Identification of Surrogate Reference Chemicals for Volatile Organic Compounds Commonly Encountered at Hazardous Waste Sites†

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ABSTRACT

The USEPA has derived reference concentrations (RfCs) for many volatile organic compounds (VOCs) to quantify potential noncarcinogenic human health hazards for purposes of risk assessment. For VOCs that have not been assigned an RfC (or other regulatory equivalent), the previous convention was to extrapolate the oral reference dose to an inhalation reference dose. While this practice was tenuous from a toxicological standpoint, data gaps necessitated such an approach to assess human health hazards for VOCs encountered at hazardous waste sites. In 2009, the USEPA revised the methodology used to quantify potential inhalation health hazards to be consistent with the inhalation dosimetry methodology, for which the exposure metric is concentration of the chemical in air (e.g., mg/m^3), rather than inhalation intake of the chemical as a dose (e.g., mg/kg-day). This effectively eliminated the ability to use extrapolated inhalation RfDs, thereby limiting VOC inhalation hazard index calculations to only those VOCs with RfCs (or other regulatory equivalent) derived from inhalation studies. This reduced the number of VOCs that could be quantitatively assessed from over 100 to approximately 50. The Nevada Division of Environmental Protection (NDEP), in an effort to expand the quantification of health hazards from VOCs, recently employed a toxicological surrogate approach to identify RfCs for 36 chemicals. The identification of toxicological surrogates was based on available dose-response data and structural similarity and supported in some cases by metabolism data. The surrogate-based RfCs were used by NDEP to derive inhalation-based Basic Comparison Levels (BCLs), which are risk-based screening levels. The surrogate-based RfCs and their derivation are described in this presentation.

METHODS

Inhalation is the primary exposure pathway for VOCs, which are generally assessed using EPA Method 8260B or TO-15. Currently there are a number of VOCs reported by these analytical methods for which a reference concentration (RfC) is not listed in the Integrated Risk Information System (IRIS; USEPA, 2011) or other toxicity criteria sources (USEPA, 2003). The lack of inhalation toxicity criteria for these chemicals results in the inability to quantitatively assess risk/hazard and the potential for underestimation of cumulative risk/hazard. To rectify this, the Nevada Division of Environmental Protection (NDEP) initiated a study to identify noncancer toxicological surrogates for these VOCs. To determine if a chemical would be included in the study, the following criteria were considered:

1. The chemical is currently on the BCL* list for non-inhalation pathways;
2. The chemical is defined as a VOC based on molecular weight and Henry's Law Constant‡; and
3. The chemical is included on the EPA Method 8260B and/or TO-15 analytical list.

* The NDEP currently has a listing of generic soil, air and water screening levels termed Basic Comparison Levels (BCLs; NDEP, 2011).

‡ USEPA defines a chemical as a VOC if it has a molecular weight of 200 grams/mole or less and a Henry's Law Constant greater than 10^{-5} atm-m^3/mol (USEPA, 2002).

Using these criteria, 36 VOCs were identified as needing RfCs (see Table 1). The chemicals were initially sorted by chemical class to allow for toxicological surrogate selection for multiple chemicals simulataneously. The initial sorting resulted in three chemicals classes and "other" VOCs that did not fall into mutual classes. The selection of surrogate chemicals is discussed further below.

Table 1
Surrogate Inhalation Toxicity Criteria for Volatile Organic Compounds

Chemical Constituent	CAS	Chemical Surrogate	Surrogate CAS	Surrogate RfC (mg/m^3)	Surrogate Criterion Source
Acetophenone	98-86-2	Isopropylbenzene (Cumene)	98-82-8	4.00E-01	USEPA, 2010a
Benzaldehyde	100-52-7	Isopropylbenzene (Cumene)	98-82-8	4.00E-01	USEPA, 2010a
Bromodichloromethane	75-27-4	Dichloromethane	75-09-2	1.00E+00	ATSDR, 2010
n-Butylbenzene	104-51-8	Isopropylbenzene (Cumene)	98-82-8	4.00E-01	USEPA, 2010a
sec-Butylbenzene	135-98-8	Isopropylbenzene (Cumene)	98-82-8	4.00E-01	USEPA, 2010a
tert-Butylbenzene	98-06-6	Isopropylbenzene (Cumene)	98-82-8	4.00E-01	USEPA, 2010a
1-Chlorobutane	109-69-3	Ethyl chloride	75-00-3	1.00E+01	USEPA, 2010a
2-Chlorophenol	95-57-8	Chlorobenzene	108-90-7	5.00E-02	PPRTV (USEPA, 2010b)
o-Chlorotoluene	95-49-8	Chlorobenzene	108-90-7	5.00E-02	PPRTV (USEPA, 2010b)
1,2-Dichloroethylene (cis)	156-59-2	trans-1,2-Dichloroethylene	156-60-5	6.00E-02	PPRTV (USEPA, 2010b)
1,3-Dichloropropane	142-28-9	1,2-Dichloropropane	78-87-5	4.00E-03	USEPA, 2010a
N-N-Dimethylaniline	121-69-7	Aniline	62-53-3	1.00E-03	USEPA, 2010a
Ethyl acetate	141-78-6	Methyl methacrylate	80-62-6	7.00E-01	USEPA, 2010a
Ethyl ether	60-29-7	Methyl tert-Butyl Ether (MTBE)	1634-04-4	3.00E+00	USEPA, 2010a
Ethyl methacrylate	97-63-2	Methyl methacrylate	80-62-6	7.00E-01	USEPA, 2010a
Furan	110-00-9	Tetrahydrofuran	109-99-9	3.50E-02	RIVM (TERA 2010)
Isobutyl alcohol (Isobutanol)	78-83-1	sec-Butyl Alcohol	78-92-2	3.00E+01	PPRTV (USEPA, 2010b)
Methyl acetate	79-20-9	Methyl methacrylate	80-62-6	7.00E-01	USEPA, 2010a
Methyl acrylate	96-33-3	Methyl methacrylate	80-62-6	7.00E-01	USEPA, 2010a
Methyl styrene (alpha)	98-83-9	Styrene	100-42-5	1.00E+00	USEPA, 2010a
Polynuclear Aromatic Hydrocarbons	--	--	--	--	--
Acenaphthene	83-32-9	Naphthalene	91-20-3	3.00E-03	USEPA, 2010a
Acenaphthylene	208-96-8	Naphthalene	91-20-3	3.00E-03	USEPA, 2010a
Anthracene	120-12-7	Naphthalene	91-20-3	3.00E-03	USEPA, 2010a
Fluorene	86-73-7	Naphthalene	91-20-3	3.00E-03	USEPA, 2010a
Phenanthrene	85-01-8	Naphthalene	91-20-3	3.00E-03	USEPA, 2010a
Pyrene	129-00-0	Naphthalene	91-20-3	3.00E-03	USEPA, 2010a
n-Propylbenzene	103-65-1	Isopropylbenzene (Cumene)	98-82-8	4.00E-01	USEPA, 2010a
1,1,2-Trichloropropane	598-77-6	1,2,3-Trichloropropane	96-18-4	3.00E-04	USEPA, 2010a
1,3-Dichlorobenzene	541-73-1	1,2-Dichlorobenzene	95-50-1	2.00E-01	HEAST
4-Isopropyltoluene	99-87-6	Isopropylbenzene (Cumene)	98-82-8	4.00E-01	USEPA, 2010a
1,3,5-Trimethyl Benzene	108-67-8	1,2,4-Trimethylbenzene	95-63-6	7.00E-03	PPRTV (USEPA, 2010b)
para-Ethyltoluene	622-96-8	Isopropylbenzene (Cumene)	98-82-8	4.00E-01	USEPA, 2010a
Isobutylbenzene	538-93-2	Isopropylbenzene (Cumene)	98-82-8	4.00E-01	USEPA, 2010a
Isopropyl Alcohol	67-63-0	sec-Butyl Alcohol	78-92-2	3.00E+01	PPRTV (USEPA, 2010b)
tert-Butyl Alcohol	75-65-0	sec-Butyl Alcohol	78-92-2	3.00E+01	PPRTV (USEPA, 2010b)
n-Butyl Alcohol (1-Butanol)	71-36-3	sec-Butyl Alcohol	78-92-2	3.00E+01	PPRTV (USEPA, 2010b)
Propyl Alcohol	71-23-8	sec-Butyl Alcohol	78-92-2	3.00E+01	PPRTV (USEPA, 2010b)

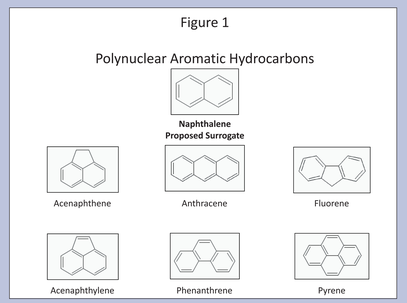
USEPA 2010a. Integrated Risk Information System. http://www.epa.gov/ncea/iris/index.html
USEPA 2010b. Regional Screening Table. http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm
RIVM; National Institute of Public Health and the Environment, the Netherlands as compiled by TERA 2010. http://www.tera.org/ITER/index.html

Polynuclear Aromatic Hydrocarbons

Polynuclear aromatic hydrocarbons (PAHs) that are defined as volatile are acenaphthene, acenaphthylene, anthracene, fluorine, phenanthrene, and pyrene. The toxicological surrogate for these PAHs was identified as naphthalene, as this is the only PAH currently assigned an RfC (USEPA, 2011) (Figure 1).

Figure 1

Polynuclear Aromatic Hydrocarbons

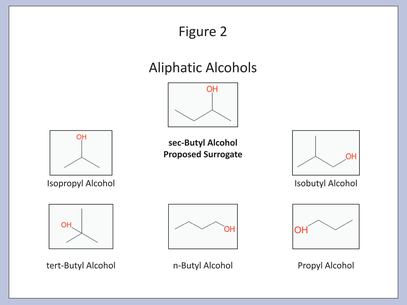


Aliphatic Alcohols

The aliphatic alcohols in need of chemical surrogates included isopropyl alcohol, tert-butyl alcohol, n-butyl alcohol, isobutyl alcohol, and propyl alcohol. For these, sec-butyl alcohol was selected as the surrogate chemical based upon similar structure, toxicity endpoints, effect levels, and metabolism (Veenstra et al, 2009; USEPA, 2005; OECD, 2001; USEPA, 1995) (Figure 2).

Figure 2

Aliphatic Alcohols

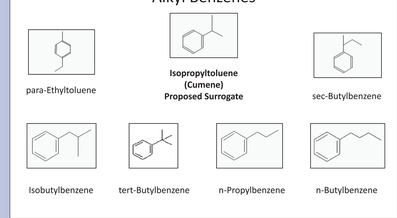


Alkyl Benzenes

Six alkyl benzenes required chemical surrogates: para-ethyltoluene, isobutylbenzene, tert-butylbenzene, n-propylbenzene, sec-butylbenzene, and n-butylbenzene. Isopropyltoluene (more commonly known as cumene) was identified as a reasonable health protective surrogate chemical based upon structure, toxicity endpoints, and limited metabolism data (USEPA, 2011; ATSDR, 2000, 2007, 2010; Tardif et al., 1997; CalEPA/OEHHA, 2000; Smith et al., 1953) (Figure 3).

Figure 3

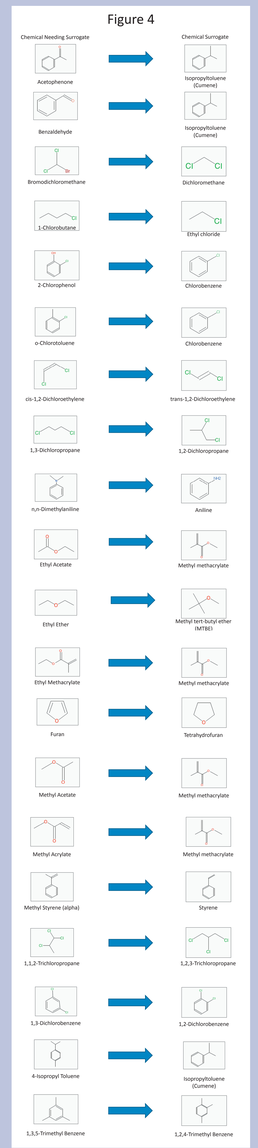
Alkyl Benzenes



Other VOCs

The remaining 20 VOCs, which did not fall into chemical class groups, were examined on an individual basis to determine which chemical would be best suited as a toxicological surrogate. These chemicals and their surrogates are provided in Figure 4. The primary basis for the selection of toxicological surrogates was structural similarity as toxicity data were unavailable or limited for these VOCs.

Figure 4



RESULTS

Table 1 lists the VOCs lacking inhalation toxicity criteria and the selected toxicological surrogates.

DISCUSSION

The methodology proscribed in USEPA Risk Assessment Guidance for Superfund Part F (USEPA, 2009) relies solely upon inhalation RfCs such that many VOCs previously quantified in human health risk assessments via route extrapolation can no longer be evaluated in that manner. In the absence of inhalation toxicity criteria from USEPA and other toxicological databases, many risk assessors and risk managers were at a loss on a quantitative means of addressing potential noncarcinogenic health impacts and were often left with just a qualitative analysis. This has been especially noticed by regulators in Nevada where one area in particular has been heavily impacted with various VOCs. Therefore the NDEP has required the responsible parties (RPs) to propose surrogate-based RfCs for those site-related chemicals currently lacking inhalation toxicity criteria. To streamline the process and to ensure consistency of regulatory enforcement, the NDEP has recently issued a listing of surrogate RfCs for application to commonly encountered VOCs. Should the use of surrogate-based RfCs result in an exceedance of an inhalation hazard index of 1, then additional assessment may be warranted.

As for other aspects of the BCLs, the surrogate-based RfCs will be periodically updated as new toxicity information becomes available. For now though, these surrogates provide a screening approach in which potential human health hazards may be quantitatively addressed. The BCLs may be found on the world wide web: http://ndep.nv.gov/bmi/technical.htm#risk
and: Guidance document: http://ndep.nv.gov/bmi/docs/bcl_guidance_document_january_2011.pdf
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