Supporting Materials for a Safe Use Determination for Diisononyl Phthalate (DINP) in Interface GlasBac® and GlasBac®RE Modular Carpet Tiles

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Summary

This document presents an evaluation of a request from Interface, Inc. for a Safe Use Determination (SUD)[1] for diisononyl phthalate (DINP) in Interface GlasBac® and GlasBac®RE modular carpet tiles. It is specific to the information provided to OEHHA and is not directly applicable to any other product or exposure scenario.

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 Interface modular 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 level of exposure associated with a one in 100,000 excess cancer risk, which is the No Significant Risk Level (NSRL) of 146 micrograms (µg) per day.

According to information provided in the SUD request, DINP is present in these modular carpet tiles only in the structural backing layer, which comprises 56% of the mass of the total tile. The concentration of DINP in the backing layer is reported to be as high as 9% by weight in GlasBac®RE tiles and 16.06% by weight in GlasBac® tiles. This is equivalent to a DINP concentration in the whole tile of 5.04% by weight in GlasBac®RE tiles and 9% by weight in GlasBac® tiles.

Based on the screening level analyses discussed in this document, and the NSRL of 146 µg/day, the estimated exposure to DINP from Interface GlasBac® and GlasBac®RE modular carpet tiles where DINP content does not exceed the concentrations reported by Interface:

- Corresponds to a calculated excess cancer risk of less than one in 100,000 for exposures to residents with Interface GlasBac® and GlasBac®RE modular carpet tiles installed in their homes. Thus OEHHA determined that exposure of residents to DINP from Interface GlasBac® and GlasBac®RE modular carpet tiles that do not exceed the DINP content levels reported by Interface is below

[1] Title 27, Cal. Code of Regulations, section 25204

the NSRL. A warning for DINP is not required for residents or other occupants of homes and other buildings where these specific products are installed.

- Corresponds to a calculated excess cancer risk of less than one in 100,000 for professional installers as a result of installing Interface GlasBac® and GlasBac®RE modular carpet tiles. Thus OEHHA determined that exposure of professional installers to DINP is at or below the NSRL where DINP content does not exceed the concentrations reported by Interface for the GlasBac® or GlasBac®RE modular carpet tiles. A warning would not be required for workers (i.e., professional installers) for Interface GlasBac® and GlasBac®RE modular carpet tile 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 Interface GlasBac® and GlasBac®RE modular 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 Interface GlasBac® and GlasBac®RE modular 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 Interface GlasBac® and GlasBac®RE modular 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 [2]. On May 19, 2017, OEHHA announced that it had received a request from Interface, Inc. for a Safe Use Determination (SUD) for the use of diisononyl phthalate (DINP) in Interface GlasBac® and GlasBac®RE modular carpet tiles, pursuant to Title 27 of the California Code of Regulations, section 25204 [3].

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

[2] 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.

[3] All further references are to sections of Title 27 of the Cal. Code of Regulations.

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) [4].

A public comment period on this SUD request was held from May 19 to June 19, 2017. 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 Interface GlasBac® and GlasBac®RE modular carpet tiles, and residents of homes and other facilities that have these carpet tile products installed.

This document first provides a brief description of Interface GlasBac® and GlasBac®RE modular carpet tile products covered by the SUD request and how they are used and installed. This is followed by a brief summary of the exposure analyses submitted by Interface, Inc. (referred to hereafter as the Interface analyses) of professional installer and resident exposures to DINP that accompanied the SUD request. OEHHA's analyses of professional installer and resident exposures to DINP from Interface GlasBac® and GlasBac®RE modular carpet tiles are then presented.

1.1 Product Description

The following is based on information provided in the SUD request. Interface GlasBac® and GlasBac®RE modular carpet tiles are composed of a top wear layer of recycled Nylon yarn and a bottom structural backing layer made of polyvinyl chloride (PVC, or vinyl) composites with an embedded layer of nonwoven fiberglass. The Nylon yarn is tufted into a non-woven polyester 'tufting carrier' and bonded to the tufting carrier by an ethylene vinyl acetate-based 'backing' or 'precoat'. The PVC composite structural backing layer of the carpet tile is available in two forms, GlasBac® and GlasBac®RE, the latter of which incorporates post-consumer carpet tiles reclaimed by the Interface ReEntry™ carpet tile recycling program.

The GlasBac® structural backing layer contains nonwoven fiberglass (i.e., post-industrial calcium alumina glass spheres), PVC resin, DINP, calcium oxide, lecithin, a calcium zinc heat stabilizer, and carbon black pigment.

The GlasBac®RE structural backing layer is made with a mixture of post-consumer carpet tile and post-industrial carpet scrap, and contains nonwoven fiberglass (post-industrial calcium alumina glass spheres, other fiberglass), PVC resin, DINP, polyester,

[4] Section 25705(b)(1).

Nylon, calcium oxide, lecithin, a calcium zinc heat stabilizer, carbon black pigment, ethylene vinyl acetate, calcium carbonate, alcohol ethoxysulfate, and Intersept®.

According to information provided in the SUD request, DINP is present in these modular carpet tiles only in the structural backing layer, which comprises 56% of the mass of the total tile. The concentration of DINP in the backing layer is reported to be as high as 9% by weight in GlasBac®RE tiles and 16.06% by weight in GlasBac® tiles. This is equivalent to a DINP concentration in the whole tile of 5.04% by weight in GlasBac®RE tiles and 9% by weight in GlasBac® tiles.

1.2 Product Use and Installation

According to information provided in the SUD request, Interface GlasBac® and GlasBac®RE modular carpet tiles are "primarily used as a floor covering for commercial interiors." The tiles are available in a range of shapes and sizes, but the majority of tiles are 50 centimeter (cm) by 50 cm in size." According to the SUD request (page 19), it is also possible that these carpet tiles "could be installed in a residence." These carpet tiles can be installed by professional installers or do-it-yourself consumers. The "[r]ecommended installation methods for Interface carpet tiles are either "free-lay" or applied with TacTiles™.... TacTiles™ connectors are 3" by 3" squares of polyethylene film with a small amount of adhesive on one side. They are used to connect one carpet tile to another" to create a floating floor. "All carpet tile installation is done by hand. Tiles are installed one-by-one according to a sequence and pattern directed by the manufacturer as appropriate for the particular aesthetic design on the nylon face cloth."

According to the SUD request (page 15), "[i]ndustry information suggests that installation of up to 100 yd^2 (900 ft^2) per day is a conservative assumption for the average installer, but we extrapolated up to 200 yd^2 (1800 ft^2) per day to derive exposure estimates based upon a range of possible installation scenarios."

1.3 Exposure Analyses Provided by Interface

Interface assessed DINP exposure from Interface GlasBac® and GlasBac®RE modular carpet tiles and concluded that professional installers and residents may be exposed to DINP by incidental ingestion via hand-to-mouth (HTM) activities, dermal absorption, and inhalation (for residents only). Exposure to DINP was assessed separately for professional installers of the products and for residents and other occupants of homes and other structures where the products have been installed. Two exposure estimates were presented by Interface for each scenario, and were referred to as "average" and "bounding" estimates for professional installers, and "simplified-bounding" and "OEHHA-bounding" estimates for residents. The "bounding" estimate for installers and the "OEHHA-bounding" estimate for residents were calculated using the same approaches and assumptions as those used by OEHHA in assessing a recent SUD request for

another modular carpet tile product (see the 2016 document entitled: Supporting Materials for a Safe Use Determinations for Diisononyl Phthalate (DINP) in Tandus Centiva ER3® Modular Vinyl Carpet Tiles [OEHHA, 2016]).

Interface submitted technical data from the testing of GlasBac® carpet tiles as part of the SUD request. Testing was only performed on GlasBac® carpet tiles, since they contain a higher DINP concentration (16.06%) in the structural backing layer than do GlasBac®RE tiles (9%). Data submitted include (i) measurements of DINP content in PVC scrapings collected from the four quadrants of the structural backing layer (" the bottom PVC layer of the tile") from each of four tiles, (ii) wipe samples from the top and bottom surfaces of three tiles, (iii) hand wipe samples[5] of the right or left hands[6] of two professional installers simulating installation of the carpet tiles, and (iv) air emission data for three individual tiles from chamber studies conducted in a Micro-Chamber with a sampling duration of approximately 3.5 days, and a DINP detection limit of 0.5 µg/m^3.

1.3.1 Interface exposure analysis for professional installers

Interface assessed DINP exposure to professional installers during installation of Interface GlasBac® and GlasBac®RE modular carpet tiles and presented 'average' and 'bounding' estimates. Interface estimated the "average" exposure of a professional installer to DINP is 0.05 µg/day if 100 yards^2 of the carpet product is installed in a work day (and 0.06 µg/day if 200 yards^2 of the carpet product is installed in a work day), and the "bounding" exposure of a professional installer to DINP is 99 µg/day (after rounding up from 98.9 µg/day).

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

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

Interface used hand wipe samples from two professional installers simulating installation of Interface GlasBac® modular carpet tiles to estimate the dermal loading of DINP on the hands. Hand wipes of the palmar surface of five fingertips and the remainder of the hand were taken from each subject after installation of 15, 30, 45, 60, 75 and 90 tiles. Two types of wipe data were used for estimating exposures by two different pathways: wipes of the palmar surface of the fingertips and the remainder of the palmar surface of

[5] The palmar surface of the hand was wiped (either just the palmar side of fingertips, or the remainder of the palmar surface)

[6] Hand wipe samples of the right (R) or left (L) hand were taken from two individuals after simulated installation of different numbers of tiles (15, 30, 45, 60, 75, and 90 tiles). For Subject #1, the hand wiped at the different intervals was L, L, L, R, L, R, respectively. For Subject #2, the hand wiped at the different intervals was R, R, R, L, R, L, respectively.

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 palmar surface of the right hand after handling 75 tiles (sum of sample ID “DRF-75” and “DRH-75”; 93.6 µg), and from wipes of the fingertips of the right hand after handling 75 tiles (sample ID “DRF-75”; 56.6 µg).

To estimate the “average” exposure of a professional installer, Interface converted the hand wipe data from “µg/wipe” to “µg/cm^2” for further regression analysis. The hand wipe data was regressed against the number of tiles installed, up to 90, and then extrapolated up to installation of 665 tiles. Interface estimated the “maximum” hand loading for installers under the two scenarios of handling either 665 tiles (equivalent to 200 yards^2) or 333 tiles (equivalent to 100 yards^2). The “maximum” DINP concentrations under these two scenarios are 2.01 and 1.67 µg/cm^2, respectively, for fingertips, and 0.51 and 0.42 µg/cm^2, respectively, for the remainder of the palmar surface of the hand.

Interface estimated the DINP loaded on both hands after installing 100 yards^2 of carpet tiles as 284 µg and assumed a dermal absorption of 0.15% to derive a dermal exposure estimate of 0.43 µg per work day (see page 20 of the SUD submission). For oral ingestion, Interface applied a series of assumptions (e.g., surface area of the hand in contact with the mouth assumed to be 4 cm^2, hand-to-mouth (HTM) contact frequency assumed to be 4 per hour), to derive an ingestion exposure estimate of 2 µg per work day (see pages 20-21 of the SUD submission).

Table 1 summarizes the Interface estimates of “average” DINP exposures to professional installers by pathway, under the assumption that carpet tile is installed at the rate of 100 yards^2/day. This table also includes the adjustment factors employed in the Interface analysis to derive the adjusted lifetime average daily dose of 0.05 µg/day.

Table 1. Summary of Interface evaluation of professional installer 'average' exposure to DINP during installation of Interface GlasBac® modular carpet tiles (100 yards^2 per work day)

Exposure Variable	Unit	Value	Basis
A. Dermal dose	µg/day	0.43	284 µg hand loading and dermal absorption of 0.15% (p. 20)
B. Incidental ingestion dose	µg/day	2	Multiple assumptions listed on pp. 20-21
C. Daily dose from all exposure pathways	µg/day	2.4	= A + B
D. Lifetime averaging adjustment factor	unitless	0.021	= 5 day/7 day x 48 wk/52 wk x 25 yr/70 yr x 9.1% (market share of modular carpet tile)
E. Adjusted lifetime average daily dose	µg/day	0.05	= C x D

Interface's "bounding" estimate for DINP exposure to professional installers follows the assumptions and calculation framework employed by OEHHA in the document entitled, "Supporting Materials for a Safe Use Determinations for Diisononyl Phthalate (DINP) in Tandus Centiva ER3® Modular Vinyl Carpet Tiles" (OEHHA, 2016), yielding a value of 98.9 µg/day (rounds up to 99 µg/day). The assumptions and calculation framework for the OEHHA-bounding estimate are described in Section 2.1.

1.3.2 Interface exposure analysis for residents

Interface assessed DINP exposure to residents of homes and other facilities where Interface GlasBac® and GlasBac®RE modular carpet tiles have been installed, and presented "simplified-bounding" and "OEHHA-bounding" estimates. Interface estimated that the expected exposure of a resident to DINP is 2.1 µg/day based on the "simplified-bounding" approach, and 93.1 µg/day based on the "OEHHA-bounding" approach.

Interface's "simplified-bounding" estimate was calculated 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 carpet tiles. Interface assumed that DINP remains in the bottom layer (i.e., structural backing layer) of the tile, and does not migrate out of that layer through the upper layer to the surface of the carpet tile. Interface used the data from wipe samples taken from the top surface of three replicate Interface GlasBac® modular

carpet tiles, all below the detection limit of 189 µg/square meter [m^2], to derive an "upper bound" estimate of the total DINP available to the resident of a home, office, or other facility. Interface used the detection limit of 189 µg/m^2 to represent the maximum amount of DINP available to the resident. In calculating the resident's exposure, Interface assumed that the area covered with either Interface GlasBac® or GlasBac®RE modular carpet tiles was 3000 square feet (= 278.7 m^2) and that the entire mass of available DINP (189 µg/m^2 multiplied by 278.7 m^2) is absorbed by a single resident over a 70-year lifetime. This "simplified-bounding" estimate yields an estimated lifetime average daily dosage of DINP of [(189 × 278.7) / (70 × 365)] = 2.1 µg/day.

This analysis is based on the unsubstantiated premise that the amount of DINP measured by wiping the top surface of a new tile, less than the detection limit of 189 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 for continuous exposure from various pathways (inhalation, dermal uptake and incidental ingestion).

Interface's "OEHHA-bounding" estimate for DINP exposure to residents follows the assumptions and calculation framework employed by OEHHA in the document entitled, "Supporting Materials for a Safe Use Determinations for Diisononyl Phthalate (DINP) in Tandus Centiva ER3® Modular Vinyl Carpet Tiles" (OEHHA, 2016), yielding a value of 93.1 µg/day. The assumptions and calculation framework for the OEHHA-bounding estimate are described in Section 2.2.

2. OEHHA Analyses of DINP Exposures from Interface GlasBac® and GlasBac®RE Modular Carpet Tiles

OEHHA conducted screening-level exposure analyses to derive upper-end estimates of DINP exposure to professional installers (98.9 µg/day; Table 2) and residents (93.1 µg/day; Table 3).

The potential exposure pathways included in OEHHA's analysis are:

- Inhalation of DINP in the air (residents only).
- Dermal absorption of DINP:
  - Via direct contact with the carpet tiles for installers;
  - Via dust-to-dermal and air-to-dermal absorption for residents (direct contact with the 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. These same assumptions and approaches were employed by Interface to generate a "bounding" estimate for installers and an "OEHHA-bounding" estimate for residents.

2.1 OEHHA Exposure Analysis for Professional Installers

The upper-end estimate of DINP exposures to professional carpet installers during the installation of Interface GlasBac® and GlasBac®RE modular carpet containing 16.06% DINP by weight in the backing layer, and a maximum of 9% DINP by weight in the tile as a whole, is 98.9 µg/day.

Inhalation exposure 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 Interface GlasBac® and GlasBac®RE modular carpet tiles

Parameter	Unit	Value	Basis
Dermal absorption			
A. Hand (palmar surface) DINP loading	µg/day	187.2	= (93.6 µg/hand) x (two hands), maximum, measured @ 75 tiles, Interface
B. Human dermal absorption coefficient	unitless	0.15%	McKee *et al.* (2002); Scott *et al.* (1987) (see below)
C. Dermal dose	µg/day	0.3	= A x B
Hand-to-Mouth (HTM) ingestion			
D. HTM fingertip DINP loading	µg/event	34.0	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 Interface's assumption
H. HTM ingestion dose	µg/day	251.9	= D x E x F x G
Total exposure by all pathways			
I. Total daily dose (all pathways)	µg/day	252.2	= 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	98.9	= 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 0.3 µg per working day (Line C, Table 2). 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 TacTiles™ connectors to create a 'floating floor' covering, or 'free-laying' the tiles on the 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 of the fingertips and single-hand wipe samples of the remainder of the palmar surface of the hand from two

professional installers handling 15 - 90 new carpet tiles, OEHHA used the reported maximum total palmar concentration (93.6 µg/hand, measured at 75 tiles) to estimate the dermal dose from two DINP-loaded hands (93.6 µg/hand x 2 hands = 187.2 µg; Table 2, Line A).

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)

2.1.2 HTM ingestion pathway

OEHHA estimated the dose of DINP to the professional carpet installer by the HTM ingestion pathway as 251.9 µg per working day (Line H, Table 2). 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 work day 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.

3. Based on the results of five-fingertip wipe samples from two subjects handling 15 - 90 new carpet tiles, OEHHA used the reported maximum fingertip concentration of DINP (56.6 µg/five fingertips) to estimate the loading on three fingertips. The fingertip loading used for HTM exposure is 34.0 µg (= 56.6 µg × 3/5; Table 2, Line D). The DINP concentration in the backing layer of the GlasBac® carpet tiles used to generate the five-fingertip wipe samples was reported by Interface to be 16.06% by weight.
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). Interface, in deriving an "average" estimate for professional installers, 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 the more conservative estimate of 50%, based on the study by Camann *et al*. (2000), for HTM transfer efficiency.
5. In the absence of data on the frequency of HTM activity by professional installers of modular 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. 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 Interface (Table 2, Line G). This is a reasonable estimate of the time spent working with new carpet tiles per 8-hr work day, 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 (98.9 µg/day, Table 2, Line K) was calculated as the product of the sum of the daily doses for the two exposure routes (252.2 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 98.9 µg/day, below the NSRL for DINP of 146 µg/day. As indicated by Interface, DINP exists only in the backing layer of the carpet tiles at maximum concentrations in that layer of 9% by weight in GlasBac®RE carpet tiles and 16.06% by weight in GlasBac® carpet tiles. These DINP levels in the backing layer correspond to DINP concentrations in the whole tile of 5% by weight in GlasBac®RE carpet tiles and 9% by weight in GlasBac® carpet tiles. GlasBac® carpet tiles were used in the simulated installation scenario from which the five-fingertip wipe data was generated, and the DINP content of these tiles was assumed to be 16.06% DINP by weight in the backing layer, as reported by Interface.

2.1.4 Uncertainties associated with professional installers' exposure estimate

1. Laboratory reports included in the SUD submission indicate that the relative standard deviation (RSD) of the measured DINP content in samples of the whole tile from three GlasBac® carpet tiles is 15.12%, while the RSD of the measured DINP content in the backing layer of four GlasBac® tiles is 2.7%. Although to some extent different efficiencies of extraction of DINP from the backing layer compared to the whole carpet tile may contribute to the disparity in RSDs, the magnitude of the difference in the measured DINP suggests possible variation of the composition of the modular carpet tiles themselves, which supports the need to specify DINP content by weight in the backing layer and by the whole modular tile.

2. Interface states that the DINP concentration in the backing layer of GlasBac® carpet tiles is 16.06% by weight; however, the submitted DINP concentrations that were measured in the backing layers of four tiles averaged 13.7% by weight, and the maximum among the four tiles was 14.2% by weight. It is possible that the DINP concentrations measured in the backing layers of the four tiles are lower than the level specified by Interface in the product description (i.e., 16.06% by weight) due to differences across laboratory extraction methods and efficiencies. It is also possible that the DINP content in the backing layer may differ across batches of carpet tiles. Uncertainty in the level of DINP in the carpet tiles could under- or over-estimate DINP exposure.

3. 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, based on the assumption that installers wash their hands before eating or smoking. Indirect hand-to-mouth contact (e.g., transfer from contaminated hands to objects such as food or cigarettes that are put in the mouth) is not assumed to occur. This assumption, if incorrect, could underestimate DINP exposure.
    ii. Five-fingertip wipe data:
        - Five-fingertip wipe samples were collected in a limited number of subjects (N = 2).
        - Hand wipe samples were collected alternating from the left hand to the right hand (or vice versa) every 15 tiles from 15 to 90 tiles. From the limited data presented in Table 10 of the Interface SUD submission, it shows a pattern that right-hand wipe concentrations are usually higher than left-hand levels for the same subject/installer. In general, hand wipe samples should be taken from the dominant hand, if only one hand is sampled, to better estimate upper-bound dermal loading for most activities.
        - There is considerable intra- and inter-individual variability apparent in the wipe data.
        - Wipe data were collected only up to the handling of 90 carpet tiles. This is equivalent to carpet tile installation in a room the size of 26.9 $yards^2$, based on a tile size of 50 cm by 50 cm. From the information provided in the SUD application, professional installers can install up to 100 yd^2 per day, equivalent to installation of 333 carpet tiles per day. From the DINP hand loading plots shown in the SUD application (Figures 2 - 5), there is no level-off pattern for hand loading. This suggests that collecting wipe samples after handling a maximum of 90 tiles may not be sufficient to represent the upper bound level of DINP hand loading for professional installers in a typical work day. Also, uncertainty in the level of DINP in the carpet tiles used to generate the wipe data could under- or over-estimate DINP exposure.
        - Actual installers' contact with the carpet tiles may differ from that of the two studied subjects.

        Thus, use of the wipe sample data could under- or over-estimate DINP exposure.
    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.

4. 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. Uncertainties with the palmar surface hand wipe data are similar to those discussed above with regard to the five-fingertip wipe data: The hand wipe samples (wipes of the five-finger tips and of the remaining palmar surface of the hand) were collected in a limited number of subjects (n = 2). Alternating sampling between the right and left hands may fail to adequately capture the loading of the dominant hand. 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 studied subjects. Also, as discussed above, uncertainty in the level of DINP in the carpet tiles used to generate the wipe data could under- or over-estimate DINP exposure.

5. Additional potential exposure pathways not evaluated in this analysis include worker exposure to contaminated clothing after work and exposure during removal of GlasBac® or GlasBac®RE modular carpet tiles. This could underestimate DINP exposure.

6. Interface adjusted workers' DINP exposure according to the 9.1% market share of modular carpet in their "average" exposure estimate. OEHHA conservatively assumed that carpet installers work full-time installing Interface GlasBac® and GlasBac®RE modular carpet tiles. This could overestimate DINP exposure if workers also install carpet tiles that do not contain DINP.

   OEHHA conservatively assumed that carpet installers work for 40 years[7]; workers may install Interface GlasBac® and GlasBac®RE modular carpet tiles less than 40 years. This could overestimate DINP exposure for workers with less than 40 working years.

[7] Section 25721(d)(3)

2.2 OEHHA Exposure Analysis for Residents

The upper-end estimate of DINP exposures to residents of homes and other facilities that have Interface GlasBac® and GlasBac®RE modular carpet tile installed, assuming the tiles contain 16.06% DINP by weight in the backing layer, and a maximum of 9% DINP by weight in the tile as a whole, is 93.1 µg/day.

OEHHA evaluated the lifetime daily DINP exposure for residents in homes carpeted with Interface GlasBac® and GlasBac®RE modular carpet tiles. DINP, an SVOC, is commonly found in gas and condensed phases, moving from the emission source to indoor air and interior surfaces, including airborne particles, dust and skin. DINP will volatilize 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).

Exposure from installation of the carpet tiles by residents ("do it yourself" installation) is not included in the exposure estimate, as exposure from a one-, two-, or three-time occurrence of this activity by the resident will be minimal after averaging over 70 years. For example, if the resident installs Interface GlasBac® or GlasBac®RE modular carpet tile twice in the lifetime and spends five working days per installation, using the workers' exposure level in one working day (252 µg/day) as the daily exposure level for the "do-it-yourself" resident, the lifetime average exposure for the resident from installation would be 0.1 µg/day (= (252 µg/day x 5 day/installation × 2 installation) / (365 day/yr × 70 yr)).

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 and other facilities with Interface GlasBac® and GlasBac®RE modular carpet tiles

Parameter	Unit	Value	Basis
Inhalation			
A. Airborne gas-phase concentration	µg/m^3	0.1247	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	0.057	= A × B × C
E. Total DINP air concentration	µg/m^3	0.182	= 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	2.8	= 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	9.6	= I x J x K × Q
N. Dermal intake from gas	µg/day	1.2	= A x G x I x L x 24 h/day
O. Dermal absorption dose	µg/day	10.8	= 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	2057.6	= 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	79.4	= Q x R
Total exposure by all pathways			
T. Lifetime daily dose	µg/day	93.1	= H + O + S

2.2.1 Inhalation pathway

The inhalation dose for residents with Interface GlasBac® and GlasBac®RE modular carpet tiles installed in their home is estimated to be 2.8 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 Interface modular 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 0.45, the ratio of the maximum DINP concentration in Interface GlasBac® modular carpet as a whole (9%) to that in the PVC tile (20%) tested by Liang and Xu (2014) (i.e., 0.42 µg/m^3 × 9% ÷ 20% = 0.189 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 modular 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/day (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/m^3	0.189	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	m^3/µg	0.023	Weschler and Nazaroff (2010), Liang and Xu (2014) (see text)
F. Floor surface area	m^2	279	3000 ft^2, assumed
G. Room height	m	2.6	8.5 ft, standard ceiling height
H. Room volume	m^3	725.4	= F × G
I. Air changes per hour	/hr	0.23	CDPH EHLB (2010) default
J. Ventilation rate	m^3/s	0.0463	= H × I × (1/3600 h/s)
K. Total suspended particles	µg/m^3	20	Little *et al.* (2012)
L. Gas-phase DINP concentration	µg/m^3	0.1247	= (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 10.8 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 the carpet tiles (< 0.1 µg/day) is considered negligible relative to dust-to-dermal absorption (9.6 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 m^2, 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/m^2-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.
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

Incidental ingestion refers to non-dietary ingestion of dust loaded with the contaminant/chemical, possibly via the hands or food. Residents' DINP intake from incidental ingestion of dust containing DINP is estimated to be 79.4 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 rate of daily incidental ingestion of dust.

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/day (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 93.1 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 Interface GlasBac® and GlasBac®RE modular carpet tiles is calculated to fall below the level posing significant cancer 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 $\mu g/m^3$) from Interface, conducted in approximately 3.5 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, SVOCs will persist indoors for weeks or years because all indoor surfaces have become coated with SVOCs (LBNL IAQ Resources Bank). Though we do not have good quantification of the DINP emission from Interface GlasBac® and GlasBac®RE modular carpet tiles, we do know from studies on other SVOCs that over time DINP is likely to slowly volatilize 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 Interface GlasBac® modular 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 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 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 GlasBac® and GlasBac®RE modular carpet tiles, which have a wear layer of non-DINP containing material above the structural 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 25ºC to 36ºC. 36ºC is not a comfortable indoor temperature; however, 30ºC (= 86ºF) 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 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
0.1247	2057.6	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)
0.0082-0.214	258-4100	Raffy *et al.* (2017)[#]

* MDL: method detection limit.

[#] The 5th and 95th percentile values were reported for airborne and dust concentrations.

Among the different exposure pathways for residents, intake from the incidental ingestion of dust is highest (79.4 µg; about 85% of total intake), followed by dermal absorption (10.8 µg) and inhalation (2.8 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.

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 Interface GlasBac® and GlasBac®RE modular carpet tiles containing up to 16.06% DINP by weight in the backing layer and a maximum of 9% DINP by weight for the tile as a whole, is 98.9 µg/day. This estimate is below the No Significant Risk Level (NRSL) for DINP of 146 µg/day.

Therefore, no warning is needed for DINP exposures for professional installers of Interface GlasBac® and GlasBac®RE modular carpet tiles containing 16.06% DINP by weight, or less, in the backing layer of the tile, and a maximum of 9% DINP by weight for the tile as a whole.

3.2 Residents

Based on this screening level exposure analysis for residents with Interface GlasBac® and GlasBac®RE modular carpet tiles installed in their homes or other facilities, an upper-end estimate of DINP exposures is 93.1 µg/day, which is approximately 64% of the NSRL for DINP. The estimated exposure to DINP for residents as a result of the use of these carpet tiles in residences and other facilitates corresponds to an excess cancer risk of less than one in 100,000.

Therefore, DINP exposures to residents from Interface GlasBac® and GlasBac®RE modular carpet tiles containing 16.06% DINP by weight, or less, in the backing layer of

the tile, and a maximum of 9% DINP by weight for the tile as a whole 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 Interface GlasBac® and GlasBac®RE modular 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 25ºC.

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

$Y_{0:}$ 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),

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

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

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

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

$f_{om\ part}$: volume fraction of organic matter associated with airborne particle; 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**