Read-across of 90-Day Rat Oral Repeated-Dose Toxicity: A Case Study for Selected 2-Alkyl-1-alkanols

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Abstract: 2-Alkyl-1-alkanols offer an example whereby the category approach to read-across can be used to predict repeated-dose toxicity for a variety of derivatives. Specifically, the NOAELs of 125 mg/kg bw/d for 2-ethyl-1-hexanol and 2-propyl-1-heptanol, the source substances, can be read across with confidence to untested 2-alkyl-1-alkanols in the C5 to C13 category based on a LOAEL of low systemic toxicity. These branched alcohols, while non-reactive and exhibiting unspecific, reversible simple anaesthesia or nonpolar narcosis mode of toxic action, have metabolic pathways that have significance to repeated-dose toxic potency. In this case study, the chemical category is limited to the readily bioavailable analogues. The read-across premise includes rapid absorption via the gastrointestinal tract, distribution in the circulatory system and first-pass metabolism in the liver via Phase 2 glucuronidation prior to

urinary elimination. 2-Ethyl-1-hexanol and 2-propyl-1-heptanol, the source substances, have high quality 90-day oral repeated-dose toxicity studies (OECD TG 408) that exhibit qualitative and quantitative consistency. Findings include only mild changes consistent with low-grade effects including decreased body weight and slightly increased liver weight, which in some cases is accompanied by clinical chemical and haematological changes but generally without concurrent histopathological effects at the LOAEL. These findings are supported by results from the TG 408 assessment of a semi-defined mixture of isotridecanols. Chemical similarity between the analogues is readily defined and data uncertainty associated with toxicokinetic and toxicodynamics similarities are low. Uncertainty associated with mechanistic relevance and completeness of the read-across is reduced by the concordance of *in vivo* and *in vitro* results, as well as high throughput and *in silico* methods data. As shown in detail, the 90-day rat oral repeated-dose NOAEL values for the two source substances can be read across to fill the data gaps of the untested analogues in this category with uncertainty deemed equivalent to results from a TG 408 assessment.

Keywords: read-across, n-alkanols, repeated-dose toxicity, No Observed Adverse Effect Level (NOAEL), Lowest Observed Adverse Effect Level (LOAEL), weight-of-evidence (WoE), uncertainty

Highlights:

- The category is limited to readily bioavailable 2-alkyl-1-akanols of intermediate size (C5 to C13)
- 2-Alkyl-1-akanols are toxicants acting via a simple narcosis mechanism
- Toxicokinetically and toxicodynamically, the 2-alkyl-1-akanols are highly similar
- 2-ethyl-hexanol and 2-propyl-1-heptanol can be read across to other analogues with acceptable uncertainty

1 Introduction

1.1 Read-across

In a toxicity based read-across, it is imperative to demonstrate that all target substances exhibit similar chemical, toxicokinetic and toxicodynamic properties so experimentally-derived information and data from the source substances may be read across to fill the data gap for the target substances [1, 2]. This type of data gap filling is particularly useful for cosmetic ingredients where *in vivo* testing in Europe is prohibited by legislation [3].

While read-across has been used by industry and regulators for decades, recent advances, especially in non-animal test methods, has resulted in read-across today being held to a higher standard [4, 5].

The read-across strategy employed here focuses on assessing the similarity between target(s) and source substance(s) and the uncertainties in the read-across process and ultimate prediction, two fundamentals of a read-across estimation [6]. Briefly, the justification of read-across prediction needs to be robust, reliable and easily explicable. The crucial principles of similarity are clearly documented and supported by scientific literature and data. Sources of uncertainty, the uncertainty associated with the justification of similarity, and the uncertainty associated with the particular application are identified and accommodated.

As such, the current study describes a case that illustrates a number of issues associated with a category approach for the scenario in which metabolism, while straight forward, is important in determining molecular similarity. Thus, establishing toxicodynamic, as well as toxicokinetic

similarity, is critical to reducing uncertainties associated with the repeated-dose toxicity predictions.

The present study builds on an early finding [2]. Specifically, an initial evaluation of a wide variety of saturated alcohols revealed that, based on consideration of a common metabolic pathway the saturated alcohols need to be sub-categorised prior to making read-across predictions.

1.2 C5-C13 2-alkyl-1-alkanols: Overview of Existing Knowledge

As previously noted [2], intermediate chain-length primary alkanols are considered non-polar narcotics which act mechanistically in a manner similar to depressant anaesthetics. Perfused rat liver toxicity data from Strubelt et al. [7] for the C5 primary alkanol exposure of 65.1 mmol/l for 2 hours suggests that 2-alkyl-1-alkanols may not be in the same read-across category as other primary alkanols (Table 1). These data support the premise that *in vitro* toxicity (e.g., O_2 consumption and ATP production) of 2-alkyl-1-alkanols is due, in large part, to loss of membrane integrity, as indicated by cytosolic enzyme (LDH) leakage. While it is likely that enzyme leakage is the result of alteration in membrane fluidity due to partitioning in the cell membrane, loss of membrane integrity as a result of soft electrophilic reactivity and indicated by a 50% reduction in free glutathione (GSH) is not likely.

Table 1. *In vitro* toxicity profiles for selected alkanols.

Name	**log Kow**	**O_2 Consumption (μmol/g x min)**	**ATP (μmol/g)**	**LDH (U/l)**	**GSH (μmol/g)**
Control		1.54 ± 0.07	1.25 ± 0.20	1109 ± 265	2.52 ± 0.29
2-Methyl-1-butanol	1.30	0.30 ± 0.03	0.10 ± 0.01	20521±1087	1.33 ± 0.29
3-Methyl-1-butanol	1.16	0.22 ± 0.07	0.27 ± 0.05	8680 ± 1216	2.27 ± 0.37
1-Pentanol	1.40	0.06 ± 0.01	0.20 ± 0.03	28959 ± 4142	2.82 ± 0.36

LDH – lactate dehydrogenase; ATP - adenosine triphosphate; GSH – reduced glutathione

Due to bioavailability, and distribution and mechanistic considerations, the applicability domain for this case study is limited to 2-alkyl-1-alkanols with a carbon atom (C) chain length range of C5 to C13. Since long-chain derivatives are typically transported via carrier molecules, alcohols of C14 and greater are not included in this category. Since shorter-chain derivatives (e.g., isopropyl alcohol) have the potential to volatilise, they also are not included in this category.

Among the 2-alkyl-1-alkanols, 2-ethyl-1-hexanol is the most widely studied [8, 9, 10, 11, 12].

Dermal penetration of intermediate size alkanols does not readily occur and absorption from inhalation is extremely limited [13]. Thus, the primary route of exposure, which is toxicologically relevant, is oral. Two-alkyl-1-alkanols within the range C5-C13 are expected to be readily absorbed by the gastrointestinal tract and distributed in the blood in solution [14].

Metabolism of 2-alkyl-1-alkanols, while highly efficient, involves processes that are more complex than n-alkanol metabolism. Experimental data reveals the major pathways of metabolism and fate of 2-alkyl-1-alkanols include: 1) conjugation of the alcohol group with glucuronic acid; 2) oxidation of the alcohol group; 3) side-chain oxidation yielding additional polar metabolites, which may be subsequently conjugated and be excreted or further oxidised, and 4) excretion of the unchanged parent compound. For example, in rabbits, the glucuronide of 2-ethyl-1-hexanoic acid was identified as the main metabolite (87%) after oral application of 2-ethyl-1-hexanol [15, 16]. In contrast, in the same species, only about 9% of the administered dose of 2-methyl-1-butanol was found in the form of the glucuronides [15, 16].

Belsito et al. [14] reviewed the toxicity of branched chain saturated alcohols, including secondary ones. Patocka and Kuca [17] summarized the toxicity of C1 to C6 alkanols. The

efficacy of alkanols to induce ataxia [18] and enzyme release from liver cells [19] has been interpreted as being due to the hydrophobic property of the alkanols. Based on rat and fish studies, 2-alkyl-1-alkanols, like other alkanols, act in a manner similar to depressant anaesthetics [20, 21]. Koleva et al. [22] reported multiple-regression type quantitative structure-toxicity relationships (QSARs) for oral log $LD50^{-1}$ data for rodents and the 1-octanol/water partition coefficient (log Kow). Comparison of measured toxicity data with predictions from baseline QSARs reveals that straight-chain and branched, saturated monohydric alcohols consistently behave as classic nonpolar narcotics.

A cursory summary of the rodent oral acute and oral repeated-dose toxicity of intermediate size 2-alkyl-1-akanols are presented in Table 2. In general, 2-alkyl-1-akanols acute oral toxicity (LD50) is very low ranging from ≈2000 to < 5000 mg/kg bw with an average value of ≈3500 mg/kg bw.

Table 2. Acute and repeated-dose oral toxicity of selected 2-alkyl-1-alkanols

Alcohol	Species	Oral LD50 (mg/kg)	Reference	90-d Oral NOAEL (mg/kgbw/d)	Reference
2-Methyl-1-butanol	Rat	4010	[23]	Not determined	
2-Methyl-1-pentanol		Not determined		Not determined	
2-Ethyl-1-butanol	Rat	1850	[24]	Not determined	
2-Ethyl-1-pentanol	Rat	Not determined		Not determined	
2-Ethyl-1-hexanol	Rat	>3730	[25]	125	[26, 27]
	Rat	≈2000	[27]	Not determined	
	Mouse	2500	[28]	125	[26]
2-Propyl-1-pentanol		Not determined		Not determined	
2-Methyl-1-octanol		Not determined		Not determined	
2-Ethyl-1-octanol		Not determined		Not determined	
2-Propyl-1-heptanol	Rat	5400	[29]	150	[29]
2-Methyl-1-undecanol		Not determined		Not determined	
2-Ethyl-1-decanol		Not determined		Not determined	
2-Propyl-1-decanol		Not determined		Not determined	

2-Alkyl-1-akanols are slightly toxic in oral repeated-dose testing; typically, the rodent, oral, 90-day, repeated-dose No Observed Adverse Effect Level (NOAEL) in mg/kg bw/d is ≥ 125 mg/kg bw/d (see Table 2). This value is characteristically based on clinical symptoms, haematological values outside the normal range, or whole body effects different from normal. However, if ingested in large enough quantities, alkanols may cause systemic damage to the liver, heart, kidneys, and/or nervous system.

2 Method and Materials

This evaluation of selected 2-alkyl-1-akanols follows the workflow of Schultz et al. [2]. It is in accord with the guidance proposed by Organization for Economic Co-Operation and Development (OECD) [30] and Schultz and co-workers [6]. *In vivo* data used in the assessment were taken from the literature, including ECHA REACH Registered Substances database [31]. Mechanistic relevance, as well as toxicokinetic and toxicodynamic similarity of the category analogues, was established using relevant non-animal data.

2.1 Target and Source Substances

In this case study, the analogues (listed in Table 3) include ten target and two source chemicals; the latter, those with repeated-dose data derived from a 90-day OECD TG 408 assay, are noted in bold print. This list is not meant to be all inclusive, rather it represents existing industrial organic materials that are likely to be found in a governmental or industrial inventory (e.g., OECD High Production Volume Chemicals). Additional substance identifier information, such as chemical structures and molecular formulas are available in Table 1 of the supplemental information.

Table 3. 2-Alkyl-1-alkanols considered part of the chemical category. The source chemicals are in bold.

ID	Name	CAS	Molecular formula
1	2-Methyl-1-butanol	137-32-6	C5H12O
2	2-Methyl-1-pentanol	105-30-6	C6H14O
3	2-Ethyl-1-butanol	97-95-0	C6H14O
4	2-Ethyl-1-pentanol	27522-11-8	C7H16O
5	**2-Ethyl-1-hexanol**	**104-76-7**	**C8H18O**
6	2-Propyl-1-pentanol	58175-57-8	C8H18O
7	2-Methyl-1-octanol	818-81-5	C9H20O
8	2-Ethyl-1-octanol	20592-10-3	C10H22O
9	**2-Propyl-1-heptanol**	**10042-59-8**	**C10H22O**
10	2-Methyl-1-undecanol	10522-26-6	C12H26O
11	2-Ethyl-1-decanol	21078-65-9	C12H26O
12	2-Propyl-1-decanol	60671-35-4	C13H28O

2.2 Endpoint

The NOAEL for the 90-day rat oral repeated-dose is the single endpoint for which this category approach is applied. The 90-day oral repeated-dose data for 2-ethyl-hexanol and 2-propyl-1-heptanol are particularly well-suited for read-across; the NOAELs are based on experimental results from a 4-dose exposure scenario (0, <100, between 100 and 200 and > 500 mg/kg bw/d) following a standard test guideline (OECD TG 408) where the LOAEL symptoms are reported.

2.3 Hypothesis of the category

The premise for this read-across case study is:

- 2-Alkyl-1-akanols of intermediate chain length (i.e., C5 to C13) are direct-acting toxicants (i.e., metabolic activation and detoxification is not a major factor in toxicity) with a similar reversible mode of action (i.e., non-polar narcosis or simple anaesthesia).
- The chemical category is based on simple structure similarities- C-atom chain length and 2-alkan-1-ol hydrocarbon scaffolding.

- With C5 to C13 2-alkanol-1-ol derivatives, C-atom chain length affects most physico-chemical properties with property values increasing with increasing chain length. However, this trend is not toxicologically significant and does not significantly affect bioavailability in sub-chronic oral exposure.
- These 2-alkyl-1-akanols are rapidly and nearly completely absorbed from the gut and distributed in the blood in solution; first past metabolism leads to glucuronidation with subsequent elimination in the urine and/or oxidative metabolism in the liver resulting in a carboxylic acid, which subsequently undergoes mitochondrial β-oxidation, and/or resulting in additional polar metabolites which are glucuronidated prior to excretion in the urine.
- Toxicodynamically, these 2-alkyl-1-akanols are highly similar. Briefly, *in vivo* they exhibit low systemic toxicity and *in vitro* they exhibit no chemical reactivity or receptor-mediated interactions.
- Repeated-dose tested NOAEL data for 2-ethyl-hexanol and 2-propyl-1-heptanol can be read across to other category members listed in Table 3 with acceptable uncertainty.

3. Results

3.1. Read-across Justification

3.1.1 Rodent repeated-dose toxicity for 2-ethyl-1-hexanol

From a repeated-dose perspective, 2-ethyl-1-hexanol is well-studied. More specifically, in a 90-day study similar in design to an OECD TG408, Fischer F344 rats were administered doses of 0, 25, 125, 250 or 500 mg 2-ethyl-1-hexanol/kg bw/d by gavage [32]. A NOAEL of 125

mg/kg bw/d based on reduced body weight and body weight gain, changes in blood chemistry were reported.

A second sub-chronic gavage study is reported by the same authors [33] in which Fischer rats were exposed to doses of 0, 25, 250 and 500 mg/kg bw/d. Relative weight changes are reported for kidney and liver, as well as a decrease of alanine aminotransferase at 250 mg/kg bw/d. Further weight changes occurred in brain, testes and stomach at highest dose, together with a slight decrease in body weight. Changes in clinical chemistry parameters were reported, including an increased activity of the enzyme palmitoyl coenzyme A activity (pCoA), decrease of cholesterol, total protein and albumin, as well as an increase in reticulocytes. Since no doses between 25 and 250 were tested, the NOAEL of this study is 25 mg/kg bw/d.

In a chronic Fischer F344 rat study, 2-ethyl-1-hexanol was administered by gavage at doses of 0, 50, 150 or 500 mg/kg bw/d, 5 days per week for 2 years [34]. Food consumption, body weights, and haematological parameters were examined at specific intervals during the study. At the end of the study, gross and histopathological examinations were conducted. No treatment-related adverse effects were observed at the 50 mg/kg bw/d dose level. At the 150 mg/kg bw/d dose level, rats exhibited a body weight gain reduction of approximately 16% in males and 12% in females. An increase of brain and liver weight also is reported. However, no histopathological changes were observed at same or higher doses. In addition, the rats also displayed a slightly increased incidence of clinical signs, such as poor general condition and laboured breathing. We conclude that the NOAEL for this study is 150 mg/kg bw/d.

Shorter-term repeated dose studies are also available for 2-ethyl-1-hexanol. In an 11-day study, Fischer 344 rats were exposed by gavage at doses of 0, 100, 330, 1000 and 1500 mg/kg bw/d [35]. From 330 mg/kg bw/d on, atrophy of the thymus was reported being most pronounced at

1500 mg/kg bw/d. At 1000 mg/kg bw/d a decrease in reticulocytes and clinical chemistry parameters such as cholesterol, glucose and ALAT was reported, as well as a marked inflammation of the forestomach. At highest tested dose, additional adverse effects were reported, including focal hepatocellular necrosis, hepatocellular hypertrophy and several organ weight changes. Transient clinical signs were reported at 1000 and 1500 mg/kg bw/d, namely ataxia, lethargia and lateral and abdominal posturing. A NOAEL of 100 mg/kg bw/d was determined.

A second short-term gavage study was done with Fischer rats exposed to doses of 0, 100, 320 and 950 mg/kg bw/d for 28 days [36]. At the highest dose of 950 mg/kg bw/d body weight gain was reduced and kidney and liver weight and triglycerides were increased. At 320 mg/kg bw/d an induction of peroxisome proliferation was observed, as well as hepatic cyanide-insensitive palmitoyl coenzyme A activity (pCoA). At 100 mg/kg bw/d a reduction of neutral lipids in liver is reported; however, we do not consider this toxicologically relevant and, thus, we conclude the NOAEL for this study to be 100 mg/kg bw/d.

In a 90-day study, B6C3F1 mice received doses of 0, 25, 125, 250 or 500 mg 2-ethyl-1-hexanol/kg bw/d [26] and the 90-day oral NOEL was noted as 125 mg/kg bw/d.

In another B6C3F1 mouse study, 2-ethyl-1-hexanol mice were administered by gavage at doses of 0, 50, 200 or 750 mg/kg bw/d, five days per week for 18 months [32]. Food consumption, body weights and haematological parameters were examined at specific intervals during the study. At the end of the study, gross and histopathological examinations were conducted. While no treatment-related adverse effects were observed in the mice receiving 50 or 200 mg 2-ethyl-1-hexanol/kg bw/d, at the 750 mg/kg bw/d dose level, body weight gain reductions of approximately 26 and 24% in males and females, respectively. Further high dose effects

consist of changes in haematology (lymphocytes, neutrophil increase after 12 months), weight changes of different organs (kidney, liver), and hyperplasia in the forestomach. We conclude the NOAEL for this study to be 200 mg/kg bw/d.

3.1.2 Rodent repeated-dose toxicity for 2-propyl-1-heptanol

In an OECD TG 408 test, oral 90-day repeated-dose assay, male and female Fischer 344 rats were exposed via gavage to 0, 30, 150 and 600 mg/kg bw/d of 2-propyl-1-heptanol [29]. Histopathological findings at 600 mg/kg bw/d include diffuse liver hypertrophy, likely the result of peroxisome proliferation, diffuse hypertrophy of follicular cells in the thyroid gland, and vacuolation of basophilic (thyrotropic) cells in the glandular part of the pituitary gland. Additionally, alterations based on clinical signs were observed at 600 mg/kg bw/d. Disregarding peroxisomal proliferation, the NOAEL for this study was 150 mg/kg bw/d.

3.1.3 Other related rodent repeated-dose studies

Isotridecanol (i.e., C13-rich mixture of iso-alcohols of C11-14, CAS No. 68526-86-3) was tested by gavage to Sprague–Dawley rats [14]. In a 90-day study, according to OECD TG 408 with doses of 0, 100, 500, or 1000 mg/kg bw/d, the NOAEL of 100 mg/kg bw/d was reported [14].

While ECHA CHEM notes a reliable read-across from 3-methyl-1-butanol to 2-methyl-1-butanol, the current study disregarded these data. This decision was based on the finding of Strubelt and co-workers. [7]. Data (see Table 1) for the C5 primary alkanols exposure 65.1 mmol/l for 2 hours suggest that 2-methyl-1-butanol may not be in the same read-across category as 3-methyl-1-butanol or n-pentanol.

In summary, two 2-alkyl-1-akanols (i.e., 2-ethyl-hexanol and, 2-propyl-1-heptanol) have high quality quantitative (e.g., OECD TG 408) 90-day oral exposure repeated-dose test data. These data exhibit qualitative and quantitative consistency between and within rodent species. Specifically, results of oral repeated-dose testing for these two source substances suggest mild changes consistent with low-grade effects, including decreased body weight, accompanied by clinical chemical and haematological changes but generally without concurrent histopathological effects. While it can be argued that these effects are not adverse, we still considered them in determining the NOAEL. The 90-day oral exposure repeated-dose NOAEL values ≥ 125 mg/kg bw/d are based on experimental results from a four dose exposure scenario, typically 0, <100, between 100 and 200, >200 and ≥500. While there is not repeated-dose toxicity data for 2-methyl derivatives, they are included in the category.

3.2. Applicability domain

As previously noted, the applicability domain for this case study is confined to branched primary alkanols of intermediate size, C5 to C13. Straight-chain derivatives, which exhibit a different toxicokinetic profile, are excluded from this chemical category. Briefly, metabolism of straight-chain saturated alcohols resulting in the corresponding carboxylic acid, which subsequently undergoes mitochondrial β-oxidation to CO_2 with only minor amounts of Phase 2 glucuronidation [2].

3.3. Purity/impurities

A purity/impurity profile for the analogues listed in Table 3 is not reported. No effort was made to take into account impurities based on production. Since the category is structurally

limited, the impurities are expected to be similar if not the same across the members and are not expected to significantly impact the toxicity profile of any analogue.

3.4 Data matrices for assessing similarity

As earlier noted, in order for a read-across prediction to be accepted, there is the requirement to establish similarity between the source and target substance; toxicokinetic similarity, especially for metabolism, and toxicodynamic similarity, especially in regard to mechanistic plausibility is required for repeated dose-toxicity endpoints [1, 2].

3.4.1 Structural similarity

As demonstrated in Tables 1 and 3 of the supplemental information, all the branched alkanols included in the category are structurally highly similar. Specifically, they: 1) belong to a common chemical class, aliphatic alcohols and the subclasses primary alkanols and 2-alkyl-1-alkanols, and 2) possess a similar molecular scaffolding, a C-atom backbone with alkyl branching in the 2-position. Structurally, the main variations are the length of the backbone, C5-C11 and the length of the alkyl-substituent, C1-C3.

3.4.2 Chemical property similarity

As demonstrated in Table 2 of the supplemental information, all the primary alkanols included in the category have a large portion of their physio-chemical properties determined experimentally. Properties, with the exception of density and pKa, tread in values related to C-atom number within a scaffold. Specifically, all category members exhibit molecular weights from 88 to 200 g/mol. While hydrophobicity (log Kow) increases with number of C-atoms from >1.0 to <6.0, density and pKa are constant at 0.8 g/cm^3 and 15. While vapour pressure

and water solubility decrease with molecular size, melting point and boiling point increase with molecular size.

3.4.3 Chemical constituent similarity

As demonstrated in Table 3 of the supplemental information, all the branched primary alkanols included in the category have common constituents in the form of: 1) a single key substituent, OH, and 2) structural fragments, CH_3, CH_2 and CH.

3.4.4 Toxicokinetic similarity

As demonstrated in Table 4 of the supplemental information, while the analogues tested are limited, the toxicokinetic understanding of 2-position branched primary alkanol is fairly complete. Two-alkyl-1-alkanols are rapidly absorbed following oral administration [13] and are rapidly excreted [37]. Data for 2-ethyl-1-hexanol and to a lesser extent 2-methyl-1-butanol and 2-ethyl-1-butanol demonstrate that branched primary alcohols exhibit common metabolic pathways. These metabolic pathways include oxidation of the alcohol group and oxidation of the side chain at various positions, glucuronidation of the oxidation products and decarboxylation [37]. Glucuronidation increases with increased chain length of the alkanols [38].

Two adult male CD-strain rats (300 g) were gavaged with radiolabeled 2-ethyl-1-^{14}C-hexanol (^{14}C- labeled 2-ethyl-1-hexanol; 1 µCi; 8.8 µg) in cotton seed oil. Two others were given the same amount of ^{14}C-EH and cotton seed oil but also were given 0.1 ml (0.64 mmol) of unlabeled 2-ethyl-1-hexanol. Following administration, rats were housed in metabolism cages and expired CO_2, urine, and faeces were collected every hour for 28 hrs. Most (99.8%) of the

orally administered radioactivity was accounted for by radioactivity in expired CO_2, urine, faeces, an ethanol wash of the metabolism cage at the end of the experiment, heart, brain, liver, kidneys, and "residual carcass". Two-ethyl-1-hexanol was efficiently absorbed following oral administration and rapidly excreted in respired CO_2 (6-7%), urine (80-82%), and faeces (8-9%); elimination was essentially complete by 28 hrs [10, 27, 37].

Deisinger et al. [39, 40] examined the elimination of ^{14}C-labeled 2-ethyl-1-hexanol in rats. After oral administration to rats, 69-75% of a dose of 500 mg ^{14}C-labeled 2-ethyl-1-hexanol/kg bw was excreted in the urine within 96 hours; about 13 to 15% of the dose was excreted in the faeces and about the same amount was exhaled as ^{14}C-labeled CO_2. After intravenous administration to rats, about 74% of a dose of 1 mg ^{14}C-labeled 2-ethyl-1-hexanol/kg bw was excreted in the urine within 96 hours. About 4% of the dose was excreted in the faeces and 23% was exhaled. More than 50% of the dose was excreted within 8 hours and the terminal half-life was estimated to be 60 hours [39, 40].

Haggard et al. [41] examined the metabolic fate of 2-methyl-1-butanol in rats. Specifically, intraperitoneal injection in four equal doses of 250mg/kg bw at 15-min intervals resulted in a maximum blood concentration of 550 mg/l. Blood concentration decreased over the next nine hours. Of the total dose of 1000mg/kg bw, only 5.6% was excreted in air and 2% in the urine. The remainder was metabolised, first to the corresponding aldehyde and then to the acid [41]. After a single oral dose of 25 mmoles of 2-methyl-1-butanol to rabbits [15], 9.6% of the dose was excreted in the urine as glucuronides. Glucuronide excretion occurred within 24 hours, the urine did not contain aldehydes or ketones. Iwersen and Schmoldt [42] studied the alcohol dehydrogenase-independent metabolism of aliphatic alcohols (oxidation and glucuronidation). Briefly, male Sprague-Dawley rats were pre-treated with 10% ethanol in the drinking water for

two weeks. Rats were sacrificed and microsomes were prepared for glucuronidation experiments and trials, as well as oxidation experiments with aliphatic alcohols. *In vitro* experiments have demonstrated additional oxidation of 2-methyl-1-butanol by rat liver microsomes via CYP P450 enzymes and glucuronidation. At very low ethanol concentrations (5-10 mmo/L) competitive inhibiting effect of ethanol on oxidation of 2-methyl-1-butanol was observed [42].

A rabbit was given 2.55g of 2-ethyl-1-butanol and the 24-hr urine was collected [16]. 2-Ethyl-1-butanol was excreted mainly as glucuronides, along with a minor amount of methyl n-propyl ketone.

3.4.5 Metabolic similarity

As demonstrated in Table 5 of Annex I with data from *in silico* predictions, it is highly likely that all of the category members undergo successive oxidation to their corresponding aldehyde and carboxylic acid [43, 44].

Kamil et al. [15, 16] examined the metabolic fate of 2-methyl-1-hexanol in rats. Via acid extraction of urine, the major urinary metabolite of 2-ethyl-1-hexanol was revealed to be 2-ethyl hexanoic acid. This metabolite may undertake partial ß-oxidation and decarboxylation to produce $^{14}CO_2$ and 2- and 4-heptanone (in the urine). Other urinary metabolites identified in this study were 2-ethyl-5-hydroxyhexanoic acid, 2-ethyl-5-ketohexanoic acid, and 2-ethyl-1,6-hexanedioic acid. Approximately 3% of the parent compound was excreted unchanged. Metabolic saturation was seen with 500 mg/kg body weight applied [15, 16].

Typically, the presence of a side chain does not terminate the oxidation process of alkanols. However, in most cases, it alters it. The position and size of the alkyl substituent plays a role in

metabolism with degradation to CO_2 decreasing and glucuronidation increasing with branching and increasing chain length.

Alkyl acids formed during metabolic transformation of branched alkanols have their own set of metabolic pathways. Acids with a methyl substituent located at an even-numbered carbon (e.g., 2-methyl pentanoic acid or 4-methyl decanoic acid) are extensively metabolised to CO_2 via ß-oxidative cleavage in the fatty acid pathway. If the methyl group is located at the 3-position, ß-oxidation is inhibited and omega (ω-) oxidation predominates, primarily leading to polar, acidic metabolites capable of being further oxidised or conjugated and excreted in the urine [44]. As chain length and lipophilicity increase, ω-oxidation competes with ß-oxidative cleavage. Methyl substituted acids (e.g., 3-methylnonanoic acid) are, to some extent, ω-oxidized in animals to form diacids which can be detected in the urine [45].

Oxidation of these branched fatty acids is accomplished by alpha (α-) oxidation. α-Oxidation is a complex catabolic process. It initially involves hydroxylation of the α-C atom. Subsequently, the terminal carboxyl group is removed, and there is a concomitant conversion of the α-hydroxyl group to a new terminal carboxyl group. Lastly, there is a linking of CoA to the terminal carboxyl group. This new branched, fatty acyl-CoA functions in the β-oxidation. In humans, α-oxidation is used in peroxisomes to break down dietary branched acids which cannot undergo β-oxidation due to β-methyl branching.

Metabolism of methyl-substituted alcohols is determined primarily by the position of the methyl group(s) on the hydrocarbon-chain. Following successive oxidation to the corresponding carboxylic acids, the branched-chain acids are metabolised via ß-oxidation. With longer branched-chain derivatives, this is followed by cleavage to yield linear acid fragments which are typically completely metabolised to CO_2. At high-dose levels, the longer

branched-chain acids may go through omega-oxidation to yield diacids, which subsequently may undergo further oxidation and cleavage.

The presence of an ethyl- or propyl-substitution at the α-position, such as in 2-ethyl-1-hexanol, inhibits ß-oxidation [46]. Detoxication pathways of ω- and ω-1 oxidation compete with ß-oxidation of these sterically hindered substances; the parent alcohol or corresponding carboxylic acid undergoes a combination of reactions (e.g., ω- or ω-1 oxidation and functional group oxidation) leading to polar, acidic metabolites capable of being excreted in the urine [40, 45]. When the principal pathway is saturated, the corresponding carboxylic acid conjugates with glucuronic acid and is excreted in the urine [, 37, 40, 45].

One of the best studied 2-postion branched carboxylic acid is 2-propyl pentanoic acid (valproic acid). The toxicokinetic aspects of 2-propyl pentanoic acid have been reviewed [47, 48]. 2-Propyl pentanoic acid is almost entirely metabolised by the liver, so it is not surprising that the liver is also the dominant target organ of toxicity. The multiple metabolic pathways involved in 2-propyl pentanoic acid biotransformation give rise to more than 50 known metabolites [47]. Ghodke-Puranik and co-workers [48] estimate that, while 30 - 50% of 2-propyl pentanoic acid is excreted in the urine as a glucuronide conjugate, 40% goes through mitochondrial β-oxidation and about 10% undergoes cytochrome P450-mediated oxidation. It has been postulated that the hepatotoxicity of 2-propyl-pentanoic acid results from the mitochondrial β-oxidation of its cytochrome P450 metabolite, 2-propyl-4-pentenoic acid to 2-propyl-(E)-2,4-pentadienoic acid which, in the CoA thioester form, either depletes GSH or produces a putative inhibitor of β-oxidation enzymes. Pent-4-enoate, 2-propyl-4-pentenoic acid and 2-propyl-(E)-2,4-pentadienoic acid are potent inducers of microvesicular steatosis in rats [49]. However, since 2-propyl-pentanoic acid failed to induce discernible liver lesions in young rats, even at

near lethal doses of 700 mg/kg/day, Kesterson et al. [49] suggested that β-oxidation inhibition observed in both valproic acid and unsaturated metabolite-treated rats occurred by different mechanisms. Specifically, 2-propyl pentanoic acid inhibits transient sequestering of CoA, while the CoA esters of some metabolites, particularly 2-propyl-4-pentenoic acid, inhibit specific enzyme(s) in the β-oxidation sequences [49].

Ghodke-Puranik et al. [48] rationalised the involvement of 2-propyl-4-pentenoic acid. Specifically, 2-propyl-4-pentenoic acid enters the mitochondria, forms a complex with CoA ester and subsequent β-oxidation forms the reactive 2-propyl-(E)-2,4-pentadienoic acid-CoA ester. The latter is the putative cytotoxic metabolite that binds with glutathione to form thiol conjugates. The reactive metabolite, 2-propyl-(E)-2,4-pentadienoic acid-CoA ester, has the potential to deplete mitochondrial glutathione pools and form conjugates with CoA, which in turn inhibits enzymes in the β-oxidation pathway [48].

In summary, the experimental toxicokinetic data for 2-alkyl-1-alkanols show consistency in absorption, distribution and metabolic pathways. In contrast, there is less consistency in excretion. In particular, derivatives with 2-position ethyl and propyl groups are more likely to be excreted as a glucuronidated metabolite, while 2-position-methylated analogues are more likely to be oxidized to CO_2. The latter are metabolically similar to the less toxic n-alkanols [2]. The metabolic evidence supporting the idea that some 2-position branched carboxylic acids are metabolised to thiol reactive metabolites is not considered toxicologically relevant to this read-across, as repeated-dose toxicity through a reactive mechanism is considered unlikely as long as the reactive half-life is shorter than the dosing interval (e.g., <8-hr vs. 24-hr) and the Phase 2 conjugation mechanism is not saturated.

3.4.6 Toxicophore similarity

As shown in Table 6 of the supplemental information, 2-alkyl-1-akanols themselves do not contain a known toxicophore. However, the carboxylic acid metabolites of the same 2-position branched isomers (e.g., 2-ethyl-1-hexanol and 2-propyl-1-heptanol) are linked to developmental toxicity and chronic oral toxicity via the short-chain carboxylic acid pathway [50].

3.4.7 Mechanistic plausibility similarity

It is generally accepted that the toxicity of intermediate size 2-alkyl-1-alkanols, like other saturated alcohols, is the result of narcosis. While there is theoretical evidence for the membrane as the site of action for anaesthetic-like 2-alkyl-1-alkanols, biochemical, cellular and physiological evidence is largely restricted to 1-alkanol derivatives [20, 21]. Narcosis, in the broadest sense, is the non-covalent disruption of hydrophobic interactions within membranes with a particular volume fraction rather than molar fraction [51]. It is the accumulation of alcohols in cell membranes which disturbs their function; however, the exact mechanism is not known yet. There are three competing theories of general anaesthetic action: 1) the lipid solubility-anaesthetic potency correlation (i.e., the Meyer-Overton correlation); 2) the modern lipid hypothesis and 3) the membrane protein hypothesis.

As shown in Table 7 of Annex I, the alkanols included in the category are associated with the simple narcosis mechanism of toxicity that is equivalent to depressant anaesthetics. Measured acute toxicity for 2-alkyl-1-alkanols is consistent with predictions from QSAR models [52, 53] for the nonpolar narcosis mode of action [54].

The contributions of functional groups in acute rat oral toxicity have been calculated using alkanes as the baseline [55]. The toxic contribution of alcohols is -0.108. This situation has not been observed in acute fish toxicity because the threshold of excess toxicity is too high to distinguish differences in toxicity. Critical body residues (CBRs) calculated from percentage of absorption and bioconcentration factors indicate that most of aliphatic alcohols share the same modes of toxic action between fish and rat. Specifically, fish and rat log (1/CBR) and number of alcohols are 1.65; 18 and 1.58; 348, respectively [55].

It should be noted that some 2-alkyl-1-alkanols are associated with development toxicity via their conversion to the corresponding 2-alkyl-carboxcylic acids. The experimental evidence is largely confined to 2-ethyl-1-hexanol and the results are mixed.

In rats administrated 1600 mg/kg bw 2-ethyl-1-hexanol by gavage (but not 800 mg/kg bw) on day 12 of gestation, Ritter et al. [56] reported a statistically significant increase in the number of teratogenic live fetuses; malformations included hydronephrosis, tail and limb defects. Maternal toxicity was not reported in this study.

In another study, Ritter et al. [57] proposed that the teratogen di(2-ethylhexyl) phthalate acts by *in vivo* hydrolysis to 2-ethyl-1-hexanol, which in turn is metabolised to the definitive teratogen 2-ethyl-1-hexanoic acid. They conducted teratological studies with Wistar rats administering one of the three agents on day 12 of gestation. Briefly, it was revealed that, on an equimolar basis, the phthalate derivative was least potent, the alcohol derivative was intermediate, and the acid derivative was most potent. Similarity in the types of malformation induced by each derivative suggests a common mechanism of action. *In toto*, these findings are consistent with the hypothesis [57].

Two-ethyl-1-hexanol was evaluated for developmental toxicity in mice [58]. There were no effects on any gestational parameters upon exposure to dietary 2-ethyl-1-hexanol. Specifically, the number of corpora lutea, uterine implantation sites (live, dead, resorbed), pre- and post-implantation loss, sex ratio (% males), and live fetal body weight per litter (all foetuses or separately by sex) were all equivalent across all groups. Moreover, there were no maternal toxic effects observed at any of the concentrations tested [58].

Tyl et al. [59] examined the developmental toxicity of 2-ethyl-1-hexanol administered dermally. In range-finding (8 females / treatment) and definitive investigations (25 females / treatment), 2-ethyl-1-hexanol was administered by occluded dermal application for 6-hours per day on gestation days 6 through 15 to pregnant Fischer 344 rats. Treatment levels for range-finding were equivalent to 0, 420, 840, 1680, and 2520 mg/kg bw/d; treatment levels for definitive experiments were equivalent to 0, 252, 840, and 2520 mg/kg bw/d. Controls included negative- deionised water, dermal-positive- 2-methoxyethanol and oral reference - valproic acid.

For 2-ethyl-1-hexanol, the findings are: 1) maternal weight gain was reduced at the two highest dose levels, 2) maternal liver, kidney, thymus, spleen, adrenal and uterine weights, as well as gestational and foetal parameters were unaffected by any treatment, and 3) there were no treatment-related increases in the incidence of individual or pooled external, visceral, and skeletal malformations or variations. The dermal NOAELs for the maternal toxicity of 2-ethyl-1-hexanol were 252 mg/kg/d based on skin irritation and 840 mg/kg/d based on systemic toxicity. The developmental toxicity NOAEL was at least 2520 mg/kg/d, with no teratogenicity. While the Fischer 344 rat is susceptible to known rodent teratogens, such as 2-methoxyethanol by the dermal route and valproic acid by the oral route, in the Fischer 344 rat,

494 2-ethyl-1-hexanol is not a developmental toxicant by the dermal route at and below treatment
495 levels which produce maternal toxicity.

496 Narotsky et al. [60] studied the developmental toxicity and structure-activity relationships of
497 aliphatic acids in rats. 14 acids were administered by gavage to Sprague-Dawley rats once
498 daily during organogenesis. Only 2-ethyl hexanoic and 2-propyl hexanoic acid caused effects
499 similar to valproic acid (i.e., mortality, extra pre-sacral vertebrae, fused ribs, and delayed
500 parturition) on rat development. Developmental toxicity of α-branched acids is, in part, due to
501 maternal toxicity resulting in alterations in zinc (Zn) metabolism that affects the developing
502 conceptus [61]. Developmentally toxic doses of 2-ethyl hexanoic acid, 2-ethyl-1-hexanol and
503 valproic acid on Zn metabolism were investigated in the pregnant rat. At the higher dose levels
504 of 2-ethyl-1-hexanoic acid, 2-ethyl-1-hexanol, and at all dosages of valproic acid, the
505 percentage of ^{65}Zn retained in maternal liver was higher than controls, while that in the
506 embryos was lower than controls. Two-ethyl-1- hexanoic acid exposed dams fed Zn-containing
507 diets during gestation exhibited a dose-dependent reduction in teratogenic effects.

508 Toxicokinetic parameters are important determinants of teratogenic outcome of α-alkyl-
509 substituted carboxylic acids, which helps explain differing potencies of structurally similar
510 chemicals [62]. Valproic acid (2-propyl-1- pentanoic acid), 2-ethyl-1-hexanoic acid, and 1-
511 octanoic acid are isomeric analogues with markedly different teratogenic potencies. Valproic
512 acid induces moderate to severe malformations after a single oral administration of 6.25
513 mmoles/kg on day 12 of rat pregnancy. Twice as much 2-ethyl-1-hexanoic acid (12.5
514 mmoles/kg) induces a less severe response and 1-octanoic acid is non-teratogenic, even at the
515 higher dose of 18.75 mmoles/kg [62]. While 1-octanoic acid exhibits poor intestinal
516 absorption, the peak concentration and duration of exposure to valproic acid and 2-ethyl-1-

hexanoic acid were very similar. A fourth agent, 2-methyl-1-hexanoic acid, which is non-teratogenic when administered orally at 14.1 mmoles/kg, exhibits peak concentration and duration of exposure intermediate to 2-ethyl-1-hexanoic acid and 1-octanoic acid. The differences in the severity of developmental malformations for the α-alkyl-substituted derivatives indicated higher intrinsic activity for analogues with C2 and especially, C3 α-alkyl-substituents.

In summary, there is reasonable evidence that some 2-alkyl-1-alkanols via oxidation to their corresponding acid are probable development toxicants. However, there is no evidence that this mechanism is related to repeated-dose toxicity.

3.4.8 Other endpoint similarity

In mammals, alkanols, in general, are considered baseline inhalation toxicants which model as simple narcotics [53].

In fish, alkanols are considered to act via the nonpolar narcosis mode of action, as first reported by Veith et al. [52]. Alkanols are also represented within the USEPA DSSTox Fathead Minnow Acute Toxicity (EPAFHM) database. They exhibit toxic potencies not statistically different from baseline predictions. Because of concerns for aquatic toxicity, a large number of alcohols, especially saturated ones, have been tested *in vitro* for cell population growth inhibition [63]. Structure-activity results from *in vivo* and *in vitro* tests are highly consistent [64]. Briefly, from a structural standpoint, the aquatic toxicity of alkanols is partition-dependent, regardless of endpoint being assessed.

Generally, *in vitro,* alkanols ascribed to unspecific interactions with biological membranes; such effects are directly correlated with 1-octanol/water partition coefficients [65]. The 2-

539 alkyl-1-alkanols were screened with a variety of *in silico* nuclear receptor binding predictions
540 [66]. Specifically, profilers for nuclear receptor binding were run to identify potential binding
541 to the following nuclear receptors: PPARs (peroxisome proliferator-activated receptors), AR
542 (androgen receptor), AHR (aryl hydrocarbon receptor), ER (oestrogen receptor), GR
543 (glucocorticoid receptor), PR (progesterone receptor), FXR (farnesoid X receptor), LXR (liver
544 X receptor), PXR (pregnane X receptor), THR (thyroid hormone receptor), VDR (vitamin D
545 receptor), as well as RAR/RXR (retinoic acid receptor/ retinoid X receptor). The evaluation of
546 potential binding to the receptors is based on structural fragments and physico-chemical
547 features that have been identified as essential to bind to these nuclear receptors and induce a
548 response. No potential receptor binding was predicted. It is worth noting that ToxCast also
549 tested for all of these receptors, and all assays were negative.

550 HTS data from US EPA's ToxCast [67, 68] are available for a variety of saturated alcohols
551 [69]. Of the 711 assays available in ToxCast ToxCast, 2-ethyl-1-hexanol has been evaluated in
552 602 of them and 2-propyl-1-heptanol has been assessed in about 250 assays. The number of
553 active assays varies, six for 2-ethyl-1-hexanol and four for 2-propyl-1-heptanol. No other
554 category members have been screened by ToxCast. However, alkanols, in general, are one of
555 the least promiscuous chemical classes with < 3% of the ToxCast assays show any activity up
556 to highest concentration tested. None of the active assay are associated with specific bioactivity
557 [2].

558 Taken collectively, the findings for other endpoints are not inconsistent with the previously
559 cited *in vivo* data and the premise that in oral repeated-dose toxicity, 2-alkyl-1-alkanols act in a
560 manner similar to depressant anaesthetics.

4. Statement of uncertainty

The categorical assessments of uncertainties along with summary comments are presented in Tables 4 and 5. 2-Alkyl-1-alkanols are a category with acceptable data uncertainty and robust strengths-of-evidence for repeated-dose toxicity. Briefly, chemical dissimilarity has no impact on repeated-dose toxicity. Data uncertainty with the fundamental aspects of toxicokinetics is low. Regardless of the species of mammal, all such category members are judged to be readily absorbed orally and to have similar distributions metabolism elimination as glucuronides. Data uncertainty with the fundamental aspects of toxicodynamics is low, in that category members exhibit a low-toxic profile with respect to *in vivo* repeated-dose NOAEL and LOAEL values.

The uncertainty associated with mechanistic relevance and completeness of the read-across is acceptable. While relevant non-animal data are minimal, the *in vivo* WoE is high. 2-Alkyl-1-alkanols are thought to be associated with the nonpolar narcosis mechanisms of toxicity. While well-studied, this molecular mechanism is not well-understood and no adverse outcome pathway (AOP) is currently available. Moreover, it is unclear if oral repeated-dose toxicity is related to this mechanism; however, there is no evidence to suggest it is not.

Table 4. Assessment of data uncertainty and strengths-of-evidence associated with the fundamentals of chemical, transformation/toxicokinetic and toxicodynamic similarity.

Similarity Parameter	Data Uncertainty [a]	Strength-of-Evidence [b]	Comment
Substance identification, structure and chemical classifications	Low	High	All category members are discrete organic substance of simple structure. They all have CAS numbers, similar 2D structure and belong to the same chemical class and subclass.
Physio-chem & molecular properties	Empirical: Low	High	All category members are appropriately similar with respect to key physicochemical and molecular properties. Where appropriate (e.g., log Kow) changes in values are linked to

Similarity Parameter	Data Uncertainty [a]	Strength-of-Evidence [b]	Comment
	Modelled: Low		changes in C-atom number. There is a high degree of consistency between measured and model estimated values.
Substituents, functional groups, & extended structural fragments	Low	High	Substituents and functional groups are consistent across all category members. There are no extended structural fragments.
Transformation/toxicokinetics and metabolic similarity	Empirical: *In vivo*: Medium *In vitro*: none Simulated: Medium	Medium	Based on *in vivo* data for multiple category members, there is evidence for similar toxicokinetics and metabolic pathways. It is extremely likely that absorption and distribution are consistent within the category. It is likely that the metabolic pathways are consistent with the category. Comparison of results from empirical studies and model predictions indicate similar metabolism among category members. Experimental data support the idea that 2-alkyl-alkanols often undergo oxidation of the alcohol group to an acid with degradation to CO_2, as well as oxidation or hydroxylation of the alkyl chains at various positions, and subsequent glucuronidation prior to excretion. There is evidence the % of glucuronidation varies within the category; higher % of glucuronidation is associated with 2-position branching > C1. There is also evidence supporting the idea that some 2-position branched carboxylic acids are metabolised to thiol reactive metabolites which exhibit enhanced cellular toxicity. Bioavailability while affected by size is not considered a factor in these predictions.
Potential metabolic products	Simulated: Low	High	Based on *in silico* metabolic simulations, metabolites from hydroxylation and oxidation are predicted to be produced by any of the category members.
Toxicophores /mechanistic alerts	Medium	High	Based on *in silico* profilers, no category member contains any established toxicophores related to repeated-dose toxicity.
Mechanistic plausibility and AOP-related events	Medium	High	Although no AOP is currently available for the hypothesized mode of action, many category members have been tested for what is generally accepted as mechanistically-relevant events (i.e., anaesthesia and narcosis).
Other relevant, *in vivo*, *in vitro* and *ex vivo* endpoints	Low	High	Although not directly related to the repeated-dose endpoint, many category members have been tested for *in vivo* acute effects in rodents and fish. In addition, many category members have been tested *in vitro* for cellular effects. There is general agreement in the trend of the reported LD50, LC50 and EC50 values. The primary alkanols (both straight-chain and branched) are among the "least promiscuous chemical classes" (i.e., only 104 of 4412 assay are positive) within ToxCast with no positive assay being associated with specific bioactivity. None of the 2-alkyl-1-

Similarity Parameter	Data Uncertainty [a]	Strength-of-Evidence [b]	Comment
			alkanols reveal any propensity for receptor binding within the SEURAT-1 suite of *in silico* profilers.

[a] Uncertainty associated with underlying information/data used in the exercise (empirical, modelled; low, medium, high)

[b] Consistency within the information/data used to support the similarity rational and prediction (low, medium, high)

Table 5. Assessment of uncertainty associated with mechanistic relevance and completeness of the read-across.

Factor	Uncertainty or WoE[a]	Comment
The problem and premise of the read-across	Low	The endpoint to be read across, oral 90-day repeated-dose toxicity, for 2-alkyl-1-alkanols is well-studied and fairly well-understood mechanistically. The scenario of the read-across hinges on metabolism affecting toxic potency but not the mode of toxic action (i.e., reversible narcosis). 2-alkyl-1-alkanols, themselves, have no obvious chemical reactivity, do not bind to any know receptor and exhibit no specific receptor interactions.
***In vivo* data read across**		
Number of analogues in the source set	Low; 2 of 12 analogues	There are two suitable category members (i.e., 2-ethyl-1-hexanol, 2-propyl-1-heptanol) with high quality *in vivo* 90-day, oral repeated-dose data usable for read-across.
Quality of the *in vivo* apical endpoint data read across	Low	Generally, the *in vivo* data are consistent in regards to qualitative description of repeated-dose effects. Lowest observed effects are typically haematological or whole body parameters and not organ-specific effects. High quality empirical data from accepted guidelines for the 90-day repeated-dose endpoint exist for 2-ethyl-1-hexanol and 2-propyl-1-heptanol and are supported by 90-day oral repeated-dose toxicity data for the isotridecano1 mixture.
Severity of the apical *in vivo* hazard	Low	The consensus is 2-alkyl-1-alkanols have no obvious chemical reactivity, do not bind to any known receptor and exhibit no specific mode of toxic action. Potency data for the *in vivo* 90-d oral repeated-dose NOAEL is ≈125 mg/kg bw/d based on general whole body effects for both sexes.
Evidence to the biological argument for read-across		
Robustness of analogue data set	Low; numerous endpoints reveal the same structure-activity relationships.	The available data from acute *in vivo* and *in vitro* studies for the category members is extensive with several assays being used to assess most if not all the analogues, especially the source analogues. The tests were judged to be reliable and conducted under the appropriate conditions.
Concordance with regard to the intermediate and	Low to medium; limited by indirect rationale (e.g., acute to chronic) of	Since there is no toxicity pathway for repeated-dose effects for this chemical category, there are no true intermediate events. There is agreement among the dose-response relationships of the

apical effects and potency data	mechanistic plausibility.	tested category members for relevant *in vitro* events.
Weight of Evidence	High/ medium for 2-methyl-1-alkanols	Overall the available information is mainly consistent with the stated premise. The structural limitations (i.e., 2-alkyl-1-alkanols) of the category strengthen the WoE. While the toxicokinetics data is limited, the consistency of the metabolic pathway adds to the WoE. Having two well-studied source substances with highly similar *in vivo* 90-day repeated-dose data that are supported by similar data for a mixture of C11 to C14 branched alkanols adds to the *in vivo* WoE. Having both 28-day repeated-dose and chronic (18-month and 2-year) studies for 2-ethyl-1-hexanol with qualitative and quantitative data similar to the 90-day repeated-dose data adds to the *in vivo* WoE. Having repeated-dose studies for 2-ethyl-1-hexanol with qualitative and quantitative similar data in both rat and mouse data adds to the *in vivo* WoE. The lack of *in vivo* repeated-dose data for 2-methyl derivatives reduced the WoE for including these analogues in the category.

[a] Uncertainty: low, medium, high

One observed uncertainty is associated with the fact that, while 2-methyl-substituted derivatives are considered with the domain of the category, there is no *in vivo* experimental data supporting their inclusion. However, there is high quality repeated-dose data for 3-methyl-1-butanol (CAS 123-51-3). In a 90-day study with rats, according to OECD Test Guideline 408, 3-methyl-1-butanol was administered in the drinking water in concentrations of 0, ≈80, ≈340 and ≈1250 mg/kg bw/d [70]. A NOAEL of 340 mg/kg bw/d for males and 1250 mg/kg bw/d for females was reported. 3-Methyl-1-butanol was also tested in a 17-week toxicity study with Ash/CSE rats [71]. The test substance was administered by gavage to group of 15 rats/sex at dose levels of 0, 150, 500, or 1000 mg/kg bw/d in corn oil. While a variety of whole body clinical pathological and histopathological endpoints were examined, the only observed effects were a statistically significant reduced body weight in males and a non-statistical reduction in food intake at the highest dose level. A NOAEL of 500 mg/kg bw/d for males and 1000 mg/kg bw/d for females was reported. In addition, 3-methyl-1-butanol was administered to male and

599 female Wistar rats (≈2000 mg/kg bw/d) in drinking water for 56 weeks. No treatment-related
600 effects were observed for whole body, clinical pathology or histopathological endpoints [72].

601 In rats, oral administration of 2000 mg 3-methyl-1-butanol /kg bw led to a peak concentration
602 of 170 mg/l blood at 1 hour [13, 73]; more than 50% of the dose was excreted within 24 hours.
603 In another study [41], rats were intraperitoneally administered of 250 mg/kg bw four times in
604 15 minute-intervals. Complete absorption of the substance was observed within 1 hr after final
605 administration. No test substance was detectable after 4 hrs. Excretion was 2% in urine and 5.6
606 in expired air. Kamil et al. [15] reported after gavage administration of a dose of 25 mmol per
607 rabbit (corresponding to ≈ 735 mg/kg bw) of 1-pentanol, 3-methyl-1-butanol, and 2-methyl-1-
608 butanol, approximately 7%, 9%, and 10% of the dose was excreted by the rabbits into urine as
609 glucuronides, respectively. Furthermore, the urine did not contain aldehydes or ketones. It is
610 assumed the remaining 90+% of the tested derivative was excreted as CO_2.

611 The collective results for 3-methyl-1-butanol show it is toxicodynamically more similar to
612 tested n-alkanols (i.e., NOAEL = 1000 mg/kg bw/d) than it is to tested 2-alkyl-1-alkanols (i.e.,
613 NOAEL = 125 mg/kg bw/d). Toxicokinetically, 3-methyl-1-butanol and 2-methyl-1-butanol
614 are highly similar to n-alkanols, especially 1-pentanol.

615 **5. Conclusions**

616 This is the third in a series of read-across case studies. This specific study is a result of findings
617 which came to light during evaluations of n-alkanols [2]. *In vivo* oral repeated-dose exposure to
618 2-alkyl-1-alkanols gives rise to a set of non-specific symptoms, including clinical symptoms,
619 haematological values outside the normal range, or whole body effects different from normal.
620 The category limitation to C5 to C13 analogues assures that the impact of bioavailability on the

toxicokinetic and toxicodynamic profiles is limited. 2-Alkyl-1-alkanols are toxicants which act via a reversible mode of toxic action. The main route of exposure is oral with rapid gastrointestinal absorption, distribution via the blood, prompt Phase 2 metabolism and eliminated in the urine.

Repeated-dose toxicity test results exhibit qualitative consistency between and within species. While protocols vary, results of oral repeated-dose testing exhibit qualitative consistency between and within mammals. Typical findings are only mild changes, including decreased body weight, slightly increased liver weight, as well as clinical chemical and haematological changes, but typically without concurrent histopathological effects. The 90-day rat oral repeated-dose NOAEL values for 2-ethyl-1-hexanol and 2-propyl-1-heptanol are particularly well suited for read-across. Moreover, the predictions are supported by highly similar results for an isotridecanol mixture.

A NOAEL value of 125 mg/kg bw/d can be read across to fill the data gaps among the analogues in this category for the purpose of risk assessment. Specifically, the data gaps for 2-propyl-1-pentanol and 2-ethyl-1-octanol are filled with very low uncertainty (very high confidence) by interpolation from 2-ethyl-1-hexanol and 2-propyl-1-heptanol. The data gaps for 2-ethyl-1-butanol, 2-ethyl-1-pentanol, 2-ethyl-1-decanol and 2-propyl-1-decanol are filled with low uncertainty (high confidence) by extrapolation from 2-ethyl-1-hexanol and 2-propyl-1-heptanol. The data gaps for 2-methyl-1-butanol, 2-methyl-1-pentanol, 2-methyl-1-octanol and 2-methyl-1-undecanol are filled with acceptable uncertainty as worst-case scenarios. The latter uncertainty results from incomplete knowledge of how a methyl group, rather than an ethyl or propyl moiety, affects the ratio of excretion in respired CO_2, in urine as a conjugate and in faeces, a as well as repeated-dose toxic potency.

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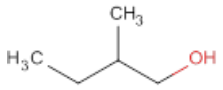
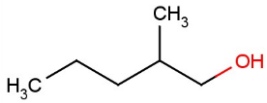
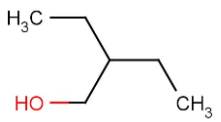
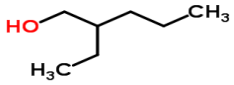
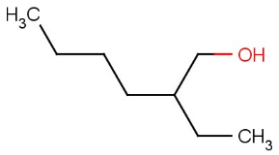
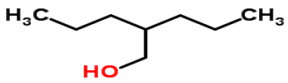
Supplementary material

Read-across of 90-Day Rat Oral Repeated-Dose Toxicity: A Case Study for Selected 2-Alkyl-1-alkanols

Annex I Tables for Assessing Similarity of Analogues and Category Members for Read-Across

Table 1. Comparison of Substance Identification, Structure and Chemical Classifications

ID	Name	CAS No	SMILES	2D Structure	Molecular Formula
1	2-Methyl-1-butanol	137-32-6	CCC(C)CO		C5H12O
2	2-Methyl-1-pentanol	105-30-6	CCCC(C)CO		C6H14O
3	2-Ethyl-1-butanol	97-95-0	CCC(CC)CO		C6H14O
4	2-Ethyl-1-pentanol	27522-11-8	CCCC(CC)CO		C7H16O
5	2-Ethyl-1-hexanol	104-76-7	CCCCC(CC)CO		C8H18O
6	2-Propyl-1-pentanol	58175-57-8	CCCC(CCC)CO		C8H18O

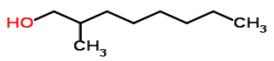
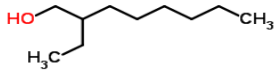
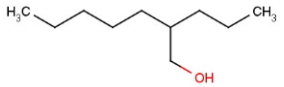
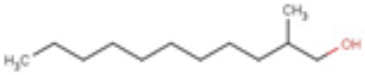
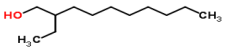
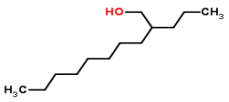
ID	Name	CAS No	SMILES	2D Structure	Molecular Formula
7	2-Methyl-1-octanol	818-81-5	CCCCCCC(C)CO		C9H20O
8	2-Ethyl-1-octanol	20592-10-3	CCCCCCC(CC)CO		C10H22O
9	2-Propyl-1-heptanol	10042-59-8	CCCCCC(CCC)CO		C10H22O
10	2-Methyl-1-undecanol	10522-26-6	CCCCCCCCCC(C)CO		C12H26O
11	2-Ethyl-1-decanol	21078-65-9	CCCCCCCCC(CC)CO		C12H26O
12	2-Propyl-1-decanol	60671-35-4	CCCCCCCCC(CCC)CO		C13H28O

Table 2: Comparison of Physico-Chemical and Molecular Properties[1]

ID	Name	Molecular Weight[1]	Log Kow[1a]	Vapor Pressure (Pa, 25 degC)[1b]	Density[2] (g/cm^3)	Melting Point (deg C)[1b]	Water Solubility (mg/L, 25 degC) [1c]	Boiling Point (deg C)[1b]	pKa[3]
1	2-Methyl-1-butanol	88.15	1.26 1.29 (M)	606 416 (M)	0.8±0.1	-61.49	32200 29700 (M)	123.17 128 (M)	15.24
2	2-Methyl-1-pentanol	102.18	1.75	191 256 (M)	0.8±0.1	-49.23	11950 6000 (M)	145.86 149 (M)	15.05
3	2-Ethyl-1-butanol	102.18	1.75	213 204 (M)	0.8±0.1	-49.23 <-15 (M)	11950 4000 (M)	145.86 147 (M)	15.05
4	2-Ethyl-1-pentanol	116.21	2.24	66.2	0.8±0.1	-37.23	4089	167.64	15.05
5	2-Ethyl-1-hexanol	130.23	2.73	24.6 18.1 (M)	0.8±0.1	-25.50 -70 (M)	1379 880 (M)	188.52 184.6 (M)	15.05
6	2-Propyl-1-pentanol	130.23	2.73	19.5	0.8±0.1	-25.50	1379	188.52	15.05
7	2-Methyl-1-octanol	144.26	3.22	5.88	0.8±0.1	-14.04	459.7	208.49	15.09
8	2-Ethyl-1-octanol	158.29	3.71	1.81	0.8±0.1	-2.83	151.8	227.56	15.09
9	2-Propylheptan-1-ol	158.29	3.71	3.38	0.8±0.1	-2.83	151.8	227.56 217.5 (M)	15.09

ID	Name	Molecular Weight[1]	Log Kow[1a]	Vapor Pressure (Pa, 25 degC)[1b]	Density[2] (g/cm^3)	Melting Point (deg C)[1b]	Water Solubility (mg/L, 25 degC) [1c]	Boiling Point (deg C)[1b]	pKa[3]
10	2-Methyl-1-undecanol	186.34	4.70	0.186	0.8±0.1	18.78	16.18	262.99	15.04
11	2-Ethyl-1-decanol	186.34	4.70	0.186	0.8±0.1	18.78	16.18	262.99	15.04
12	2-Propyl-1-decanol	200.37	5.19	0.0615	0.8±0.1	29.19	5.237	279.35	15.06

M = measured value

[1]Values typically derived from EPISuite v4.1, [a] KOWWIN Program (v1.68), [b] MPBPWIN v1.43, [c] at 25 deg C; (mg/L) Kow (WSKOW v1.42); [2] ACD/Lab Percepta Platform - PhysChem Module (from ChemSpider); [3] Predicted by ACD (Advanced Chemistry Development Inc., Toronto, Canada)

Table 3: Comparison of Substituents, Functional Groups, and Extended Structural Fragments

ID	Name	Key Substituent(s)	Functional Group(s)	Extended Fragment(s)	Chemical Class	Chemical Sub-Class
1	2-Methyl-1-butanol	-OH	$-CH_3$, $-CH_2-$, -CH-	–	saturated aliphatic alcohols	2-alkyl-1-alkanol
2	2-Methyl-1-pentanol	-OH	$-CH_3$, $-CH_2-$, -CH-	–	saturated aliphatic alcohols	2-alkyl-1-alkanol
3	2-Ethyl-1-butanol	-OH	$-CH_3$, $-CH_2-$, -CH-	–	saturated aliphatic alcohols	2-alkyl-1-alkanol
4	2-Ethyl-1-pentanol	-OH	$-CH_3$, $-CH_2-$, -CH-	–	saturated aliphatic alcohols	2-alkyl-1-alkanol
5	2-Ethyl-1-hexanol	-OH	$-CH_3$, $-CH_2-$, -CH-	–	saturated aliphatic alcohols	2-alkyl-1-alkanol
6	2-Propyl-1-pentanol	-OH	$-CH_3$, $-CH_2-$, -CH-	–	saturated aliphatic alcohols	2-alkyl-1-alkanol
7	2-Methyl-1-octanol	-OH	$-CH_3$, $-CH_2-$, -CH-	–	saturated aliphatic alcohols	2-alkyl-1-alkanol
8	2-Ethyl-1-octanol	-OH	$-CH_3$, $-CH_2-$, -CH-	–	saturated aliphatic alcohols	2-alkyl-1-alkanol
9	2-Propylheptan-1-ol	-OH	$-CH_3$, $-CH_2-$, -CH-	–	saturated aliphatic alcohols	2-alkyl-1-alkanol
10	2-Methyl-1-undecanol	-OH	$-CH_3$, $-CH_2-$, -CH-	–	saturated aliphatic alcohols	2-alkyl-1-alkanol

ID	Name	Key Substituent(s)	Functional Group(s)	Extended Fragment(s)	Chemical Class	Chemical Sub-Class
11	2-Ethyl-1-decanol	-OH	$-CH_3$, $-CH_2-$, -CH-	–	saturated aliphatic alcohols	2-alkyl-1-alkanol
12	2-Propyl-1-decanol	-OH	$-CH_3$, $-CH_2-$, -CH-	–	saturated aliphatic alcohols	2-alkyl-1-alkanol

Table 4: Comparison of Abiotic Transformation and Toxicokinetics

ID	Name	Abiotic Transformation	Toxicokinetics		
			Absorption	Half-life	Elimination
1	2-Methyl-1-butanol		Efficiently following oral administration[a]	< 24 hrs	9.6% excreted in the urine as a glucuronides within 24 hrs[b] 5.6% excreted in air and 2% in urine, remainder metabolized, first to the corresponding aldehyde, then to the acid [c] Additional oxidation of 2-methyl-1-butanol by rat liver microsomes via CYP P450 enzymes, and glucuronidation[d]
2	2-Methyl-1-pentanol		Efficiently following oral administration [a]		
3	2-Ethyl-1-butanol		Efficiently following oral administration [a]		Excreted mainly as a glucuronides[e]
4	2-Ethyl-1-pentanol		Efficiently following oral administration [a]		

5	2-Ethyl-1-hexanol	atmospheric lifetime of 24.6 hrs	Efficiently following oral administration[a]	< 24 hrs terminal half-life 60 hours	Rapidly excreted in respired CO_2 (6-7%), urine mainly as glucuronides (80-82%), and faeces (8-9%); elimination was essentially complete by 28 hrs[f] After oral administration to rats, within 96 hrs; 69-75% excreted in urine, about 13-15% in faeces, about the same amount exhaled. After intravenous administration to rats, within 96 hours about 74% excreted in urine, about 4% in faeces and 23% exhaled. More than 50% excreted within 8 hrs.[g] Glucuronide main metabolite (87%) in rabbits [b,e]
6	2-Propyl-1-pentanol		Efficiently following oral administration [a]		
7	2-Methyl-1-octanol		Efficiently following oral administration [a]		
8	2-Ethyl-1-octanol		Efficiently following oral administration [a]		
9	2-Propyl-1heptanol		Efficiently following oral administration [a]		
10	2-Methyl-1-undecanol		Efficiently following oral administration[a]		

11	2-Ethyl-1-decanol		Efficiently following oral administration[a]		
12	2-Propyl-1-decanol		Efficiently following oral administration[a]		

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Table 5: Comparison of Potential Metabolic Products as Predicted *in silico*

ID	Name	Liver metabolism simulator Toolbox v3.3		MetaPrint2D-React software	SMARTCyp version 2.4.2	Meteor Nexus
		Rat liver S9	Skin metabolism			
1	2-Methyl-1-butanol	Hydroxylation (3) Oxidation (1)	Hydroxylation (3)	Hydroxylation Oxidation Acylation	Possible sites of metabolism have been identified	Hydroxylation (4) Oxidation (1)
2	2-Methyl-1-pentanol	Hydroxylation (2) Oxidation (1)	Hydroxylation (1)	Hydroxylation Oxidation Acylation Methylation Dealkylation	Possible sites of metabolism have been identified	Hydroxylation (2) Oxidation (1)
3	2-Ethyl-1-butanol	Hydroxylation (2) Oxidation (1)	Hydroxylation (2)	Hydroxylation Oxidation Acylation Dealkylation	Possible sites of metabolism have been identified	Hydroxylation (3) Oxidation (1)
4	2-Ethyl-1-pentanol	Hydroxylation (4) Oxidation (1)	Hydroxylation (3)	Hydroxylation Oxidation Acylation Dehydroxylation Methylation Alkylation Dealkylation	Possible sites of metabolism have been identified	Hydroxylation (4) Oxidation (1)
5	2-Ethyl-1-hexanol	Hydroxylation (4) Oxidation (1)	Hydroxylation (4)	Hydroxylation Oxidation Acylation Methylation Alkylation Dealkylation Dehydration Demethylation	Possible sites of metabolism have been identified	Hydroxylation (6) Oxidation (1)

ID	Name	Liver metabolism simulator Toolbox v3.3		MetaPrint2D-React software	SMARTCyp version 2.4.2	Meteor Nexus
		Rat liver S9	Skin metabolism			
6	2-Propyl-1-pentanol	Hydroxylation (2) Oxidation (1)	Hydroxylation (4)	Hydroxylation Oxidation Acylation Dehydroxylation Methylation Dealkylation Dehydration Demethylation	Possible sites of metabolism have been identified	Hydroxylation (2) Oxidation (1) beta-Oxidation of Carboxylic Acids (1)
7	2-Methyl-1-octanol	Hydroxylation (3) Oxidation (1)	Hydroxylation (3)	Hydroxylation Oxidation Methylation Dealkylation Demethylation Alkylation Acylation	Possible sites of metabolism have been identified	Hydroxylation (5) Oxidation (1)
8	2-Ethyl-1-octanol	Hydroxylation (4) Oxidation (1)	Hydroxylation (4)	Hydroxylation Oxidation Methylation Dealkylation Dehydration Demethylation Alkylation Acylation	Possible sites of metabolism have been identified	Hydroxylation (6) Oxidation (1)
9	2-Propyl-1-heptanol	Hydroxylation (4) Oxidation (1)	Hydroxylation (4)	Hydroxylation Oxidation Acylation Methylation Alkylation Dealkylation Dehydration Demethylation	Possible sites of metabolism have been identified	Hydroxylation (7) Oxidation (1)
10	2-Methyl-1-undecanol	Hydroxylation	Hydroxylation (3)	Hydroxylation	Possible sites of	Hydroxylation (5)

ID	Name	Liver metabolism simulator Toolbox v3.3		MetaPrint2D-React software	SMARTCyp version 2.4.2	Meteor Nexus
		Rat liver S9	**Skin metabolism**			
		(3) Oxidation (1)		Oxidation Acylation Methylation Alkylation Dealkylation Demethylation	metabolism have been identified	Oxidation (1)
11	2-Ethyl-1-decanol	Hydroxylation (4) Oxidation (1)	Hydroxylation (3)	Hydroxylation Oxidation Acylation Dehydroxylation Methylation Dealkylation Dehydration Demethylation	Possible sites of metabolism have been identified	Hydroxylation (4) Oxidation (1)
12	2-Propyl-1-decanol	Hydroxylation (3) Oxidation (1)	Hydroxylation (1)	Hydroxylation Oxidation Acylation Dehydroxylation Methylation Dehydration	Possible sites of metabolism have been identified	Hydroxylation (3) Oxidation (1)

Table 6: Comparison of Toxicophores

ID	Name	Toxicophores[1]	DNA binding by OECD[1]	Protein binding by OECD[1]	Nuclear receptor binding[2]	Liver& Mitochondria toxicity[2]
1	2-Methyl-1-butanol	Cramer Class I	No alert	No alert	Inactive	No alert
2	2-Methyl-1-pentanol	Cramer Class I	No alert	No alert	Inactive	No alert
3	2-Ethyl-1-butanol	Cramer Class I	No alert	No alert	Inactive	No alert
4	2-Ethyl-1-pentanol	Cramer Class I	No alert	No alert	Inactive	No alert
5	2-Ethyl-1-hexanol	Cramer Class I	No alert	No alert	Inactive	No alert
6	2-Propyl-1-pentanol	Cramer Class I	No alert	No alert	Inactive	No alert
7	2-Methyl-1-octanol	Cramer Class I	No alert	No alert	Inactive	No alert
8	2-Ethyl-1-octanol	Cramer Class I	No alert	No alert	Inactive	No alert
9	2-Propyl-1-heptanol	Cramer Class I	No alert	No alert	Inactive	No alert
10	2-Methyl-1-undecanol	Cramer Class I	No alert	No alert	Inactive	No alert
11	2-Ethyl-1-decanol	Cramer Class I	No alert	No alert	Inactive	No alert
12	2-Propyl-1-decanol	Cramer Class I	No alert	No alert	Inactive	No alert

[1] OECD QSAR Toolbox 3.3; [2] COSMOS profilers available via COSMOS space: http://cosmosspace.cosmostox.eu

Table 7: Comparison of Mechanistic Plausibility and AOP-Related Event Data

ID	Name	Mechanistic Plausibility	Adverse Outcome Pathway or Mode of Toxic Action:	Molecular Initiating Event:	Key Event 1 etc.	Key Event Relationship 1 etc.	Other Mechanistically-Relevant Events
1	2-Methyl-1-butanol		Narcosis - depressant anesthesia	Unspecific interactions with biological membranes			
2	2-Methyl-1-pentanol		narcosis - depressant anesthesia	Unspecific interactions with biological membranes			
3	2-Ethyl-1-butanol		narcosis - depressant anesthesia	Unspecific interactions with biological membranes			
4	2-Ethyl-1-pentanol		narcosis - depressant anesthesia	Unspecific interactions with biological membranes			
5	2-Ethyl-1-hexanol		narcosis - depressant anesthesia	Unspecific interactions with biological membranes			

ID	Name	Mechanistic Plausibility	Adverse Outcome Pathway or Mode of Toxic Action:	Molecular Initiating Event:	Key Event 1 etc.	Key Event Relationship 1 etc.	Other Mechanistically-Relevant Events
6	2-Propyl-1-pentanol		narcosis - depressant anesthesia	Unspecific interactions with biological membranes			
7	2-Methyl-1-octanol		narcosis - depressant anesthesia	Unspecific interactions with biological membranes			
8	2-Ethyl-1-octanol		narcosis - depressant anesthesia	Unspecific interactions with biological membranes			
9	2-Propyl-1-heptanol		narcosis - depressant anesthesia	Unspecific interactions with biological membranes			
10	2-Methyl-1-undecanol		narcosis - depressant anesthesia	Unspecific interactions with biological membranes			

ID	Name	Mechanistic Plausibility	Adverse Outcome Pathway or Mode of Toxic Action:	Molecular Initiating Event:	Key Event 1 etc.	Key Event Relationship 1 etc.	Other Mechanistically-Relevant Events
11	2-Ethyl-1-decanol		narcosis - depressant anesthesia	Unspecific interactions with biological membranes			
12	2-Propyl-1-decanol		narcosis - depressant anesthesia	Unspecific interactions with biological membranes			

Table 8: Comparison of Toxicologically Relevant *in vivo, in vitro* and *ex vivo* Data

Name	2-Methyl-1-butanol	2-Methyl-1-pentanol	2-Ethyl-1-butanol	2-Ethyl-1-pentanol	2-Ethyl-1-hexanol	2-Propyl-1-pentanol	2-Methyl-1-octanol	2-Ethyl-1-octanol	2-Propyl-1-heptanol	2-Methyl-1-undecanol	2-Ethyl-1-decanol	2-Propyl-1-decanol
Endpoint: NOAEL (Repeat dose toxicity)					25-1000 (mg/kg/d) [2, 3, 5, 22]				30-150 (mg/kg/d) [4, 21]			
Endpoint: NOEL (Repeat dose toxicity)	≥6400 (mg/m^3) [1]											
Endpoint: NOAEL (short-term repeated dose study)					100-200 (mg/kg bw/d) [5, 23-26]							
Endpoint: LOAEL (Repeat dose toxicity)					1525 (mg/kg/d) [5]				150-600 (mg/kg/d) [4]			
Endpoint: NOAEC (Repeat dose toxicity)					120-638.4 (mg/kg/d) [6]							
Endpoint: NOAEL (Reproductive toxicity)					130-2520 (mg/kg/d) [6]				50 (mg/kg/d) [7]			
Endpoint: NOAEL (Teratogenicity)					191-650 (mg/kg/d) [6]				158-600 (mg/kg/d) [7]			
Endpoint: HNEL (Carcinogenic/ Genotoxicity)					50-200 (mg/kg/d) [8]							
Endpoint: LEL					150-750 (mg/kg/d)							

(Carcinogenic/ Genotoxicity)						[8]							
Endpoint: LC50 (Acute toxicity)						0.89- 5.3 (mg/Lair) [6]				>0.13(mg/L air) [7]			
Endpoint: LD50 (Acute toxicity)		1900-5000 (mg/kg) 12.53-16.6 (mg/Lair) 3.54 (mL/kg) [1, 9]				3730 (mg/kg) [6, 10, 11]				5100-5400 (mg/kg) [7]			
Endpoint: oral LD50 (mg/kg) (Acute toxicity)		4010 mg/kg bw [17]		1850 mg/kg bw [18]		2000-3730 mg/kg bw [5, 19-20]				5400 mg/kg bw [21]			
Endpoint: LDLo (Acute toxicity)		1900- 2448 (mg/kg) [1, 12]											
Endpoint: Genotoxicity (AMES, Chromosomal abrration, gene mutation)		2 x Negative [13-16]				9 x Negative [5]				5 x Negative [4]			
Toxcast [27]	ATG_ERa_TRANS					11.9							
	ATG_ERa_TRANS_perc					5.77							
	ATG_PXRE_CIS					31.1							
	ATG_PXRE_CIS_perc					31.1							
	OT_ERa_ERELUC_AG_1440									3.14			
	Tox21_AR_BLA_Agonist_ch1									0.00219			

	Tox21_ELG1_LUC_Agonist_viability									54.9			

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