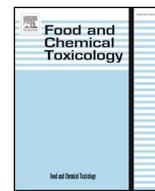




ELSEVIER

Contents lists available at ScienceDirect

Food and Chemical Toxicology

journal homepage: www.elsevier.com/locate/foodchemtox

Short Review

RIFM fragrance ingredient safety assessment, pentyl benzoate, CAS Registry Number 2049-96-9



A.M. Api^a, D. Belsito^b, D. Botelho^a, M. Bruze^c, G.A. Burton Jr.^d, J. Buschmann^e, M.L. Dagli^f, M. Date^a, W. Dekant^g, C. Deodhar^a, M. Francis^a, A.D. Fryer^h, L. Jones^a, K. Joshi^a, S. La Cava^a, A. Lapczynski^a, D.C. Lieblerⁱ, D. O'Brien^a, A. Patel^a, T.M. Penning^j, G. Ritacco^a, J. Romine^a, N. Sadekar^a, D. Salvito^a, T.W. Schultz^k, I.G. Sipes^l, G. Sullivan^{a,*}, Y. Thakkar^a, Y. Tokura^m, S. Tsang^a

^a Research Institute for Fragrance Materials, Inc., 50 Tice Boulevard, Woodcliff Lake, NJ, 07677, USA

^b Member RIFM Expert Panel, Columbia University Medical Center, Department of Dermatology, 161 Fort Washington Ave., New York, NY, 10032, USA

^c Member RIFM Expert Panel, Malmo University Hospital, Department of Occupational & Environmental Dermatology, Sodra Forstadsgatan 101, Entrance 47, Malmo, SE-20502, Sweden

^d Member RIFM Expert Panel, School of Natural Resources & Environment, University of Michigan, Dana Building G110, 440 Church St., Ann Arbor, MI 48109, USA

^e Member RIFM Expert Panel, Fraunhofer Institute for Toxicology and Experimental Medicine, Nikolai-Fuchs-Strasse 1, 30625, Hannover, Germany

^f Member RIFM Expert Panel, University of Sao Paulo, School of Veterinary Medicine and Animal Science, Department of Pathology, Av. Prof. Dr. Orlando Marques de Paiva, 87, Sao Paulo, CEP 05508-900, Brazil

^g Member RIFM Expert Panel, University of Wuerzburg, Department of Toxicology, Versbacher Str. 9, 97078, Wuerzburg, Germany

^h Member RIFM Expert Panel, Oregon Health Science University, 3181 SW Sam Jackson Park Rd., Portland, OR, 97239, USA

ⁱ Member RIFM Expert Panel, Vanderbilt University School of Medicine, Department of Biochemistry, Center in Molecular Toxicology, 638 Robinson Research Building, 2200 Pierce Avenue, Nashville, TN, 37232-0146, USA

^j Member of RIFM Expert Panel, University of Pennsylvania, Perelman School of Medicine, Center of Excellence in Environmental Toxicology, 1316 Biomedical Research Building (BRB) II/III, 421 Curie Boulevard, Philadelphia, PA, 19104-3083, USA

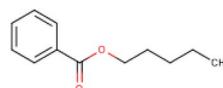
^k Member RIFM Expert Panel, The University of Tennessee, College of Veterinary Medicine, Department of Comparative Medicine, 2407 River Dr., Knoxville, TN, 37996-4500, USA

^l Member RIFM Expert Panel, Department of Pharmacology, University of Arizona, College of Medicine, 1501 North Campbell Avenue, P.O. Box 245050, Tucson, AZ, 85724-5050, USA

^m Member RIFM Expert Panel, The Journal of Dermatological Science (JDS), Editor-in-Chief, Professor and Chairman, Department of Dermatology, Hamamatsu University School of Medicine, 1-20-1 Handayama, Higashi-ku, Hamamatsu 431-3192, Japan

Version: 050818. This version replaces any previous versions.

Name: Pentyl benzoate CAS Registry Number: 2049-96-9

**Abbreviation/Definition List:**

2-Box Model - A RIFM, Inc. proprietary *in silico* tool used to calculate fragrance air exposure concentration

AF - Assessment Factor

BCF - Bioconcentration Factor

Creme RIFM Model - The Creme RIFM Model uses probabilistic (Monte Carlo) simulations to allow full distributions of data sets, providing a more realistic estimate of aggregate exposure to individuals across a population (Comiskey et al., 2015, 2017; Safford et al., 2015, 2017) compared to a deterministic aggregate approach

DST - Dermal Sensitization Threshold

ECHA - European Chemicals Agency

EU - Europe/European Union

GLP - Good Laboratory Practice

IFRA - The International Fragrance Association

LOEL - Lowest Observable Effect Level

MOE - Margin of Exposure

MPPD - Multiple-Path Particle Dosimetry. An *in silico* model for inhaled vapors used to simulate fragrance lung deposition

NA - North America

NESIL - No Expected Sensitization Induction Level

* Corresponding author.

E-mail address: gsullivan@rifm.org (G. Sullivan).

<https://doi.org/10.1016/j.fct.2018.11.005>

Received 8 May 2018; Received in revised form 11 October 2018; Accepted 1 November 2018

Available online 05 November 2018

0278-6915/ © 2018 Elsevier Ltd. All rights reserved.

NOAEC - No Observed Adverse Effect Concentration
 NOAEL - No Observed Adverse Effect Level
 NOEC - No Observed Effect Concentration
 NOEL - No Observed Effect Level
 OECD - Organisation for Economic Co-operation and Development
 OECD TG - Organisation for Economic Co-operation and Development Testing Guidelines
 PBT - Persistent, Bioaccumulative, and Toxic
 PEC/PNEC - Predicted Environmental Concentration/Predicted No Effect Concentration
 QRA - Quantitative Risk Assessment
 REACH - Registration, Evaluation, Authorisation, and Restriction of Chemicals
 RfD - Reference Dose
 RIFM - Research Institute for Fragrance Materials
 RQ - Risk Quotient
Statistically Significant - Statistically significant difference in reported results as compared to controls with a $p < 0.05$ using appropriate statistical test
 TTC - Threshold of Toxicological Concern
 UV/Vis spectra - Ultraviolet/Visible spectra
 VCF - Volatile Compounds in Food
 VoU - Volume of Use vPvB - (very) Persistent, (very) Bioaccumulative
 WoE - Weight of Evidence

The Expert Panel for Fragrance Safety* concludes that this material is safe under the limits described in this safety assessment.

This safety assessment is based on the RIFM Criteria Document (Api et al., 2015), which should be referred to for clarifications.

Each endpoint discussed in this safety assessment includes the relevant data that were available at the time of writing (version number in the top box is indicative of the date of approval based on a 2-digit month/day/year), both in the RIFM database (consisting of publicly available and proprietary data) and through publicly available information sources (e.g., SciFinder and PubMed). Studies selected for this safety assessment were based on appropriate test criteria, such as acceptable guidelines, sample size, study duration, route of exposure, relevant animal species, most relevant testing endpoints, etc. A key study for each endpoint was selected based on the most conservative endpoint value (e.g., PNEC, NOAEL, LOEL, and NESIL).

*The Expert Panel for Fragrance Safety is an independent body that selects its own members and establishes its own operating procedures. The Expert Panel is comprised of internationally known scientists that provide RIFM with guidance relevant to human health and environmental protection.

Summary: The use of this material under current conditions is supported by existing information.

Pentyl benzoate was evaluated for genotoxicity, repeated dose toxicity, reproductive toxicity, local respiratory toxicity, phototoxicity/photoallergenicity, skin sensitization, and environmental safety. Data from read-across analog hexyl benzoate (CAS # 6789-88-4) show that pentyl benzoate is not expected to be genotoxic. Data from read-across analog methyl benzoate (CAS # 93-58-3) show that pentyl benzoate is not a concern for skin sensitization at the current, declared levels of use. The repeated dose, reproductive, and local respiratory toxicity endpoints were completed using the TTC for a Cramer Class I material, and the exposure to pentyl benzoate is below the TTC (0.03 mg/kg/day, 0.03 mg/kg/day, and 1.4 mg/day, respectively). The phototoxicity/photoallergenicity endpoint was completed based on UV spectra; pentyl benzoate is not expected to be phototoxic/photoallergenic. The environmental endpoints were evaluated; pentyl benzoate was found not to be PBT as per the IFRA Environmental Standards, and its risk quotients, based on its current volume of use in Europe and North America (i.e., PEC/PNEC), are < 1 .

Human Health Safety Assessment

Genotoxicity: Not genotoxic. (RIFM, 2014a; RIFM, 2014b)

Repeated Dose Toxicity: No NOAEL available. Exposure is below the TTC.

Reproductive Toxicity: No NOAEL available. Exposure is below the TTC.

Skin Sensitization: No safety concerns under the current, declared levels of use. (ECHA REACH Dossier: Methyl benzoate, accessed 6/14/17)

Phototoxicity/Photoallergenicity: Not phototoxic/photoallergenic. (UV Spectra, RIFM DB)

Local Respiratory Toxicity: No NOAEC available. Exposure is below the TTC.

Environmental Safety Assessment

Hazard Assessment:

Persistence: Screening-level: 3.2 (BIOWIN 3)

(EPI Suite v4.1; US EPA, 2012a)

Bioaccumulation: Screening-level: 147 L/kg

(EPI Suite v4.1; US EPA, 2012a)

Ecotoxicity: Screening-level: Fish LC50: 7.185 mg/L

(RIFM Framework; Salvito et al., 2002)

Conclusion: Not PBT or vPvB as per IFRA Environmental Standards

Risk Assessment:

Screening-level: PEC/PNEC (North America and Europe) < 1

(RIFM Framework; Salvito et al., 2002)

Critical Ecotoxicity Endpoint: Fish LC50: 7.185 mg/L

(RIFM Framework; Salvito et al., 2002)

RIFM PNEC is: 0.007185 µg/L

•Revised PEC/PNECs (2015 IFRA VoU): North America and Europe: Not applicable; cleared at the screening-level

1. Identification

- 1 Chemical Name: Pentyl benzoate
- 2 CAS Registry Number: 2049-96-9
- 3 **Synonyms:** Amyl benzoate; Benzoic acid, pentyl ester; 安息香酸戊基酯 (C = 1 ~ 8); Pentyl benzoate
- 4 Molecular Formula: C₁₂H₁₆O₂
- 5 Molecular Weight: 192.26
- 6 RIFM Number: 6184

2. Physical data

- 1 **Boiling Point:** 269.08 °C (EPI Suite)
- 2 **Flash Point:** > 93 °C (GHS)
- 3 **Log K_{ow}:** 3.79 (EPI Suite)
- 4 **Melting Point:** 32.02 °C (EPI Suite)

- 5 **Water Solubility:** 27.63 mg/L (EPI Suite)
- 6 **Specific Gravity:** Not Available
- 7 **Vapor Pressure:** 0.00484 mm Hg @ 20 °C (EPI Suite v4.0), 0.02 mm Hg @ 20 °C (FMA), 0.00859 mm Hg @ 25 °C (EPI Suite)
- 8 **UV Spectra:** No significant absorbance between 290 and 700 nm; molar absorption coefficient is below the benchmark (1000 L mol⁻¹ · cm⁻¹)
- 9 **Appearance/Organoleptic:** Colorless to pale yellow clear and oily liquid with floral, green, musky, amber, and balsam odor*

* <http://www.thegoodscentcompany.com/data/rw1047711.html>, retrieved 6/22/2017.

3. Exposure

- 1 **Volume of Use (worldwide band):** 0.1–1 metric ton per year (IFRA, 2015)

- 2 **95th Percentile Concentration in Hydroalcoholics:** 0.31% (RIFM, 2017)
- 3 **Inhalation Exposure*:** 0.00013 mg/kg/day or 0.0093 mg/day (RIFM, 2017)
- 4 **Total Systemic Exposure**:** 0.0017 mg/kg/day (RIFM, 2017)

*95th percentile calculated exposure derived from concentration survey data in the Creme RIFM aggregate exposure model (Comiskey et al., 2015; Safford et al., 2015; Safford et al., 2017; and Comiskey et al., 2017).

**95th percentile calculated exposure; assumes 100% absorption unless modified by dermal absorption data as reported in Section IV. It is derived from concentration survey data in the Creme RIFM aggregate exposure model and includes exposure via dermal, oral, and inhalation routes whenever the fragrance ingredient is used in products that include these routes of exposure (Comiskey et al., 2015; Safford et al., 2015; Safford et al., 2017; and Comiskey et al., 2017).

4. Derivation of systemic absorption

- 1 **Dermal:** Assumed 100%
- 2 **Oral:** Assumed 100%
- 3 **Inhalation:** Assumed 100%

5. Computational toxicology evaluation

- 1 Cramer Classification: Class I, Low

Expert Judgment	Toxtree v 2.6	OECD QSAR Toolbox v 3.2 (OECD, 2012)
I	I	I

2 Analogs Selected:

- a **Genotoxicity:** Hexyl benzoate (CAS # 6789-88-4)
 - b Repeated Dose Toxicity: None
 - c Reproductive Toxicity: None
 - d **Skin Sensitization:** Methyl benzoate (CAS # 93-58-3)
 - e Phototoxicity/Photoallergenicity: None
 - f Local Respiratory Toxicity: None
 - g Environmental Toxicity: None
- 3 Read-across Justification: See Appendix below

6. Metabolism

Not considered for this risk assessment and therefore not reviewed except where it may pertain in specific endpoint sections as discussed below.

7. Natural occurrence (discrete chemical) or composition (NCS)

Pentyl benzoate is reported to occur in the following foods*:

Beer
Cocoa category
Crispbread
Sapodilla fruit (*Achras sapota* L.)
Vaccinium species

*VCF Volatile Compounds in Food: database/Nijssen, L.M.; Ingen-Visscher, C.A. van; Donders, J.J.H. (eds). – Version 15.1 – Zeist (The Netherlands): TNO Triskelion, 1963–2014. A continually updated database that contains information on published volatile compounds that have been found in natural (processed) food products. Includes FEMA GRAS and EU-Flavis data.

8. IFRA standard

None.

9. REACH dossier

Pre-registered for 2010; no dossier available as of 5/8/2018.

10. Summary

10.1. Human health endpoint summaries

10.1.1. Genotoxicity

Based on the current existing data, pentyl benzoate does not present a concern for genotoxicity.

10.1.1.1. Risk assessment. Pentyl benzoate was assessed in the BlueScreen assay and found negative for genotoxicity, with and without metabolic activation (RIFM, 2013). There are no data assessing the mutagenic activity of pentyl benzoate; however, read-across can be made to hexyl benzoate (CAS # 6789-88-4; see Section V). The mutagenic activity of hexyl benzoate has been evaluated in a bacterial reverse mutation assay conducted in compliance with GLP regulations and in accordance with OECD TG 471 using the standard plate incorporation method (OECD, 2015). *Salmonella typhimurium* strains TA98, TA100, TA1535, TA1537, and *Escherichia coli* strain WP2uvrA were treated with hexyl benzoate in dimethyl sulfoxide (DMSO) at concentrations up to 5000 µg/plate. No increases in the mean number of revertant colonies were observed at any tested dose in the presence or absence of S9 (RIFM, 2014a). Under the conditions of the study, hexyl benzoate was not mutagenic in the Ames test, and this can be extended to pentyl benzoate.

There are no data assessing the clastogenic activity of pentyl benzoate; however, read-across can be made to hexyl benzoate (CAS # 6789-88-4; see Section V). The clastogenic activity of hexyl benzoate was evaluated in an *in vitro* micronucleus test conducted in compliance with GLP regulations and in accordance with OECD TG 487. Human peripheral blood lymphocytes were treated with hexyl benzoate in DMSO at concentrations up to 2064 µg/mL in the presence and absence of metabolic activation (S9) for 3 and 24 h. Hexyl benzoate did not induce binucleated cells with micronuclei when tested up to cytotoxic levels in either non-activated or S9-activated test systems (RIFM, 2014b). Under the conditions of the study, hexyl benzoate was considered to be non-clastogenic in the *in vitro* micronucleus test, and this can be extended to pentyl benzoate.

Based on the data available, pentyl benzoate does not present a concern for genotoxic potential.

Additional References: None.

Literature Search and Risk Assessment Completed On: 06/19/2017.

10.1.2. Repeated dose toxicity

There are insufficient repeated dose toxicity data on pentyl benzoate or any read-across materials. The total systemic exposure to pentyl benzoate is below the TTC for the repeated dose toxicity endpoint of a Cramer Class I material at the current level of use.

10.1.2.1. Risk assessment. There are no repeated dose toxicity data on pentyl benzoate or any read-across materials that can be used to support the repeated dose toxicity endpoint. The total systemic exposure to pentyl benzoate (1.7 µg/kg/day) is below the TTC (30 µg/kg bw/day; Kroes et al., 2007) for the repeated dose toxicity endpoint of a Cramer Class I material at the current level of use.

Additional References: None.

Literature Search and Risk Assessment Completed On: 06/05/2017.

10.1.3. Reproductive toxicity

There are insufficient reproductive toxicity data on pentyl benzoate or any read-across materials. The total systemic exposure to pentyl benzoate is below the TTC for the reproductive toxicity endpoint of a Cramer Class I material at the current level of use.

10.1.3.1. Risk assessment. There are no reproductive toxicity data on pentyl benzoate or any read-across materials that can be used to support the reproductive toxicity endpoint. The total systemic exposure to pentyl benzoate (1.7 µg/kg/day) is below the TTC (30 µg/kg bw/day; Kroes et al., 2007; Laufersweiler et al., 2012) for the reproductive toxicity endpoint of a Cramer Class I material at the current level of use.

Additional References: None.

Literature Search and Risk Assessment Completed On: 06/05/2017.

10.1.4. Skin sensitization

Based on the existing data and read-across analog methyl benzoate (CAS # 93-58-3), pentyl benzoate does not present a safety concern for skin sensitization under the current, declared levels of use.

10.1.4.1. Risk assessment. Limited skin sensitization studies are available for pentyl benzoate. Based on the existing data and read-across analog methyl benzoate (CAS # 93-58-3; see Section V), pentyl benzoate does not present a safety concern for skin sensitization under the current, declared levels of use. The chemical structure of these materials indicates that they could possibly react with skin proteins with little to no reaction under physiological conditions. In guinea pigs, an open epicutaneous test did not present reactions indicative of sensitization in ethyl benzoate (Klecak, 1985). Read-across material methyl benzoate does not present a concern for skin sensitization. In a murine local lymph node assay, read-across material methyl benzoate was found to be negative up to a maximum tested concentration of 100%, which resulted in a Stimulation Index (SI) of 2.98 (ECHA REACH Dossier: Methyl benzoate, accessed 6/14/17). In guinea pigs, open epicutaneous tests and Freund's complete adjuvant tests with read-across material methyl benzoate did not present reactions indicative of sensitization (Klecak, 1985; Hausen et al., 1995). In a human maximization test for the read-across analog methyl benzoate, no skin sensitization reactions were observed with 4% or 2760 µg/cm² in petrolatum (RIFM, 1970). Based on the weight of evidence from structural analysis as well as animal and human studies, pentyl benzoate does not present a safety concern for skin sensitization under the current, declared levels of use.

Additional References: None.

Literature Search and Risk Assessment Completed On: 6/14/2017.

10.1.5. Phototoxicity/photoallergenicity

Based on the available UV/Vis spectra, pentyl benzoate would not be expected to present a concern for phototoxicity or photoallergenicity.

10.1.5.1. Risk assessment. There are no phototoxicity studies available for pentyl benzoate in experimental models. UV/Vis absorption spectra indicate no significant absorption between 290 and 700 nm. The corresponding molar absorption coefficient is well below the benchmark of concern for phototoxicity and photoallergenicity (Henry et al., 2009). Based on lack of absorbance, pentyl benzoate does not present a concern for phototoxicity or photoallergenicity.

10.1.5.2. UV spectra analysis. UV/Vis absorption spectra (OECD TG 101) were obtained. The spectra indicate no significant absorbance in the range of 290–700 nm. The molar absorption coefficient is below the benchmark of concern for phototoxic effects, 1000 L mol⁻¹ · cm⁻¹

(Henry et al., 2009).

Additional References: None.

Literature Search and Risk Assessment Completed On: 05/25/17.

10.1.6. Local Respiratory Toxicity

The margin of exposure could not be calculated due to lack of appropriate data. The material, pentyl benzoate, exposure level is below the Cramer Class I TTC value for inhalation exposure local effects.

10.1.6.1. Risk assessment. There are no inhalation data available on pentyl benzoate. Based on the Creme RIFM Model, the inhalation exposure is 0.0093 mg/day. This exposure is 151 times lower than the Cramer Class I TTC value of 1.4 mg/day (based on human lung weight of 650 g; Carthew et al., 2009); therefore, the exposure at the current level of use is deemed safe.

Additional References: None.

Literature Search and Risk Assessment Completed On: 6/28/2017.

10.2. Environmental endpoint summary

10.2.1. Screening-level assessment

A screening-level risk assessment of pentyl benzoate was performed following the RIFM Environmental Framework (Salvito et al., 2002), which provides 3 tiered levels of screening for aquatic risk. In Tier 1, only the material's regional VoU, its log K_{OW}, and its molecular weight are needed to estimate a conservative risk quotient (RQ), expressed as the ratio Predicted Environmental Concentration/Predicted No Effect Concentration (PEC/PNEC). A general QSAR with a high uncertainty factor applied is used to predict fish toxicity, as discussed in Salvito et al. (2002). In Tier 2, the RQ is refined by applying a lower uncertainty factor to the PNEC using the ECOSAR model (US EPA, 2012b), which provides chemical class-specific ecotoxicity estimates. Finally, if necessary, Tier 3 is conducted using measured biodegradation and ecotoxicity data to refine the RQ, thus allowing for lower PNEC uncertainty factors. The data for calculating the PEC and PNEC for this safety assessment are provided in the table below. For the PEC, the range from the most recent IFRA Volume of Use Survey is reviewed. The PEC is then calculated using the actual regional tonnage, not the extremes of the range. Following the RIFM Environmental Framework, pentyl benzoate was identified as a fragrance material with no potential to present a possible risk to the aquatic environment (i.e., its screening-level PEC/PNEC < 1).

A screening-level hazard assessment using EPI Suite v4.1 (US EPA, 2012a) did not identify pentyl benzoate as possibly persistent or bioaccumulative based on its structure and physical-chemical properties. This screening-level hazard assessment considers the potential for a material to be persistent and bioaccumulative and toxic, or very persistent and very bioaccumulative as defined in the Criteria Document (Api et al., 2015). As noted in the Criteria Document, the screening criteria applied are the same as those used in the EU for REACH (ECHA, 2012). For persistence, if the EPI Suite model BIOWIN 3 predicts a value < 2.2 and either BIOWIN 2 or BIOWIN 6 predicts a value < 0.5, then the material is considered potentially persistent. A material would be considered potentially bioaccumulative if the EPI Suite model BCFBAF predicts a fish BCF ≥ 2000 L/kg. Ecotoxicity is determined in the above screening-level risk assessment. If, based on these model outputs (Step 1), additional assessment is required, a WoE-based review is then performed (Step 2). This review considers available data on the material's physical-chemical properties, environmental fate (e.g., OECD Guideline biodegradation studies or die-away studies), fish bioaccumulation, and higher-tier model outputs (e.g., US EPA's BIOWIN and BCFBAF found in EPI Suite v4.1). Data on persistence and bioaccumulation are reported below and summarized in the Environmental Safety Assessment section prior to Section 1.

10.2.2. Risk assessment

Based on the current Volume of Use (2015), pentyl benzoate does not present a risk to the aquatic compartment in the screening-level assessment.

10.2.2.1. *Biodegradation*. No data available.

10.2.2.2. *Ecotoxicity*. No data available.

10.2.2.3. *Other available data*. Pentyl benzoate has been pre-registered for REACH with no additional data at this time.

10.2.3. *Risk assessment refinement*. Ecotoxicological data and PNEC derivation (all endpoints reported in mg/L; PNECs in µg/L).

Endpoints used to calculate PNEC are underlined.

	LC50 (Fish) (mg/L)	EC50 (Daphnia) (mg/L)	EC50 (Algae) (mg/L)	AF	PNEC (µg/L)	Chemical Class
RIFM Framework Screening-level (Tier 1)	<u>7.185</u>			1,000,000	0.007185	

Exposure information and PEC calculation (following RIFM Environmental Framework: [Salvito et al., 2002](#)).

Exposure	Europe (EU)	North America (NA)
Log K _{ow} Used	3.79	3.79
Biodegradation Factor Used	0	0
Dilution Factor	3	3
Regional Volume of Use Tonnage Band	< 1	< 1
Risk Characterization: PEC/PNEC	< 1	< 1

Based on available data, the RQ for this material is < 1. No further assessment is necessary.

The RIFM PNEC is 0.007185 µg/L. The revised PEC/PNECs for EU and NA: Not applicable; cleared at the screening-level and therefore does not present a risk to the aquatic environment at the current reported volumes of use.

Literature Search and Risk Assessment Completed On: 6/15/17.

Appendix A. Supplementary data

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.fct.2018.08.056>.

Appendix

Read-across Justification

Methods.

The read-across analogs were identified following the strategy for structuring and reporting a read-across prediction of toxicity described in [Schultz et al. \(2015\)](#). The strategy is also consistent with the guidance provided by OECD within Integrated Approaches for Testing and Assessment ([OECD, 2015](#)) and the European Chemical Agency read-across assessment framework ([ECHA, 2016](#)).

- First, materials were clustered based on their structural similarity. Second, data availability and data quality on the selected cluster were examined. Third, appropriate read-across analogs from the cluster were confirmed by expert judgment.
- Tanimoto structure similarity scores were calculated using FCFC4 fingerprints ([Rogers and Hahn, 2010](#)).
- The physical–chemical properties of the target substance and the read-across analogs were calculated using EPI Suite v4.11 ([US EPA, 2012a](#)).

11. Literature Search*

- **RIFM Database:** Target, Fragrance Structure Activity Group materials, other references, JECFA, CIR, SIDS
- **ECHA:** <http://echa.europa.eu/>
- **NTP:** <http://tools.niehs.nih.gov>
- **OECD Toolbox**
- **SciFinder:** <https://scifinder.cas.org/scifinder/view/scifinder/scifinderExplore.jsf>
- **PubMed:** <http://www.ncbi.nlm.nih.gov/pubmed>
- **TOXNET:** <http://toxnet.nlm.nih.gov/>
- **IARC:** <http://monographs.iarc.fr>
- **OECD SIDS:** <http://webnet.oecd.org/hpv/ui/Default.aspx>
- **EPA ACToR:** <https://actor.epa.gov/actor/home.xhtml>
- **US EPA HPVIS:** https://ofmpub.epa.gov/opthpv/public_search.

[publicdetails?submission_id=24959241&ShowComments=Yes&sqlstr=null&recordcount=0&User_title=DetailQuery%20Results&EndPointRpt=Y#submission](https://pubchem.ncbi.nlm.nih.gov/compound/Pentylbenzoate)

- **Japanese NITE:** <http://www.safe.nite.go.jp/english/db.html>
- **Japan Existing Chemical Data Base (JECDB):** http://dra4.nihs.go.jp/mhlw_data/jsp/SearchPageENG.jsp
- **Google:** <https://www.google.com>
- **ChemIDplus:** <https://chem.nlm.nih.gov/chemidplus/>

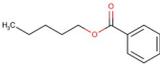
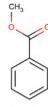
Search keywords: CAS number and/or material names.

*Information sources outside of RIFM's database are noted as appropriate in the safety assessment. This is not an exhaustive list.

Conflicts of interest

The authors declare that they have no conflicts of interest.

- J_{\max} values were calculated using RIFM's skin absorption model (SAM). The parameters were calculated using the consensus model (Shen et al., 2014).
- DNA binding, mutagenicity, genotoxicity alerts, and oncologic classification predictions were generated using OECD QSAR Toolbox v3.4 (OECD, 2012).
- ER binding and repeat dose categorization were generated using OECD QSAR Toolbox v3.4 (OECD, 2012).
- Developmental toxicity was predicted using CAESAR v2.1.7 (Cassano et al., 2010) and skin sensitization was predicted using Toxtree 2.6.13.
- Protein binding was predicted using OECD QSAR Toolbox v3.4 (OECD, 2012).
- The major metabolites for the target and read-across analogs were determined and evaluated using OECD QSAR Toolbox v3.4 (OECD, 2012).

	Target material	Read-across material	
Principal Name	Pentyl benzoate	Hexyl benzoate	Methyl benzoate
CAS No.	2049-96-9	6789-88-4	93-58-3
Structure			
Similarity (Tanimoto score)		0.96	0.71
Read-across endpoint		• Genotoxicity	• Skin sensitization
Molecular Formula	C ₁₂ H ₁₆ O ₂	C ₁₃ H ₁₆ O ₂	C ₈ H ₈ O ₂
Molecular Weight	192.26	206.29	136.15
Melting Point (°C, EPI Suite)	32.02	42.34	-11.87
Boiling Point (°C, EPI Suite)	269.08	285.11	195.93
Vapor Pressure (Pa @ 25°C, EPI Suite)	1.14	0.79	50.6
Log Kow (KOWWIN v1.68 in EPI Suite)	3.79	4.28	2.12
Water Solubility (mg/L, @ 25°C, WSKOW v1.42 in EPI Suite)	27.63	8.921	2100
J_{\max} (mg/cm²/h, SAM)	12.728	6.313	77.618
Henry's Law (Pa·m³/mol, Bond Method, EPI Suite)	1.08E-004	1.43E-004	3.47E-005
Genotoxicity			
DNA binding (OASIS v 1.4 QSAR Toolbox 3.4)	• No alert found	• No alert found	
DNA binding by OECD QSAR Toolbox (3.4)	• No alert found	• No alert found	
Carcinogenicity (genotox and non-genotox) alerts (ISS)	• NON-Carcinogen (good reliability)	• NON-Carcinogen (good reliability)	
DNA alerts for Ames, MN, CA by OASIS v 1.1	• No alert found	• No alert found	
<i>In vitro</i> Mutagenicity (Ames test) alerts by ISS	• No alert found	• No alert found	
<i>In vivo</i> mutagenicity (Micronucleus) alerts by ISS	• No alert found	• No alert found	
Oncologic Classification	• Not classified	• Not classified	
Skin Sensitization			
Protein binding by OASIS v1.1	• Acylation		• Acylation
Protein binding by OECD	• No alert found		• No alert found
Protein binding potency	• Not possible to classify		• Not possible to classify
Protein binding alerts for skin sensitization by OASIS v1.1	• No alert found		• No alert found
Skin Sensitization reactivity domains (ToxTree v2.6.13)	• No alert found		• No alert found
Metabolism			
OECD QSAR Toolbox (3.4)	See Supplemental Data 1	See Supplemental Data 2	See Supplemental Data 3
Rat liver S9 metabolism simulator and structural alerts for metabolites			

Summary.

There are insufficient toxicity data on the pentyl benzoate (CAS, 2049-96-9). Hence *in silico* evaluation was conducted by determining a read-across analog for this material. Based on structural similarity, reactivity, metabolism data, physical–chemical properties and expert judgment, analogs hexyl benzoate (CAS # 6789-88-4) and methyl benzoate (CAS # 93-58-3) were identified as read-across materials with sufficient data for toxicological evaluation.

Conclusions

- Hexyl benzoate (CAS # 6789-88-4) was identified as a read-across analog for the target material pentyl benzoate (CAS # 2049-96-9) for the genotoxicity endpoint.
 - o The target substance and the read-across analog are structurally similar and belong to the structural class of aromatic esters.
 - o The target substance and the read-across analog share a benzoate fragment.
 - o The key difference between the target substance and the read-across analog is that the target has a pentyl substitution on the alcohol portion of the ester, while the read-across has a hexyl substitution on the alcohol portion of the ester. This structural difference between the target substance and the read-across analog is toxicologically insignificant.
 - o Similarity between the target substance and the read-across analog is indicated by the Tanimoto score in the above table. The Tanimoto score is mainly driven by the benzoate fragment. Differences between the structures that affect the Tanimoto score are toxicologically insignificant.
 - o The physical–chemical properties of the target substance and the read-across analog are sufficiently similar to enable comparison of their

toxicological properties.

- o According to the QSAR OECD Toolbox (v3.4), structural alerts for toxicity endpoints are consistent between the target substance and the read-across analog.
- o The target substance and the read-across analog are expected to be metabolized similarly, as shown by the metabolism simulator.
- o The structural differences between the target material and the read-across analog do not affect consideration of the endpoints.
- Methyl benzoate (CAS # 93-58-3) was used as a read-across analog for target material pentyl benzoate (CAS # 2049-96-9) for the skin sensitization endpoint.
 - o The target substance and the read-across analog are structurally similar and belong to the structural class of aromatic esters.
 - o The target substance and the read-across analog share a benzoate fragment.
 - o The key difference between the target substance and the read-across analog is that the target has a pentyl substitution on the alcohol portion of the ester, while the read-across has a methyl substitution on the alcohol portion of the ester. This structure difference between the target substance and the read-across analog is toxicologically insignificant.
 - o Similarity between the target substance and the read-across analog is indicated by the Tanimoto score in the above table. The Tanimoto score is mainly driven by the benzoate fragment. Differences between the structures that affect the Tanimoto score are toxicologically insignificant.
 - o The physical–chemical properties of the target substance and the read-across analog are sufficiently similar to enable comparison of their toxicological properties.
 - o According to the QSAR OECD Toolbox (v3.4), structural alerts for toxic endpoints are consistent between the target substance and the read-across analog.
 - o The read-across analog and the target substance are predicted to have protein binding alerts by OASIS. The data described in the skin sensitization section above show that the read-across analog does not pose a concern for the skin sensitization endpoint. Therefore, the alert will be superseded by the availability of the data.
 - o The target substance and the read-across analog are expected to be metabolized similarly, as shown by the metabolism simulator.
 - o The structural differences between the target material and the read-across analog do not affect consideration of the endpoints.

References

- Api, A.M., Belsito, D., Bruze, M., Cadby, P., Calow, P., Dagli, M.L., Dekant, W., Ellis, G., Fryer, A.D., Fukayama, M., Griem, P., Hickey, C., Kromidas, L., Lalko, J.F., Liebler, D.C., Miyachi, Y., Politano, V.T., Renskers, K., Ritacco, G., Salvito, D., Schultz, T.W., Sipes, I.G., Smith, B., Vitale, D., Wilcox, D.K., 2015. Criteria for the research institute for fragrance materials, inc. (RIFM) safety evaluation process for fragrance ingredients. *Food Chem. Toxicol.* 82, S1–S19.
- Carthew, P., Clapp, C., Gutsell, S., 2009. Exposure based waiving: the application of the toxicological threshold of concern (TTC) to inhalation exposure for aerosol ingredients in consumer products. *Food Chem. Toxicol.* 47 (6), 1287–1295.
- Cassano, A., Manganaro, A., Martin, T., Young, D., Piclin, N., Pintore, M., Bigoni, D., Benfenati, E., 2010. CAESAR models for developmental toxicity. *Chem. Cent. J.* (4 Suppl. 1), S4.
- Comiskey, D., Api, A.M., Barratt, C., Daly, E.J., Ellis, G., McNamara, C., O'Mahony, C., Robison, S.H., Safford, B., Smith, B., Tozer, S., 2015. Novel database for exposure to fragrance ingredients in cosmetics and personal care products. *Regul. Toxicol. Pharmacol.* 72 (3), 660–672.
- Comiskey, D., Api, A.M., Barrett, C., Ellis, G., McNamara, C., O'Mahony, C., Robison, S.H., Rose, J., Safford, B., Smith, B., Tozer, S., 2017. Integrating habits and practices data for soaps, cosmetics and air care products into an existing aggregate exposure model. *Regul. Toxicol. Pharmacol.* 88, 144–156.
- ECHA, 2012. Guidance on Information Requirements and Chemical Safety Assessment Chapter R.11: PBT Assessment, November 2012 v1.1. <http://echa.europa.eu/>.
- ECHA, 2016. Read-across Assessment Framework (RAAF). Retrieved from www.echa.europa.eu/documents/10162/13628/raaf_en.pdf.
- Hausen, B.M., Simatupang, T., Bruhn, G., Evers, P., Koenig, W.A., 1995. Identification of new allergenic constituents and proof of evidence for coniferyl benzoate in Balsam of Peru. *Am. J. Contact Dermatitis* 6 (4), 199–208.
- Henry, B., Foti, C., Alsante, K., 2009. Can light absorption and photostability data be used to assess the photosafety risks in patients for a new drug molecule? *J. Photochem. Photobiol. B Biol.* 96 (1), 57–62.
- IFRA (International Fragrance Association), 2015. Volume of Use Survey, February 2015.
- Klecak, G., 1985. The freund's complete adjuvant test and the open epicutaneous test. *Curr. Probl. Dermatol.* 14, 152–171.
- Kroes, R., Renwick, A.G., Feron, V., Galli, C.L., Gibney, M., Greim, H., Guy, R.H., Lhuguenot, J.C., van de Sandt, J.J.M., 2007. Application of the threshold of toxicological concern (TTC) to the safety evaluation of cosmetic ingredients. *Food Chem. Toxicol.* 45 (12), 2533–2562.
- Laufersweiler, M.C., Gadagbui, B., Baskerville-Abraham, I.M., Maier, A., Willis, A., et al., 2012. Correlation of chemical structure with reproductive and developmental toxicity as it relates to the use of the threshold of toxicological concern. *Regul. Toxicol. Pharmacol.* 62 (1), 160–182.
- OECD, 2012. The OECD QSAR Toolbox, v3.4. Retrieved from <http://www.qsartoolbox.org/>.
- OECD, 2015. Guidance Document on the Reporting of Integrated Approaches to Testing and Assessment (IATA). ENV/JM/HA(2015)7. Retrieved from <http://www.oecd.org/>.
- RIFM (Research Institute for Fragrance Materials, Inc), 1970. The Contact Sensitizing Potential of Fragrance Materials in Humans. Report to RIFM. RIFM report number 1760. RIFM, Woodcliff Lake, NJ, USA.
- RIFM (Research Institute for Fragrance Materials, Inc), 2013. Report on the Testing of Pentyl Benzoate in the BlueScreen HC Assay (-/+ S9 Metabolic Activation). RIFM report number 66795. RIFM, Woodcliff Lake, NJ, USA.
- RIFM (Research Institute for Fragrance Materials, Inc), 2014a. Hexyl Benzoate: Bacterial Reverse Mutation Assay. RIFM report number 67291. RIFM, Woodcliff Lake, NJ, USA.
- RIFM (Research Institute for Fragrance Materials, Inc), 2014b. Hexyl Benzoate: in Vitro Micronucleus Assay in Human Peripheral Blood Lymphocytes. RIFM report number 67510. RIFM, Woodcliff Lake, NJ, USA.
- RIFM (Research Institute for Fragrance Materials, Inc), 2017. Exposure Survey 15, March 2017.
- Rogers, D., Hahn, M., 2010. Extended-connectivity fingerprints. *J. Chem. Inf. Model.* 50 (5), 742–754.
- Safford, B., Api, A.M., Barratt, C., Comiskey, D., Daly, E.J., Ellis, G., McNamara, C., O'Mahony, C., Robison, S., Smith, B., Thomas, R., Tozer, S., 2015. Use of an aggregate exposure model to estimate consumer exposure to fragrance ingredients in personal care and cosmetic products. *Regul. Toxicol. Pharmacol.* 72, 673–682.
- Safford, B., Api, A.M., Barratt, C., Comiskey, D., Ellis, G., McNamara, C., O'Mahony, C., Robison, S., Rose, J., Smith, B., Tozer, S., 2017. Application of the expanded Creme RIFM consumer exposure model to fragrance ingredients in cosmetic, personal care and air care products. *Regul. Toxicol. Pharmacol.* 86, 148–156.
- Salvito, D.T., Senna, R.J., Federle, T.W., 2002. A Framework for prioritizing fragrance materials for aquatic risk assessment. *Environ. Toxicol. Chem.* 21 (6), 1301–1308.
- Schultz, T.W., Amcoff, P., Berggren, E., Gautier, F., Klaric, M., Knight, D.J., Mahony, C., Schwarz, M., White, A., Cronin, M.T., 2015. A strategy for structuring and reporting a read-across prediction of toxicity. *Regul. Toxicol. Pharmacol.* 72 (3), 586–601.
- Shen, J., Kromidas, L., Schultz, T., Bhatia, S., 2014. An *in silico* skin absorption model for fragrance materials. *Food Chem. Toxicol.* 74, 164–176.
- US EPA, 2012a. Estimation Programs Interface Suite for Microsoft Windows, v4.0–v4.11. United States Environmental Protection Agency, Washington, DC, USA.
- US EPA, 2012b. The ECOSAR (ECOLOGICAL Structure Activity Relationship) Class Program for Microsoft Windows, v1.11. United States Environmental Protection Agency, Washington, DC, USA.