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Short Review

RIFM fragrance ingredient safety assessment, 2(10)-pinen-3-ol, CAS Registry Number 5947-36-4

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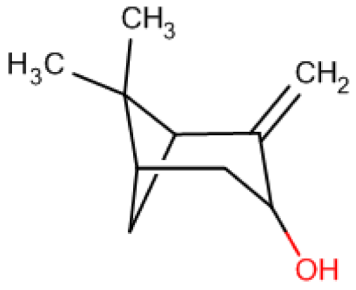
Version: 051018. This version replaces any previous versions.
Name: 2(10)-Pinen-3-ol
CAS Registry Number: 5947-36-4



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

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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., 2015a, 2015b; Safford et al., 2017) compared to a deterministic aggregate approach
DEREK - Derek Nexus is an *in silico* tool used to identify structural alerts
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
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 use conditions is supported by the existing information.

2(10)-Pinen-3-ol was evaluated for genotoxicity, repeated dose toxicity, developmental and reproductive toxicity, local respiratory toxicity, phototoxicity/photoallergenicity, skin sensitization, and environmental safety. Data from read-across material β-pinene (CAS # 127-91-3) show that 2(10)-pinen-3-ol is not expected to be genotoxic. The skin sensitization endpoint was completed using the DST for reactive materials (64 μg/cm^2); exposure is below the DST. The repeated dose, developmental and reproductive, and local respiratory toxicity endpoints were evaluated using the TTC (Threshold of Toxicological Concern) for a Cramer Class I material, and the exposure to 2(10)-pinen-3-ol is below the TTC (0.03 mg/kg/day, 0.03 mg/kg/day, and 1.4 mg/day, respectively). The phototoxicity/photoallergenicity endpoints were evaluated based on UV spectra; 2(10)-pinen-3-ol is not expected to be phototoxic/photoallergenic. The environmental endpoints were evaluated; 2(10)-pinen-3-ol was found not to be PBT as per the IFRA Environmental Standards, and its risk quotients, based on its screening-level (i.e., PEC/PNEC), are < 1.

Human Health Safety Assessment

Genotoxicity: Not genotoxic. (RIFM, 1983; RIFM, 2014b)
Repeated Dose Toxicity: No NOAEL available. Exposure is below the TTC.
Developmental and Reproductive Toxicity: No NOAEL available. Exposure is below the TTC.
Skin Sensitization: No safety concerns at current, declared use levels; exposure is below the DST.
Phototoxicity/Photoallergenicity: Not expected to be phototoxic/photoallergenic. (UV Spectra, RIFM Database)
Local Respiratory Toxicity: No NOAEC available. Exposure is below the TTC.

Environmental Safety Assessment

Hazard Assessment:

Persistence: Screening-level: 2.81 (BIOWIN 3) (EPI Suite; US EPA, 2012a)
Bioaccumulation: Screening-level: 33.1 L/Kg (EPI Suite; US EPA, 2012a)
Ecotoxicity: Screening-level: Fish LC50: 40.53 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: 40.53 mg/L (RIFM Framework; Salvito et al., 2002)
RIFM PNEC is: 0.04053 μg/L

- Revised PEC/PNECs (2011 IFRA VoU): North America and Europe: not applicable; cleared at screening-level

1. Identification

1. **Chemical Name:** 2(10)-Pinen-3-ol
2. **CAS Registry Number:** 5947-36-4
3. **Synonyms:** Bicyclo[3.1.1]heptan-3-ol, 6,6-dimethyl-2-methylene-; 6,6-Dimethyl-3-hydroxy-2-methylenebicyclo(3.1.1)heptane; 6,6-Dimethyl-2-methylenebicyclo(3.1.1)heptan-3-ol; 6,6-Dimethyl-2-methylenebicyclo[3.1.1]heptan-3-ol; 2(10)-Pinen-3-ol; Pinocarveol; 2(10)-ピネン-3-オール (ピノカルベオール); 2(10)-ピネン-3-オール (ピノカルベオール)
4. **Molecular Formula:** $C_{10}H_{16}O$
5. **Molecular Weight:** 152.24
6. **RIFM Number:** 5068
7. **Stereochemistry:** Isomer not specified. Three stereocenters and 8 stereoisomers possible.

2. Physical data

1. **Boiling Point:** 215.37 °C (US EPA, 2012a)
2. **Flash Point:** 167 °F; CC (FMA database)
3. **Log K_{OW}:** 2.81 (US EPA, 2012a)
4. **Melting Point**: 31.83 °C (US EPA, 2012a)
5. **Water Solubility:** 958.1 mg/L (US EPA, 2012a)
6. **Specific Gravity:** 0.97700 to 0.98300 @ 25.00 °C*
7. **Vapor Pressure:** 0.0126 mm Hg @ 20 °C (US EPA, 2012a), 0.03 mm Hg 20 °C (FMA database), 0.0229 mm Hg @ 25 °C (US EPA, 2012a)
8. **UV Spectra:** Minor absorbance between 290 and 700 nm; molar absorption coefficient is below the benchmark (1000 L mol^{-1} cm^{-1})
9. **Appearance/Organoleptic:** Pale yellow to clear viscous liquid with a medium herbal, camphor, woody, pine, and balsam like odor*

*http://www.thegoodscentscompany.com/data/rw1036941.html, retrieved 2/3/2014.

3. Exposure

1. **Volume of Use (Worldwide Band):** < 0.1 metric tons per year (IFRA, 2011)
2. **95th Percentile Concentration in Hydroalcoholics:** 0.0019% (RIFM, 2017)
3. **Inhalation Exposure*:** 0.00000030 mg/kg/day or 0.000018 mg/day (RIFM, 2017)
4. **Total Systemic Exposure**:** 0.000027 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., 2015a, 2015b; 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., 2015a, 2015b; 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
I	I	I

2. Analogs Selected:

a. **Genotoxicity:** β-Pinene (CAS # 127-91-3)
b. **Repeated Dose Toxicity:** None
c. **Developmental and Reproductive Toxicity:** None
d. **Skin Sensitization:** None
e. **Phototoxicity/Photoallergenicity:** None
f. **Local Respiratory Toxicity:** None
g. **Environmental Toxicity:** None

3. Read-across Justifications: See Appendix below

6. Metabolism

No relevant data available for inclusion in this safety assessment.

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

2(10)-Pinen-3-ol is reported to occur in the following foods by the VCF*:

Black currants (*Ribes nigrum* L.)
Camomile
Citrus fruits
Ginger (*Zingiber* species)
Grape brandy
Hop (*Humulus lupulus*)
Mastic (*Pistacia lentiscus*)
Mentha oils
Myrtle (*Myrtus communis* L.)
Pepper (*Piper nigrum* L.)
Thyme (*Thymus* species)
Vaccinium species
Walnut (*Juglans* species)
Xylopia 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 containing 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

Available, accessed 12/11/2017.

10. Summary

10.1. Human health endpoint summaries

10.1.1. Genotoxicity

Based on the current existing data, 2(10)-pinen-3-ol does not present a concern for genotoxicity.

10.1.1.1. Risk assessment. 2(10)-Pinen-3-ol, was assessed in the BlueScreen assay and found negative for both cytotoxicity (positive: < 80% relative cell density) and genotoxicity, with and without metabolic activation (RIFM, 2014a). BlueScreen is a screening assay that assesses genotoxic stress through alterations in gene expressions in a human cell line. Additional assays were considered to fully assess the potential mutagenic or clastogenic effects of the target material.

There are no data assessing the mutagenic potential of 2(10)-pinen-3-ol. The read-across analog β-pinene (CAS # 127-91-3; see Section V) was evaluated for mutagenicity in bacteria in an Ames assay conducted equivalent to OECD TG 471 using the standard plate incorporation method. *Salmonella typhimurium* strains TA98, TA100, TA1535, TA1537, and TA1538 were treated with β-pinene in dimethyl sulfoxide (DMSO) at concentrations up to 5 μL/plate. No increases in the mean number of revertant colonies were observed at any tested concentration in the presence or absence of S9 (RIFM, 1983). Under the conditions of the study, β-pinene was not mutagenic in the Ames test and this can be extended to 2(10)-pinen-3-ol.

There are no data assessing the clastogenic potential of 2(10)-pinen-3-ol; however, read-across can be made to β-pinene, which 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 β-pinene in DMSO at concentrations up to 1362 μg/mL in the presence and absence of metabolic activation (S9) at the 3 h and 24-h time points. β-Pinene 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, β-pinene was considered to be non-clastogenic in the *in vitro* micronucleus test and this can be extended to 2(10)-pinen-3-ol.

Taking all the available data into consideration, 2(10)-pinen-3-ol does not present a concern for genotoxic potential.

Additional References: Florin et al., 1980; RIFM, 1983; Catanzaro et al., 2011.

Literature Search and Risk Assessment Completed On: 12/05/2017.

10.1.2. Repeated dose toxicity

There are insufficient repeated dose toxicity data on 2(10)-pinen-3-ol or any read-across materials. The total systemic exposure to 2(10)-pinen-3-ol 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 2(10)-pinen-3-ol or any read-across materials that can be used to support the repeated dose toxicity endpoint. The total systemic exposure to 2(10)-pinen-3-ol (0.027 μg/kg bw/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: 11/10/2017.

10.1.3. Developmental and reproductive toxicity

There are insufficient developmental and reproductive toxicity data on 2(10)-pinen-3-ol or any read-across materials. The total systemic exposure to 2(10)-pinen-3-ol is below the TTC for the developmental and reproductive toxicity endpoints of a Cramer Class I material at the current level of use.

10.1.3.1. Risk assessment. There are no developmental or reproductive toxicity data on 2(10)-pinen-3-ol or any read-across materials that can be used to support the developmental or reproductive toxicity endpoints. The total systemic exposure to 2(10)-pinen-3-ol (0.027 μg/kg bw/day) is below the TTC (30 μg/kg bw/day; Kroes et al., 2007; Laufersweiler et al., 2012) for the developmental and reproductive toxicity endpoints of a Cramer Class I material at the current level of use.

Additional References: None.

Literature Search and Risk Assessment Completed On: 11/10/2017.

10.1.4. Skin sensitization

Based on available data and the application of the DST, 2(10)-pinen-3-ol does not present a safety concern for skin sensitization under the current, declared levels of use.

10.1.4.1. Risk assessment. The chemical structure of this material indicates that it would be expected to react with skin proteins (Toxtree 2.6.13; OECD toolbox v3.4). No predictive skin sensitization studies are available for 2(10)-pinen-3-ol or read-across materials. Additionally, in a confirmatory human repeat insult patch test (HRIPT) with 969 μg/cm^2 of 2(10)-pinen-3-ol in ethanol, no reactions indicative of sensitization were observed in any of the 38 volunteers (RIFM, 1972).

Acting conservatively, due to the limited data, the reported exposure was benchmarked utilizing the reactive DST of 64 μg/cm^2 (Safford et al., 2015a, 2015b). The current exposure from the 95th percentile concentration is below the DST for reactive materials when evaluated in all QRA categories. Table 1 provides the acceptable concentration for 2(10)-pinen-3-ol that presents no appreciable risk for skin sensitization based on the reactive DST.

Additional References: None.

Literature Search and Risk Assessment Completed On: 10/18/2017.

10.1.5. Phototoxicity/photoallergenicity

Based on UV/Vis absorption spectra, 2(10)-pinen-3-ol 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 2(10)-pinen-3-ol in experimental models. UV/Vis absorption spectra indicate minor absorbance between 290 and 700 nm. The corresponding molar absorption coefficient is below the benchmark of concern for phototoxicity and photoallergenicity (Henry et al., 2009). Based on lack of significant absorbance in the critical range, 2(10)-pinen-3-ol does not present a concern for phototoxicity or photoallergenicity.

10.1.5.2. UV spectra analysis. UV/Vis absorption spectra (OECD TG 101) for 2(10)-pinen-3-ol were obtained. The spectra indicate minor absorbance in the range of 290–700 nm. The molar absorption coefficient is below the benchmark, 1000 L mol^{-1} cm^{-1}, of concern for phototoxic effects (Henry et al., 2009).

Table 1
Acceptable concentration limits for 2(10)-pinen-3-ol based on reactive DST.

IFRA Category[a]	Description of Product Type	Acceptable Concentrations in Finished Products	Reported 95th Percentile Concentration in Finished Products
1	Products applied to the lips	0.005%	0.000%
2	Products applied to the axillae	0.001%	0.000%[b]
3	Products applied to the face using fingertips	0.029%	0.000%
4	Fine fragrance products	0.027%	0.002%[b]
5	Products applied to the face and body using the hands (palms), primarily leave-on	0.007%	0.000%[b]
6	Products with oral and lip exposure	0.016%	0.000%
7	Products applied to the hair with some hand contact	0.056%	0.000%[b]
8	Products with significant ano-genital exposure	0.003%	No Data
9	Products with body and hand exposure, primarily rinse-off	0.054%	0.000%[b]
10	Household care products with mostly hand contact	0.192%	0.000%[b]
11	Products with intended skin contact but minimal transfer of fragrance to skin from inert substrate	0.107%	No Data
12	Products not intended for direct skin contact, minimal or insignificant transfer to skin	Not Restricted	0.000%

Note:
[a] For a description of the categories, refer to the IFRA/RIFM Information Booklet.
[b] Negligible exposure (< 0.001%).

Additional References: None.

Literature Search and Risk Assessment Completed On: 10/11/2017.

10.1.6. Local Respiratory Toxicity

The margin of exposure could not be calculated due to lack of appropriate data. The exposure level for 2(10)-pinen-3-ol 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 2(10)-pinen-3-ol. Based on the Creme RIFM Model, the inhalation exposure is 0.000018 mg/day. This exposure is 77778 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: 11/30/2017.

10.2. Environmental endpoint summary

10.2.1. Screening-level assessment

A screening-level risk assessment of 2(10)-pinen-3-ol 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, 2(10)-pinen-3-ol 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 v4.11 (US EPA, 2012a) identified 2(10)-pinen-3-ol as not persistent and not 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 v4.11). 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 (2011), 2(10)-pinen-3-ol does not present a risk to the aquatic compartment in the screening-level assessment.

Key Studies:

Biodegradation: No data available.

Ecotoxicity: No data available.

Other available data

2(10)-Pinen-3-ol 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)**	40.53			1,000,000	0.04053	

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

Exposure	Europe (EU)	North America (NA)
Log K_{ow} used	2.81	2.81
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 additional assessment is necessary.

The RIFM PNEC is 0.04053 μg/L.

The revised PEC/PNECs for EU and NA are: not applicable. The material was cleared at 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: 01/31/2014.

11. Literature Search*

- **RIFM Database:** Target, Fragrance Structure Activity Group materials, other references, JECFA, CIR, SIDS
- **ECHA:** http://echa.europa.eu/
- **NTP:** https://ntp.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/oppthpv/public_search.publicdetails?submission_id=24959241&ShowComments=Yes&sqlstr=null&recordcount=0&User_title=DetailQuery%20Results&EndPointRpt=Y#submission
- **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.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.fct.2018.11.007.

Appendix

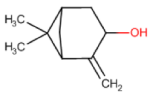
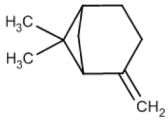
Read-across Justification

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 (US EPA, 2012a).
- 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	2(10)-Pinen-3-ol	β-Pinene
CAS No.	5947-36-4	127-91-3
Structure		
Similarity (Tanimoto Score)		0.69
Read-across Endpoint		• Genotoxicity
Molecular Formula	$C_{10}H_{16}O$	$C_{10}H_{16}$
Molecular Weight	152.24	136.24
Melting Point (°C, EPI Suite)	31.83	−15.30
Boiling Point (°C, EPI Suite)	215.37	150.80
Vapor Pressure (Pa @ 25°C, EPI Suite)	3.05	334.6
Log Kow (KOWWIN v1.68 in EPI Suite)	2.81	4.16
Water Solubility (mg/L, @ 25°C, WSKOW v1.42 in EPI Suite)	958.1	7.061
J_{max} (mg/cm^2/h, SAM)	144.495	111.796
Henry's Law (Pa·m^3/mol, Bond Method, EPI Suite)	5.90E-006	1.61E-001
Genotoxicity		
DNA Binding (OASIS v1.4, QSAR Toolbox v3.4)	• No alert found	• No alert found
DNA Binding (OECD QSAR Toolbox v3.4)	• No alert found	• No alert found
Carcinogenicity (ISS)	• Non-carcinogen (low reliability)	• Non-carcinogen (low reliability)
DNA Binding (Ames, MN, CA, OASIS v1.1)	• No alert found	• No alert found
In Vitro Mutagenicity (Ames, ISS)	• No alert found	• No alert found
In Vivo Mutagenicity (Micronucleus, ISS)	• No alert found	• No alert found
Oncologic Classification	• Not classified	• Not classified
Metabolism		
Rat Liver S9 Metabolism Simulator and Structural Alerts for Metabolites (OECD QSAR Toolbox v3.4)	See Supplemental Data 1	See Supplemental Data 2

Summary

There are insufficient toxicity data on 2(10)-pinen-3-ol (CAS # 5947-36-4). Hence, *in silico* evaluation was conducted to determine read-across analogs for this material. Based on structural similarity, reactivity, metabolism, physical–chemical properties, and expert judgment, β-pinene (CAS # 127-91-3) was identified as a read-across material with sufficient data for toxicological evaluation.

Metabolism

Metabolism of the read-across material β-pinene (CAS # 127-91-3) was predicted using the Rat Liver S9 Metabolism Simulator (OECD QSAR Toolbox v3.4). The read-across analog is predicted to be metabolized to 2(10)-pinen-3-ol (CAS # 5947-36-4) in the first step with 0.95 probability. Hence, β-pinene (CAS # 5947-36-4) can be used as a read-across for the target material. Read-across is out of domain for the *in vivo* rat and out of domain for the *in vitro* rat S9 simulator (OASIS TIMES v2.27.19). However, based on expert judgment, the model's domain exclusion was overridden, and a justification is provided.

Conclusions

- β-Pinene (CAS # 127-91-3) was used as a read-across analog for the target material 2(10)-pinen-3-ol (CAS # 5947-36-4) for the genotoxicity endpoint.
  - o The target substance and the read-across analog are structurally similar and belong to the class of alcohols and hydrocarbons, respectively.
  - o The target substance and the read-across analog share an unsaturated cyclic bridged fragment.
  - o The key structural difference between the target substance and the read-across analog is that the target substance is a secondary alcohol, while the read-across analog is a hydrocarbon. The read-across analog is predicted to be metabolically converted into the target substance via aliphatic C-oxidation. This structural difference is predicted to make the read-across analog more reactive compared to the target substance for the genotoxicity endpoint.
  - o Structural similarity between the target substance and the read-across analog is indicated by the Tanimoto score. The Tanimoto score is mainly driven by the common unsaturated cyclic bridged fragment. Differences between the structures that affect the Tanimoto score are toxicologically insignificant.

- o The differences in the physical–chemical properties of the target substance and the read-across analog can be mitigated based on the fact that the target substance is a metabolic product of the read-across analog.
- o OECD QSAR Toolbox v3.4 structural alerts for toxicological 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 alerts for the endpoints evaluated are consistent between the metabolites of the read-across analog and the target material.

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