at least for the first few years.

Liang *et al.* (2015) used the same chamber design as Liang and Xu (2014), and reported Y_0 for DINP at different temperatures. Y_0 for DINP was found to increase 10-fold (0.42 to 4.31 μg/m^3) when the chamber temperature increased from 25°C to 36°C. 36°C is not a comfortable indoor temperature; however, 30°C (= 86°F) is likely in California, especially in homes without air conditioning during the summer months. The study by Liang *et al.* (2015) indicates that Y_0 for DINP will increase with higher temperature, but the degree of increase with temperature is unknown. A change in Y_0 will result in a similar change in all DINP dose estimates for residents. The absence of product-specific emission factors (Y_0) for DINP under common usage conditions adds to the uncertainty in the exposure assessment for residents.

Other parameters used in the IAQ models are estimated using chemical properties of DINP, such as the octanol-air partition coefficient, but validation of these estimated parameter values can be difficult. For example, the vapor pressure of DINP reported in the literature from empirical experiments varies two orders of magnitude (10^{-5} to 10^{-7} pascal) (Liang and Xu, 2014). This demonstrates a challenge in SVOC research, namely that more robust data on basic parameters used in IAQ models are needed to better quantify SVOC emissions and human exposure.

The IAQ model proposed by Little *et al.* (2012) was originally developed to obtain screening-level estimates of potential indoor exposure to prioritize different SVOCs using chemical-specific properties and common IAQ parameters. We do not know whether the model overestimates or underestimates actual human exposure to DINP. The modelled DINP air and dust concentrations we predicted in homes with vinyl carpet tile are within the range of the limited published DINP data (Table 5), although those published levels were from all emission sources, and not limited to a particular flooring source.

Table 5. Comparison of predicted DINP concentrations by OEHHA and published data

Airborne concentration (µg/m^3)	Dust concentration (ppm; reported as µg/g or mg/kg)	Source
0.044	726	Predicted (see Table 3)
0.025 - 0.763	30 - 7091	Fromme *et al.* (2013)
<MDL - 0.192	10 - 1200	Kanazawa *et al.* (2010)
0.0005 - 1.293	11.3 - 674	Wormuth *et al.* (2006)

*MDL: method detection limit

Among the different exposure pathways for residents, intake from the incidental ingestion of dust is highest (28 µg; about 85% of total intake), followed by dermal absorption (3.8 µg) and inhalation (1.0 µg). This is due, in part, to the higher predicted concentration of DINP in dust, as compared to the airborne gas-phase. Findings of published studies on DINP (Wormuth *et al.*, 2006) and other phthalates (Tran and Kannan, 2015; Guo and Kannan, 2011) also indicate that DINP/phthalate concentrations in dust are higher than airborne concentrations. High molecular weight phthalates such as DEHP and DINP, which are used in floor and wall coverings, are found in house dust in high concentrations (Wormuth *et al.*, 2006; Fromme *et al.*, 2013). For example, the measured DINP concentrations in indoor air in German daycare centers were in the range of 25 to 763 ng/m^3, and the DINP dust levels range from 30 to

7091 ppm (Fromme *et al.*, 2013). Dust may serve as a reservoir for DINP exposure, similar to the results found for other SVOCs such as flame retardants. Incidental ingestion of DINP from dust is not included in the NRF exposure assessment for residents.

3. Conclusions

These screening level analyses, which relied on relatively conservative assumptions, only apply to the exposure scenarios discussed in this document. OEHHA is not drawing conclusions for other exposure scenarios or other products.

3.1 Professional Carpet Installers

Based on this screening level exposure analysis for professional carpet installers, an upper-end estimate of DINP exposures during the installation of Tandus Centiva ER3® modular vinyl carpet tiles containing 9% DINP in the backing layer is 151 µg/day, exceeding the No Significant Risk Level (NRSL) for DINP of 146 µg/day. Limiting the DINP content in the secondary backing layer to 8.7% by weight, with no DINP present in other parts of the product, would reduce the installers' daily dose to 146 µg/day, assuming a linear relationship between the DINP content in the secondary backing layer and installers' total DINP intake.

Therefore, OEHHA must restrict the safe use determination for professional carpet installers to Tandus Centiva ER3® modular vinyl carpet tiles containing 8.7% DINP by weight, or less, in the secondary backing layer of the tile, and with no DINP present in other parts of the product.

3.2 Residents

Based on this screening level exposure analysis for residents with Tandus Centiva ER3® modular vinyl carpet tiles installed in their homes, an upper-end estimate of DINP exposures is 32.8 µg/day, which is approximately 22% of the NSRL for DINP. The estimated exposure to DINP for residents as a result of the use of these carpet tiles in residences corresponds to an excess cancer risk of less than one in 100,000.

Therefore, DINP exposures to residents from Tandus Centiva ER3® modular vinyl carpet tiles fall below the level posing significant risk.

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Appendix A. Details of Indoor Air Quality Models

We provide the detailed calculations for values presented in Tables 3 and 4, namely DINP concentrations in the airborne gas-phase, the airborne particle-phase, and dust. These values are derived from the chamber study data by Liang and Xu (2014). The DINP emission parameter Y_0 obtained from this chamber study is the basis for the estimate of the DINP airborne gaseous concentration (Y_{gas}), airborne particle concentration (Y_{part}), and dust concentration (Y_{dust}) in indoor settings.

Parameters used to estimate the Y_{gas} and Y_{part} / Y_{dust} are discussed below in three sections. Section 1 describes how to estimate Y_0 from the chamber results (Liang and Xu, 2014). Section 2 details the estimation of Y_{gas} in the residence using the Y_0 data from Liang and Xu (2014). Section 3 shows how Y_{gas} is used to obtain the specific values for Y_{part} and Y_{dust}. The OEHHA DINP exposure analysis for residents that have Tandus Centiva ER3® modular vinyl carpet tiles installed in their indoor environments is estimated using all three modeled values (Y_{gas}, Y_{part}, and Y_{dust}).

1. Chamber data by Liang and Xu (2014): Y_0 (the thin-film gas phase concentration of DINP in equilibrium with the material phase)

A novel chamber study design was reported by Liang and Xu (2014) to shorten the time needed to reach equilibrium from months to a few days by maximizing the emission area and minimizing the sorption area in the specially designed stainless steel chamber. One tested polyvinyl chloride (PVC) flooring sample included in this study contained 20% DINP. Y_0 (the thin-film gas phase concentration of DINP in equilibrium with the material phase) was calculated for this sample using Eq. A-1 based on the chamber settings (Q and A), the measured Y_{ss} (steady-state DINP concentration in the chamber; 0.255 μg/m^3) and the calculated h_m (the convective mass transfer coefficient, estimated from diffusivity and molecular weight using dimethyl phthalate as the reference chemical). Y_0 was calculated from this chamber study for the PVC flooring sample containing 20% DINP as 0.42 μg/m^3 at 25°C.

$$Y_0 = (Y_{ss} \times Q)/(h_m \times A) + Y_{ss} \qquad \text{(Eq. A-1)}$$

- Y_0: The thin-layer gas-phase concentration of DINP in equilibrium with the material phase in the chamber (μg/m^3)
- Q: Volume of the chamber (m^3)
- A: Surface area of emission (m^2)
- Y_{ss}: Steady-state concentration in the chamber (measured, in μg/m^3)
- h_m: The convective mass transfer coefficient in the chamber (unit: m/s are converted to m/h for calculation), estimated from air diffusivity that is

approximated by the chemical molecular weight using dimethyl phthalate as the reference chemical.

The theory behind Eq. A-1 is a mechanistic mass-transfer model developed by Xu and Little (2006) for semi-volatile organic compounds (SVOCs). Due to the low vapor pressure of SVOCs, emission from the product is primarily subject to "external control," including equilibrium between the product surface and gas-phase SVOC concentration immediately adjacent to the product surface, convective mass transfer through the boundary layer into the bulk air, and sorption to interior surfaces. Y_0 can only be estimated in a chamber that reaches steady-state. Y_0 remains constant for a given product at the same temperature, and is the basis to estimate the corresponding airborne- and dust-concentrations of the SVOC from a specific product.

2. Estimation of indoor airborne gaseous concentration (Y_{gas}) using Y_0

A screening IAQ model was proposed by Little *et al.* (2012) to estimate the indoor gaseous concentration of SVOCs (and further estimate potential occupants' SVOC exposures) from the emissions of SVOCs that are present in materials and products as additives, based on Y_0 and other indoor parameters. The exposure estimates depend strongly on the steady state gas-phase concentration of the SVOC that can be predicted from Y_0 by Eq. A-2.

$$Y_{gas} = (h_m \times Y_0 \times A) / [h_m \times A + (1 + K_{part} \times TSP) \times V] \quad \text{(Eq. A-2)}$$

Y_{gas}: Airborne gas-phase DINP concentration (μg/m^3)
h_m: Convective mass transfer coefficient indoors (m/s); this indoor h_m is different from the h_m in the chamber setting
Y_0: The thin-film gas phase concentration of DINP in equilibrium with the material phase (μg/m^3); calculated from the chamber result at steady state
A: Surface area of flooring containing DINP (m^2)
K_{part}: Particle-air partition coefficient (m^3/μg)
TSP: Total suspended particles (μg/m^3)
V: Ventilation rate (m^3/hr; conversion to m^3/s by multiplying 3600 (hr/s))

The most reasonable value of the key parameters that affect DINP intake was used to estimate the corresponding DINP concentration by Eq. A-2 as indoor conditions vary from home to home. Each of these key parameters is discussed briefly below.

- Ventilation rate (V) = air changes per hour (ACH/hr) × home volume (m^3)

Air changes per hour (ACH) data for homes were compiled from various sources (Table A-1). To be conservative, OEHHA chose the default ACH of 0.23/hr used by the California Department of Public Health (CDPH) Environmental Health Laboratory Branch (EHLB) to calculate Y_{gas}.

Table A-1. Air change rates per hour (ACH) in homes

Data source	Mean	Minimum	Median	10th percentile
ARB (2009) 24-hr data	0.48	0.09	0.26	
ARB (2009) 2-wk data	0.45	0.11	0.24	
US EPA (2011)	0.45			0.18
CDPH EHLB (2010) default	**0.23**			

- TSP (total suspended particles)

The concentration of indoor particles depends on the indoor sources and conditions (e.g., cleaning practices, floor types - carpet versus smooth hardwood) in the home. Lower concentrations of TSP will result in higher DINP Y_{gas} and Y_{dust} concentrations (but lower Y_{part}), and subsequently a higher total DINP intake. OEHHA chose the TSP value of 20 µg/m^3, which is the average TSP used by Little *et al.* (2012), to calculate Y_{gas}.

3. Estimation of DINP concentration in airborne-particles (Y_{part}) and dust (Y_{dust})

Concentrations of DINP in airborne-particles and dust can be calculated from Y_{gas} and the partition coefficients between particle-air (K_{part}) and dust-air (K_{dust}) (Eq. A-3; Eq. A-5). K_{part} (particle-air partition coefficient) and K_{dust} (dust-air partition coefficient) are estimated from K_{oa} (octanol-air partition coefficient) using equations A-4 and A-6 below (Weschler and Nazaroff, 2010),

$$Y_{part} \text{ (in µg/g)} = K_{part} \times Y_{gas} \times 10^6 \text{ (µg/g)} \quad \text{(Eq. A-3)}$$

$$K_{part} = f_{om\ part} \times K_{oa} / D_{part} \quad \text{(Eq. A-4)}$$

$$Y_{dust} \text{ (in µg/g)} = K_{dust} \times Y_{gas} \times 10^6 \text{ (µg/g)} \quad \text{(Eq. A-5)}$$

$$K_{dust} = f_{om\ dust} \times K_{oa} / D_{dust} \quad \text{(Eq. A-6)}$$

$f_{om\ part}$: volume fraction of organic matter associated with airborne particles; 0.4; unitless
D_{part}: density of airborne particle (10^6 g/m^3 = 1 g/cm^3)
$f_{om\ dust}$: volume fraction of organic matter associated with settled dust; 0.2; unitless
D_{dust}: density of settled dust (2×10^6 g/m^3)

K_{oa}: octanol-air partition coefficient (1.07×10^{11}; unitless; estimated as no authoritative experimental value is available; Liang and Xu, 2014)

K_{part} and K_{dust} can be adjusted by an assumed particle size distribution (Xu, personal communication, 2015). Unadjusted and adjusted K_{part}/K_{dust} values are listed in Table A-2. OEHHA selected the latter, since particle size is an important factor determining human exposure. In theory, these partition coefficients could also be estimated using the vapor pressure of DINP, but the empirical data of the extremely low vapor pressure for DINP is very limited.

Table A-2. K_{part} and K_{dust} estimated by different approaches (Liang and Xu, 2014)

Partition coefficients (in $m^3/\mu g$)	Estimated by K_{oa}	Estimated by K_{oa} and particle size distribution
K_{part}	0.0429	**0.023**
K_{dust}	0.0107	**0.0165**