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Short Review

RIFM fragrance ingredient safety assessment, 2-methylpyrazine, CAS Registry Number 109-08-0

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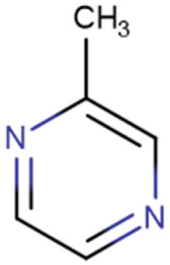
Name: 2-Methylpyrazine CAS Registry Number: 109-08-0



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
CNIH – Confirmation of No Induction in Humans test. A human repeat insult patch test that is performed to confirm an already determined safe use level for fragrance ingredients (Na et al., 2021)
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; Safford et al., 2017) compared to a deterministic aggregate approach
DEREK - Derek Nexus is an *in silico* tool used to identify structural alerts
DRF - Dose Range Finding
DST - Dermal Sensitization Threshold
ECHA - European Chemicals Agency
ECOSAR - Ecological Structure-Activity Relationships Predictive Model
EU - Europe/European Union
GLP - Good Laboratory Practice
IFRA - The International Fragrance Association
LOEL - Lowest Observed 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
Perfumery - In this safety assessment, perfumery refers to fragrances made by a perfumer used in consumer products only. The exposures reported in the safety assessment include consumer product use but do not include occupational exposures.
QRA - Quantitative Risk Assessment
QSAR - Quantitative Structure-Activity Relationship
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

(*continued on next column*)

(*continued*)

The Expert Panel for Fragrance Safety* concludes that this material is safe as described in this safety assessment. This material has not been fully evaluated for photoallergenic potential.

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 existing information supports the use of this material as described in this safety assessment. This material has not been fully evaluated for photoallergenic potential.

2-Methylpyrazine was evaluated for genotoxicity, repeated dose toxicity, reproductive toxicity, local respiratory toxicity, photoirritation/photoallergenicity, skin sensitization, and environmental safety. Data from read-across analog 2,3,5-trimethylpyrazine (CAS # 14667-55-1) show that 2-methylpyrazine is not expected to be genotoxic. The repeated dose, reproductive, and local respiratory toxicity endpoints were evaluated using the Threshold of Toxicological Concern (TTC) for a Cramer Class II material, and the exposure to 2-methylpyrazine is below the TTC (0.009 mg/kg/day, 0.009 mg/kg/day, and 0.47 mg/day, respectively). Data from read-across analog 2-ethyl-3-methylpyrazine (CAS # 15707-23-0) show that there are no safety concerns for 2-methylpyrazine for skin sensitization under the current declared levels of use. The photoirritation/photoallergenicity endpoints were evaluated based on data; 2-methylpyrazine is not expected to be photoirritating. 2-Methylpyrazine has not been fully evaluated for photoallergenic potential. The environmental endpoints were evaluated; 2-methylpyrazine was found not to be Persistent, Bioaccumulative, and Toxic (PBT) as per the International Fragrance Association (IFRA) Environmental Standards, and its risk quotients, based on its current volume of use (VoU) in Europe and North America (i.e., Predicted Environmental Concentration/Predicted No Effect Concentration [PEC/PNEC]), are <1.

Human Health Safety Assessment

Genotoxicity: Not expected to be genotoxic. (RIFM, 2016a; RIFM, 2016b)
Repeated Dose Toxicity: No NOAEL available. Exposure is below the TTC.
Reproductive Toxicity: No NOAEL available. Exposure is below the TTC.
Skin Sensitization: Not a concern for skin sensitization. (RIFM, 2018; RIFM, 2017c; RIFM, 2017b)
Photoirritation/Photoallergenicity: Not photoirritating. Photoallergy has not been evaluated. (RIFM, 2017a)
Local Respiratory Toxicity: No NOAEC available. Exposure is below the TTC.

Environmental Safety Assessment

Hazard Assessment:
Persistence:
Screening-level: 2.9 (BIOWIN 3) (EPI Suite v4.11; US EPA, 2012a)
Bioaccumulation:
Screening-level: 3.16 L/kg (EPI Suite v4.11; US EPA, 2012a)
Ecotoxicity:
Screening-level: Fish LC50: 3127 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: 3127 mg/L (RIFM Framework; Salvito et al., 2002)
RIFM PNEC is: 3.127 μg/L

- **Revised PEC/PNECs (2019 IFRA VoU):** North America and Europe: Not applicable; cleared at screening-level

1. Identification

1. **Chemical Name:** 2-Methylpyrazine
2. **CAS Registry Number:** 109-08-0
3. **Synonyms:** 2-Methyl-1,4-diazine; Pyrazine, 2-methyl-; 2-Methylpyrazine
4. **Molecular Formula:** $C_5H_6N_2$
5. **Molecular Weight:** 94.11 g/mol
6. **RIFM Number:** 6690
7. **Stereochemistry:** No stereoisomer possible.

2. Physical data

1 **.Boiling Point:** 137 °C (Fragrance Materials Association [FMA]), 146.91 °C (EPI Suite v4.11)
2 **.Flash Point:** 37 °C (Globally Harmonized System), 99 °F; closed cup (FMA)
3 **.Log K_{OW}:** 0.49 (EPI Suite v4.11)
4 **.Melting Point**: 7.28 °C (EPI Suite v4.11)
5 **.Water Solubility:** 80380 mg/L (EPI Suite v4.11)
6 **.Specific Gravity:** 1.026 (FMA)
7 **.Vapor Pressure:** 5.34 mm Hg at 20 °C (EPI Suite v4.0), 5.34 mm Hg at 20 °C (EPI Suite v4.0), 18 mm Hg at 20 °C (FMA), 7.29 mm Hg at 25 °C (EPI Suite v4.11)
8 **.UV Spectra:** Minor absorbance between 290 and 700 nm under basic conditions; molar absorption coefficient (876 L mol^{-1} • cm^{-1} under basic conditions) is below the benchmark (1000 L mol^{-1} • cm^{-1}). Significant absorbance between 290 and 700 nm, with a peak at 290 nm and returning to baseline by approximately 340 nm, under neutral and acidic conditions. Molar absorption coefficients (1324 and 1083 L mol^{-1} • cm^{-1} under neutral and acidic conditions, respectively) are above the benchmark (1000 L mol^{-1} • cm^{-1})
9 **.Appearance/Organoleptic:** Not Available

3. Volume of use (worldwide band)

1 0.1–1 metric ton per year (IFRA, 2019)

4. Exposure to fragrance ingredient (Creme RIFM aggregate exposure model v3.0)

1. **95**th **Percentile Concentration in Fine Fragrance:** 0.00015% (RIFM, 2020)
2. **Inhalation Exposure*:** 0.000066 mg/kg/day or 0.0046 mg/day (RIFM, 2020)
3. **Total Systemic Exposure**:** 0.00023 mg/kg/day (RIFM, 2020)

*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; Comiskey et al., 2017).

**95th percentile calculated exposure; assumes 100% absorption unless modified by dermal absorption data as reported in Section V. 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; Comiskey et al., 2017).

5. Derivation of systemic absorption

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

6. Computational toxicology evaluation

1 Cramer Classification: Class II, Intermediate

Expert Judgment	Toxtree v3.1	OECD QSAR Toolbox v4.5
II	II	II

2. Analogs Selected:
a. **Genotoxicity:** 2,3,5-Trimethylpyrazine (CAS # 14667-55-1)
b. **Repeated Dose Toxicity:** None
c. **Reproductive Toxicity:** None
d. **Skin Sensitization:** 2-Ethyl-3-methylpyrazine (CAS # 15707-23-0)
e. **Photoirritation/Photoallergenicity:** None
f. **Local Respiratory Toxicity:** None
g. **Environmental Toxicity:** None

3. Read-across Justification: See Appendix below

7. Metabolism

No relevant data available for inclusion in this safety assessment.
Additional References: None.

8. Natural occurrence

2-Methylpyrazine is reported to occur in the following foods by the VCF*:
Asparagus (*Asparagus officinalis* L.)
Barley.
Beans.
Beef.
Beer.
Buckwheat.
Cabbage (*Brassica oleracea*).
Cashew nut (*Anacardium occidentale*).
Cherimoya (*Annona cherimolia* Mill.)
Chicken.
*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.

9. REACH dossier

2-Methylpyrazine has been pre-registered for 2010; no dossier available as of 10/04/22.

10. CONCLUSION

The existing information supports the use of this material as described in this safety assessment.

11. Summary

11.1. Human health endpoint summaries

11.1.1. Genotoxicity

Based on the current existing data, 2-methylpyrazine does not present a concern for genotoxicity.

11.1.1.1. Risk assessment. There are no studies assessing the mutagenic or clastogenic activity of 2-methylpyrazine; however, read-across can be

made to 2,3,5-trimethylpyrazine (CAS # 14667-55-1; see Section VI).

The mutagenic activity of 2,3,5-trimethylpyrazine 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. *Salmonella typhimurium* strains TA98, TA100, TA1535, TA1537, and *Escherichia coli* strain WP2uvrA were treated with 2,3,5-trimethylpyrazine in water at concentrations up to 5000 μg/plate. Increases in the mean number of revertant colonies were observed in strain WP2uvrA in the presence or absence of S9 and strain TA98 in the presence of S9 (RIFM, 2016a). However, the increases were not dose-responsive and were within the historical control limits. Therefore, the increases were considered to be not biologically relevant. Under the conditions of the study, 2,3,5-trimethylpyrazine was not mutagenic in the Ames test, and this can be extended to 2-methylpyrazine.

The clastogenic activity of 2,3,5-trimethylpyrazine 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 2,3,5-trimethylpyrazine in water at concentrations up to 1220 μg/mL in the dose range finding (DRF) study; micronuclei analysis was conducted at concentrations up to 1220 μg/mL in the presence and absence of metabolic activation. 2,3,5-Trimethylpyrazine did not induce binucleated cells with micronuclei when tested up to the maximum concentration in either the presence or absence of an S9 activation system (RIFM, 2016b). Under the conditions of the study, 2,3,5-trimethylpyrazine was considered to be non-clastogenic in the *in vitro* micronucleus test, and this can be extended to 2-methylpyrazine.

Based on the data available2,3,5-trimethylpyrazine does not present a concern for genotoxic potential, and this can be extended to 2-methylpyrazine.

Additional References: Aeschbacher et al., 1989.

Literature Search and Risk Assessment Completed On: 04/01/22.

11.1.2. Repeated dose toxicity

There are insufficient repeated dose toxicity data on 2-methylpyrazine or any read-across materials. The total systemic exposure to 2-methylpyrazine is below the TTC for the repeated dose toxicity endpoint of a Cramer Class II material at the current level of use.

11.1.2.1. Risk assessment. There are no repeated dose toxicity data on 2-methylpyrazine or any read-across materials that can be used to support the repeated dose toxicity endpoint. The total systemic exposure to 2-methylpyrazine (0.23 μg/kg/day) is below the TTC (9 μg/kg/day; Kroes et al., 2007) for the repeated dose toxicity endpoint of a Cramer Class II material at the current level of use.

Additional References: None.

Literature Search and Risk Assessment Completed On: 03/30/22.

11.1.3. Reproductive toxicity

There are insufficient reproductive toxicity data on 2-methylpyrazine or any read-across materials. The total systemic exposure to 2-methylpyrazine is below the TTC for the reproductive toxicity endpoint of a Cramer Class II material at the current level of use.

11.1.3.1. Risk assessment. There are no reproductive toxicity data on 2-methylpyrazine or any read-across materials that can be used to support the reproductive toxicity endpoint. The total systemic exposure to 2-methylpyrazine (0.23 μg/kg/day) is below the TTC (9 μg/kg/day; Kroes et al., 2007; Laufersweiler et al., 2012) for the reproductive toxicity endpoint of a Cramer Class II material at the current level of use.

Additional References: None.

Literature Search and Risk Assessment Completed On: 03/30/22.

11.1.4. Skin sensitization

Based on existing data on the target material and read-across material 2-ethyl-3-methylpyrazine (CAS # 15707-23-0), 2-methylpyrazine presents no concern for skin sensitization.

11.1.4.1. Risk assessment. Limited skin sensitization data are available for 2-methylpyrazine. Therefore, read-across material 2-ethyl-3-methylpyrazine (CAS # 15707-23-0; see Section VI) was used for the risk assessment of 2-methylpyrazine. The data on the read-across material are summarized in Table 1 below (Table 1). Based on the existing data on the read-across material, 2-methylpyrazine is not considered a skin sensitizer. The chemical structure of the read-across material and the target material indicate that they would not be expected to react with skin proteins directly (Roberts et al., 2007; Toxtree v3.1.0; OECD Toolbox v4.5). Read-across material 2-ethyl-3-methylpyrazine is predicted *in vitro* to be a non-sensitizer when evaluated following the OECD Guideline No. 497: Defined Approaches on Skin Sensitization (OECD, 2021a). Read-across 2-ethyl-3-methylpyrazine was found to be negative in an *in vitro* direct peptide reactivity assay (DPRA), KeratinoSens, and human cell line activation test (h-CLAT) (RIFM, 2018; RIFM, 2017c; RIFM, 2017b). In a guinea pig maximization test, 2-methylpyrazine did not induce sensitization reactions (RIFM, 1983).

Based on the weight of evidence (WoE) from structural analysis and *in vitro* and animal studies on the read-across material as well as the target material, 2-methylpyrazine does not present a concern for skin sensitization.

Additional References: None.

Literature Search and Risk Assessment Completed On: 04/04/22.

11.1.5. Photoirritation/photoallergenicity

Based on *in vitro* study data, 2-methylpyrazine does not present a concern for photoirritation. 2-Methylpyrazine was not evaluated for photoallergy; however, RIFM is sponsoring an *in vitro* photoallergy research program to evaluate the photoallergy potential of 2-methylpyrazine.

11.1.5.1. Risk assessment. UV/Vis absorption spectra indicate minor absorbance between 290 and 700 nm under basic conditions. The corresponding molar absorption coefficient is below the benchmark of concern for photoirritation and photoallergenicity (Henry et al., 2009). Significant UV/Vis absorbance was evident under neutral and acidic conditions, and the molar absorption coefficients were above the benchmark of concern. In an *in vitro* 3T3-Neutral Red uptake phototoxicity study (OECD TG 432), 2-methylpyrazine was not predicted to have photoirritating potential (RIFM, 2017a). Based on available *in vitro* study data, 2-methylpyrazine does not present a concern for photoirritation. 2-methylpyrazine was not evaluated for photoallergy; however, RIFM is sponsoring an *in vitro* photoallergy research program to evaluate the photoallergy potential of 2-methylpyrazine.

11.1.5.2. UV spectra analysis. UV/Vis absorption spectra (OECD TG 101) were generated for 2-methylpyrazine. The spectra indicated minor absorbance between 290 and 700 nm under basic conditions; the molar absorption coefficient (876 L mol^{-1} • cm^{-1} under basic conditions) is below the benchmark (1000 L mol^{-1} • cm^{-1}) of concern for photoirritating effects. Significant absorbance was observed between 290 and 700 nm under neutral and acidic conditions; the molar absorption coefficients (1324 and 1462, 1083 L mol^{-1} • cm^{-1}, under neutral and acidic conditions, respectively) are above the benchmark of concern (1000 L mol^{-1} • cm^{-1}) (Henry et al., 2009).

Additional References: None.

Literature Search and Risk Assessment Completed On: 03/31/22.

Table 1
Summary of existing data on 2-ethyl-3-methylpyrazine as a read-across for 2-methylpyrazine.

WoE Skin Sensitization Potency Category[a]	Human Data				Animal Data		
	NOEL-CNIH (induction) μg/cm^2	NOEL-HMT (induction) μg/cm^2	LOEL[b] (induction) μg/cm^2	WoE NESIL[c] μg/cm^2	LLNA[d] Weighted Mean EC3 Value μg/cm^2	GPMT[e]	Buehler[e]
No evidence of sensitization[g]	NA	NA	NA	NA	NA	NA	NA
	***In vitro* Data[f]**				***In silico* protein binding alerts (OECD Toolbox v4.5)**		
	KE 1	**KE 2**	**KE 3**		**Target Material**	**Autoxidation simulator**	**Metabolism simulator**
	Negative	Negative	Negative		No alert found	No alert found	No alert found

NOEL = No observed effect level; CNIH = Confirmation of No Induction in Humans test; GPMT = Guinea Pig Maximization Test; HMT = Human Maximization Test; LOEL = lowest observed effect level; KE = Key Event; NA = Not Available.

[a] WoE Skin Sensitization Potency Category is only applicable for identified sensitizers with sufficient data, based on collective consideration of all available data (Na et al., 2021).

[b] Data derived from CNIH or HMT.

[c] WoE NESIL limited to 2 significant figures.

[d] Based on animal data using classification defined in the European Centre for Ecotoxicology and Toxicology of Chemicals (ECETOC), Technical Report No. 87 (ECETOC, 2003).

[e] Studies conducted according to the OECD TG 406 are included in the table.

[f] Studies conducted according to the OECD TG 442, Cottrez et al. (2016), or Forreryd et al. (2016) are included in the table.

[g] Determined based on Criteria for the Research Institute for Fragrance Materials, Inc. (RIFM) safety evaluation process for fragrance ingredients (Api et al., 2015).

11.1.6. Local respiratory toxicity

The margin of exposure could not be calculated due to a lack of appropriate data. The exposure level for 2-methylpyrazine is below the Cramer Class III* TTC value for inhalation exposure local effects.

11.1.6.1. Risk assessment. There are no inhalation data available on 2-methylpyrazine. Based on the Creme RIFM Model, the inhalation exposure is 0.0046 mg/day. This exposure is 102.2 times lower than the Cramer Class III* TTC value of 0.47 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.

*Per Carthew et al. (2009), Cramer Class II defaults to Cramer Class III for the local respiratory toxicity endpoint.

Additional References: None.

Literature Search and Risk Assessment Completed On: 03/28/22.

11.2. Environmental endpoint summary

11.2.1. Screening-level assessment

A screening-level risk assessment of 2-methylpyrazine 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 VoU 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-Methylpyrazine 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) did not identify 2-Methylpyrazine 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, 2017a). 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).

11.2.1.1. Risk assessment. Based on the current VoU (2019), 2-methylpyrazine does not present a risk to the aquatic compartment in the screening-level assessment.

11.2.1.2. Key studies

11.2.1.2.1. Biodegradation. No data available.

11.2.1.2.2. Ecotoxicity. No data available.

11.2.1.2.3. Other available data. 2-Methylpyrazine has been pre-registered for REACH with no data at this time.

11.2.1.2.4. 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.

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

Exposure	Europe (EU)	North America (NA)
Log K_{ow} Used	0.49	0.49
Biodegradation Factor Used	0	0
Dilution Factor	3	3
Regional VoU Tonnage Band	<1	<1
Risk Characterization: PEC/PNEC	**<1**	**<1**

- **OECD SIDS:** https://hpvchemicals.oecd.org/ui/Default.aspx
- **EPA ACToR:** https://actor.epa.gov/actor/home.xhtml

	LC50 (Fish) (mg/L)	EC50 (*Daphnia*) (mg/L)	EC50 (Algae) (mg/L)	AF	PNEC (μg/L)	Chemical Class
RIFM Framework Screening-level **(Tier 1)**	3127			1000000	3.127	

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

The RIFM PNEC is 3.127 μg/L. The revised PEC/PNECs for EU and NA are <1; therefore, the material does not present a risk to the aquatic environment at the current reported VoU.

Literature Search and Risk Assessment Completed On: 03/30/22.

12. Literature Search*

- **RIFM Database:** Target, Fragrance Structure-Activity Group materials, other references, JECFA, CIR, SIDS
- **ECHA:** https://echa.europa.eu/
- **NTP:** https://ntp.niehs.nih.gov/
- **OECD Toolbox:** https://www.oecd.org/chemicalsafety/risk-assessment/oecd-qsar-toolbox.htm
- SciFinder: https://scifinder.cas.org/scifinder/view/scifinder/scifinderExplore.jsf
- **PubChem:** https://pubchem.ncbi.nlm.nih.gov/
- **PubMed:** https://www.ncbi.nlm.nih.gov/pubmed
- **National Library of Medicine Technical Bulletin:** https://www.nlm.nih.gov/pubs/techbull/nd19/nd19_toxnet_new_locations.html
- **IARC:** https://monographs.iarc.fr
- **US EPA ChemView:** https://chemview.epa.gov/chemview/
- Japanese NITE: https://www.nite.go.jp/en/chem/chrip/chrip_search/systemTop
- **Japan Existing Chemical Data Base (JECDB):** http://dra4.nihs.go.jp/mhlw_data/jsp/SearchPageENG.jsp
- **Google:** https://www.google.com
- **ChemIDplus:** https://pubchem.ncbi.nlm.nih.gov/source/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. The links listed above were active as of 10/04/22.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome. RIFM staff are employees of the Research Institute for Fragrance Materials, Inc. (RIFM). The Expert Panel receives a small honorarium for time spent reviewing the subject work.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.fct.2023.114377.

Appendix

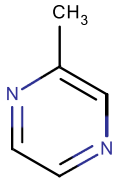
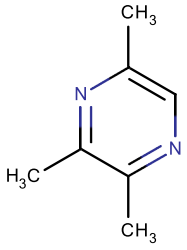
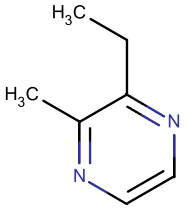
Read-across Justification

Methods

The read-across analogs were identified using RIFM fragrance chemicals inventory clustering and read-across search criteria (Date et al., 2020). These criteria are in compliance with the strategy for structuring and reporting a read-across prediction of toxicity as described in Schultz et al. (2015) and are consistent with the guidance provided by OECD within Integrated Approaches for Testing and Assessment (OECD, 2015) and the European Chemicals Agency read-across assessment framework (ECHA, 2017b).

- 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 material 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 v4.5 (OECD, 2021b).

- ER binding and repeat dose categorization were generated using OECD QSAR Toolbox v4.5 (OECD, 2021b).
- Developmental toxicity was predicted using CAESAR v2.1.7 (Cassano et al., 2010), and skin sensitization was predicted using Toxtree v2.6.13.
- Protein binding was predicted using OECD QSAR Toolbox v4.5 (OECD, 2021b).
- The major metabolites for the target material and read-across analogs were determined and evaluated using OECD QSAR Toolbox v4.5 (OECD, 2021b).
- To keep continuity and compatibility with *in silico* alerts, OECD QSAR Toolbox v4.5 was selected as the alert system.

	Target Material	Read-across Material	Read-across Material
Principal Name	2-Methylpyrazine	2,3,5-Trimethylpyrazine	2-Ethyl-3-methylpyrazine
CAS No.	109-08-0	14667-55-1	15707-23-0
Structure			
Similarity (Tanimoto Score)		0.76	0.67
Endpoint		Genotoxicity	Skin sensitization
Molecular Formula (g/mol)	$C_5H_6N_2$	$C_7H_{10}N_2$	$C_7H_{10}N_2$
Molecular Weight (g/mol)	94.12	122.17	122.17
Melting Point (°C, EPI Suite)	−29.00	20.23	17.11
Boiling Point (°C, EPI Suite)	137.00	171.50	189.48
Vapor Pressure (Pa @ 25°C, EPI Suite)	1074.58	193.32	81.06
Water Solubility (mg/L, @ 25°C, WSKOW v1.42 in EPI Suite)	1000000.00	15210.00	12020.00
Log K_{OW}	0.21	0.95	1.07
J_{max} (μg/cm^2/h, SAM)	4840.54	123.13	119.05
Henry's Law (Pa·m^3/mol, Bond Method, EPI Suite)	0.22	0.40	0.48
Genotoxicity			
DNA Binding (OASIS v1.4, QSAR Toolbox v4.5)	No alert found	No alert found	
DNA Binding (OECD QSAR Toolbox v4.5)	No alert found	No alert found	
Carcinogenicity (ISS)	No alert found	No alert found	
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 skin sensitization reactivity domain alerts were identified.	No skin sensitization reactivity domain alerts were identified.	
Oncologic Classification	Not classified	Not classified	
Skin Sensitization			
Protein Binding (OASIS v1.1)	No alert found		No alert found
Protein Binding (OECD)	No alert found		No alert found
Protein Binding Potency	Not possible to classify according to these rules (GSH)		Not possible to classify according to these rules (GSH)
Protein Binding Alerts for Skin Sensitization (OASIS v1.1)	No alert found		No alert found
Skin Sensitization Reactivity Domains (Toxtree v2.6.13)	No skin sensitization reactivity domain alerts were identified.		No skin sensitization reactivity domain alerts were identified.
Metabolism			
Rat Liver S9 Metabolism Simulator and Structural Alerts for Metabolites (OECD QSAR Toolbox v4.5)	See Supplemental Data 1	See Supplemental Data 2	See Supplemental Data 3

Summary

There are insufficient toxicity data on 2-methylpyrazine (CAS # 109-08-0). Hence, *in silico* evaluation was conducted to determine read-across material. Based on structural similarity, reactivity, metabolism data, physical–chemical properties, and expert judgment, 2,3,5-trimethylpyrazine (CAS # 14667-55-1) and 2-ethyl-3-methylpyrazine (CAS # 15707-23-0) were identified as read-across analogs with sufficient data for toxicological evaluation.

Conclusion

- 2,3,5-Trimethylpyrazine (CAS # 14667-55-1) was used as a read-across analog for the target material, 2-methylpyrazine (CAS # 109-08-0), for the genotoxicity endpoint.
  - o The target material and the read-across analog belong to the generic class of pyrazines.
  - o The key difference between the target material and read-across analog is that the read-across analog has 2 additional methyl substituents at 3rd and 5th positions, respectively. The differences between structures do not essentially change the physical–chemical properties nor raise any

additional structural alerts, and therefore, the toxicity profiles are expected to be similar.
  - The similarity between the target material and the read-across analog is indicated by the Tanimoto score. Differences between the structures that affect the Tanimoto score are toxicologically insignificant.
  - The physical–chemical properties of the target material and the read-across analog are sufficiently similar to enable a comparison of their toxicological properties.
  - According to the OECD QSAR Toolbox v4.5, structural alerts for toxicological endpoints are consistent between the target material and the read-across analog.
  - The target material and the read-across analog are expected to be metabolized similarly, as shown by the metabolism simulator.
  - The structural alerts for the endpoints evaluated are consistent between the metabolites of the read-across analog and the target material.
- 2-Ethyl-3-methylpyrazine (CAS # 15707-23-0) was used as a read-across analog for the target material, 2-methylpyrazine (CAS # 109-08-0), for the skin sensitization endpoint.
  - The target material and the read-across analog belong to the generic class of pyrazines.
  - The key difference between the target material and read-across analog is that the target material has a methyl substituent at the 2nd position while the read-across analog has an ethyl substituent at the 2nd position. In addition, the read-across analog has an additional methyl substituent at the 3rd position. The differences between structures do not essentially change the physical–chemical properties nor raise any additional structural alerts, and therefore, the toxicity profiles are expected to be similar.
  - The similarity between the target material and the read-across analog is indicated by the Tanimoto score. Differences between the structures that affect the Tanimoto score are toxicologically insignificant.
  - The physical–chemical properties of the target material and the read-across analog are sufficiently similar to enable a comparison of their toxicological properties.
  - According to the OECD QSAR Toolbox v4.5, structural alerts for toxicological endpoints are consistent between the target material and the read-across analog.
  - The target material and the read-across analog are expected to be metabolized similarly, as shown by the metabolism simulator.
  - 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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