



CHEMICAL UPDATE WORKSHEET

Chemical Name:	Benzene
CAS #:	71-43-2
Revised By:	RRD Toxicology Unit
Revision Date:	December 4, 2015

(A) Chemical-Physical Properties

	Part 201 Value	Updated Value	Reference Source	Comments
Molecular Weight (g/mol)	78.11	78.11	EPI	EXP
Physical State at ambient temp	Liquid	Liquid	MDEQ	
Melting Point (°C)	279	5.50	EPI	EXP
Boiling Point (°C)	80	80.00	EPI	EXP
Solubility (ug/L)	1.75E+6	1.790E+06	EPI	EXP
Vapor Pressure (mmHg at 25°C)	91.2	9.48E+01	EPI	EXP
HLC (atm-m³/mol at 25°C)	5.55E-3	5.55E-03	EPI	EXP
Log Kow (log P; octanol-water)	2.13	2.13	EPI	EXP
Koc (organic carbon; L/Kg)	58.2	145.8	EPI	EST
Ionizing Koc (L/kg)		NR	NA	NA
Diffusivity in Air (Di; cm²/s)	0.088	8.95E-02	W9	EST
Diffusivity in Water (Dw; cm²/s)	9.8E-6	1.0264E-05	W9	EST
Soil Water Partition Coefficient (Kd; inorganics)	NR	NR	NA	NA

	Part 201 Value	Updated Value	Reference Source	Comments
Flash Point (°C)	12 F	-11	CRC	EXP
Lower Explosivity Level (LEL; unit less)	0.012	0.012	CRC	EXP
Critical Temperature (K)		562.16	EPA2001	EXP
Enthalpy of Vaporization (cal/mol)		7.34E+03	EPA2001	EXP
Density (g/mL, g/cm ³)		0.8765	CRC	EXP
EMSOFT Flux Residential 2 m (mg/day/cm ²)	2.63E-05	2.75E-05	EMSOFT	EST
EMSOFT Flux Residential 5 m (mg/day/cm ²)	6.15E-05	6.52E-05	EMSOFT	EST
EMSOFT Flux Nonresidential 2 m (mg/day/cm ²)	3.72E-05	4.36E-05	EMSOFT	EST
EMSOFT Flux Nonresidential 5 m (mg/day/cm ²)	8.60E-05	1.02E-04	EMSOFT	EST

(B) Toxicity Values/Benchmarks

	Part 201 Value	Updated Value	Source/Reference/Date	Comments/Notes/Issues
Reference Dose (RfD) (mg/kg/day)	--	5.0E-4	ATSDR, 2007	Complete
RfD details	NA	<p>Tier 2 Source: ATSDR: Basis: ATSDR is more current than IRIS. ATSDR (December, 2014), chronic oral MRL = 0.0005 (5.0E-4) mg/kg-day. Critical Study: Lan Q, Zhang L, Li G, et al. 2004a. Hematotoxicity in workers exposed to low levels of benzene. Science 306:1774-1776. Methods: based on route-to-route extrapolation of the results of benchmark dose analysis of a hematological endpoint (B cell count) assessed in 250 workers (approximately two-thirds female) exposed to (inhalation) benzene at two shoe manufacturing facilities in Tianjin, China, and 140 age- and gender-matched workers in clothing manufacturing facilities that did not use benzene. Critical effect: decreased B cell count End point or Point of Departure (POD): $BMCL_{0.25sdADJ} = 0.014$ mg/kg/day (the $BMCL_{0.25sdADJ}$ of 0.096 mg/m3 for inhaled benzene was converted to an equivalent $BMDL_{0.25sdADJ}$ for ingested benzene using EPA (1988b) human reference values for inhalation rate (20 m3/day) and body weight (70 kg) and a factor of 0.5 to adjust for differences in absorption of benzene following inhalation versus oral exposure (50 versus 100%, respectively) Uncertainty Factors: UF = 30; 10 for intraspecies (human) variability and 3 for uncertainty in route-to-route extrapolation Source and date: ATSDR, 08/2007. From 12/2014 MRL list.</p> <p>Tier 1 and 2 Sources: IRIS: Per IRIS (4/17/2003), RfD = 4.0E-3 mg/kg-day Critical Study: Rothman, N., G.L. Li, M. Dosemeci, W.E. Bechtold, G.E. Marti, Y.Z. Wang, M. Linet, L.Q. Xi, W. Lu, M.T. Smith, N. Titenko-Holland, L.P. Zhang, W. Blot, S.N. Yin, and R.B. Hayes. 1996. Hematotoxicity among Chinese workers heavily exposed to benzene. Am. J. Ind. Med. 29: 236-246. Method(s): Occupational epidemiologic study; a cross-sectional study of 44</p>		



	Part 201 Value	Updated Value	Source/Reference/Date	Comments/Notes/Issues
		<p>workers exposed to benzene by inhalation and 44 age- and gender-matched unexposed controls. Twenty-one of the 44 subjects in the exposed and control groups were female. Mean (standard deviation) years of occupational exposure to benzene were 6.3 (4.4), with a range of 0.7-16 years. Benzene exposure was monitored by organic vapor passive dosimetry badges worn by each worker for a full work shift on 5 days within a 1-2 week period prior to collection of blood samples.</p> <p>Critical effect: Decreased lymphocyte count</p> <p>End point or Point of Departure (POD): BMDL = 1.2 mg/kg-day (BMDL was derived by route-to-route extrapolation with the assumptions that inhalation absorption was 50% and oral absorption was 100% in the dose range near the BMCL)</p> <p>Uncertainty Factors: UF = 300 (10 for intraspecies variability and 3 each for subchronic to chronic extrapolation, extrapolation from an adverse effect and database deficiency).</p> <p>Source and date: IRIS, Last revision date - 4/17/2003. IRIS Toxicological Review is available.</p> <p>PPRTV: PPRTV (9/29/2009) refers to the IRIS chronic RfD. Subchronic p-RfD = 0.01 mg/kg/day</p> <p>Tier 3 Source:</p> <p>MDEQ: Per DEQ-CCD, no value at this time.</p>		
Oral Cancer Slope Factor (CSF) (mg/kg-day)⁻¹	2.9E-2	5.5E-2	IRIS, 2000	
CSF details	Class A one-hit (pooled data); Occupational exposure (inhalation) of humans - leukemia. Risk	<p>Tier 1 Source:</p> <p>IRIS:</p> <p>Basis: IRIS is a Tier 1 source. No Tier 2 values.</p> <p>IRIS CSF = 5.5E-2 (mg/kg-day)⁻¹</p> <p>Critical Studies: 1) Rinsky, RA; Young, RJ; Smith, AB. (1981) Leukemia in benzene workers. Am J Ind Med 2:217-245; and 2) Rinsky, RA; Smith, AB; Horning, R; et al. (1987) Benzene and leukemia: an epidemiologic risk assessment. N Engl J Med</p>		Complete



	Part 201 Value	Updated Value	Source/Reference/ Date	Comments/Notes /Issues
	estimate is geometric mean four ML estimates using pooled data. Source - IRIS; CCD date – 10/01/1987	316:1044-1050. Methods: A retrospective cohort mortality study examined the leukemogenic effects of benzene exposure in 748 white male workers exposed at least 1 day while employed in the manufacture of rubber products (Infante et al., 1977). Rinsky et al. (1981) extended the analysis of the Infante et al. (1977) data and reported seven deaths from leukemia in this same cohort after achieving a 98% vital status ascertainment through June 1975. In an updated version of the Rinsky et al. (1981) study, an expanded cohort of 1165 nonsalaried white men employed in the rubber hydrochloride department were studied for at least 1 day through December 1965 and followed to December 31, 1981 (Rinsky et al., 1987). 1) <i>Dose response data:</i> Tumor Type - leukemia; Test Species - human; Route - inhalation, occupational exposure 2) <i>Extrapolation method:</i> Linear extrapolation of human occupational data Carcinogen Weight-of-Evidence (WOE) Class: A, known human carcinogen for all routes of exposure IRIS WOE Basis: convincing human evidence as well as supporting evidence from animal studies Source and Date: IRIS, Last revision date - 1/09/2000. IRIS Toxicological Review is available. Tier 1 and 2 Sources: PPRTV: PPRTV (9/29/2009) refers to the IRIS value. MRL: NA; MRLs are for non-cancer effects only. Tier 3 Source: MDEQ: Per DEQ-CCD, CSF = 2.9E-2 (mg/kg-day) ⁻¹ . Refer to Part 201 Value CSF details.		
Reference Concentration (RfC) or Initial Threshold Screening Level	3.0E+1	1.0E+1	ATSDR, 2007	



	Part 201 Value	Updated Value	Source/Reference/Date	Comments/Notes/Issues
(ITSL) (µg/m³)				
RfC/ITSL details	<p>NA based on EPA IRIS RfC; AQD: EPA's RfC is based on Rothman et al (1996) human occupationally exposure study - where decreased lymphocyte counts were observed. BMCL(adj) = 8.2 mg/m³. UF of 300 was applied to obtain 30 µg/m³.</p>	<p>Tier 2 Source: ATSDR: Basis: ATSDR is based on a more current study than IRIS. ATSDR chronic inhalation MRL/RfC = 0.01 mg/m³ (1.0E+1 µg/m³) MRL: Per ATSDR (08/2007), chronic inhalation MRL = 0.003 ppm or 0.01 mg/m³: Critical Study: Lan Q, Zhang L, Li G, et al. 2004a. Hematotoxicity in workers exposed to low levels of benzene. Science 306:1774-1776. Method(s): cross-sectional study on 250 workers (approximately two-thirds female) exposed to benzene at two shoe manufacturing facilities in Tianjin, China, and 140 age- and gender-matched workers in clothing manufacturing facilities that did not use benzene. The benzene exposed workers had been employed for an average of 6.1±2.9 years. Benzene exposure was monitored by individual organic vapor monitors (full shift) 5 or more times during 16 months prior to phlebotomy. Critical effect: decreased B cell count End point or Point of Departure (POD): BMCL_{0.25sdADJ} = 0.03 ppm Uncertainty Factors: UF = 10 for intraspecies (human) variability Source and date: ATSDR, 08/2007. From 12/2014 MRL list.</p> <p>Tier 1 and 2 Sources: IRIS: IRIS RfC = 3.0E+1 µg/m³ Critical Study: Rothman, et al. 1996. Hematotoxicity among Chinese workers heavily exposed to benzene. Am. J. Ind. Med. 29: 236-246. Methods: Occupational epidemiologic study. Critical effect: Decreased lymphocyte count End point or Point of Departure (POD): BMCL = 8.2 mg/m³ Uncertainty Factors: UF = 300 (10 for intraspecies variability and 3 each for subchronic to chronic extrapolation, extrapolation from an adverse effect and database deficiency). Source and date: IRIS, Last revision date - 4/17/2003. IRIS Toxicological Review is available.</p>		Complete



	Part 201 Value	Updated Value	Source/Reference/Date	Comments/Notes/Issues
		<p>PPRTV: PPRTV (9/29/2009) refers to the IRIS value. .</p> <p>Tier 3 Source: MDEQ: Per DEQ-CCD (2/06/2012), AQD adopted the IRIS value. The IRIS RfC = 30 $\mu\text{g}/\text{m}^3$ is assigned an annual averaging time. An acute ITSL value of is available based on ATSDR's acute-duration inhalation MRL of 0.009 ppm or 30 mg/m^3 is assigned a 24 hour averaging time. The MRL is based on Rozen et al (1984) male C57BL/6J mouse study - where a LOAEL of 10.2 ppm for significant depression of femoral lipopolysaccharide-induced B-colony-forming ability in the absence of a significant depression of total numbers of B cells.</p>		
Inhalation Unit Risk Factor (IURF) ($\mu\text{g}/\text{m}^3$)⁻¹	8.3E-6	7.8E-6	IRIS, 2000	
IURF details	<p>Inhalation potency is based on EPA IRIS reported slope factor of 8.3 E-6 ($\mu\text{g}/\text{m}^3$)⁻¹ for increased rate of leukemias based on geometric mean of four epidemiology studies (Rinsky et al 1981, Ott et al 1978, Wong et al 1983, Rinsky et al 1987). CCD date - 10/09/1987</p>	<p>Tier 1 Source: IRIS: Basis: IRIS is a Tier 1 value and a more recent review than MDEQ. IRIS IURF ranges from 2.2E-6 to 7.8E-6 ($\mu\text{g}/\text{m}^3$)⁻¹. MDEQ applied the high end of the range of IURFs (i.e., 7.8E-6) to both the residential and nonresidential risk based values calculation. Critical Studies: 1) Rinsky, RA; Young, RJ; Smith, AB. (1981) Leukemia in benzene workers. Am J Ind Med 2:217-245; 2) Rinsky, RA; Smith, AB; Horning, R; et al. (1987) Benzene and leukemia: an epidemiologic risk assessment. N Engl J Med 316:1044-1050; and 3) Crump, KS. (1994) Risk of benzene-induced leukemia: a sensitivity analysis of the Ploifilm cohort with additional follow-up and new exposure estimates. J Toxicol Environ Health 42:219-242. Method(s): 1) <i>Dose response data: Tumor Type</i> - leukemia; <i>Test Species</i> - human; <i>Route</i> - inhalation, occupational exposure 2) <i>Extrapolation method:</i> Low-dose linearity utilizing maximum likelihood estimates (Crump, 1992, 1994).</p>		Complete



	Part 201 Value	Updated Value	Source/Reference/ Date	Comments/Notes /Issues
		<p>Carcinogen Weight-of-Evidence (WOE) Class: A, known human carcinogen for all routes of exposure</p> <p>IRIS WOE Basis: convincing human evidence as well as supporting evidence from animal studies</p> <p>Source and Date: IRIS, Last revision date - 1/19/2000. IRIS Toxicological Review is available.</p> <p>Tier 1 and 2 Sources: PPRTV: Per PPRTV (9/29/2009), no value at this time. MRL: NA; MRLs are for non-cancer effects only.</p> <p>Tier 3 Source: MDEQ: Per DEQ-CCD/AQD (1987), IURF = 8.3E-6 (mg/kg-day)⁻¹. Refer to Part 201 Value IURF details</p>		
Mutagenic Mode of Action (MMOA)? (Y/N)	--	NO	USEPA, 2015	
MMOA Details	--	NA Not listed as a carcinogen with mutagenic MOA in the USEPA OSWER List.		
Developmental or Reproductive Effector? (Y/N)	No	No, the RfD is not based on a reproductive-developmental effect. <u>Note:</u> CALEPA's Chemicals Known to the State to Cause Cancer or Reproductive Toxicity List (1/23/2015) cites benzene as a male developmental toxicant.	MDEQ, 2015	
Developmental or Reproductive Toxicity Details	NA	NA		
State Drinking Water Standard (SDWS) (ug/L)	--	5.0	SDWA, 1976	
SDWS details	NA	MI Safe Drinking Water Act (SDWA) 1976 PA 399		



	Part 201 Value	Updated Value	Source/Reference/ Date	Comments/Notes /Issues
Secondary Maximum Contaminant Level (SMCL) (ug/L)	--	NO	SDWA, 1976 and USEPA SMCL List	
SMCL details	NA	MI Safe Drinking Water Act (SDWA) 1976 PA 399 and USEPA SMCL List, 2015		
Is there an aesthetic value for drinking water? (Y/N)	NO	Not evaluated.	NA	
Aesthetic value (ug/L)	--	NA	NA	
Aesthetic Value details		NA		
Phytotoxicity Value? (Y/N)	NO	Not evaluated.	NA	
Phytotoxicity details	NA	NA	NA	
Others	--	--		

(C) Chemical-specific Absorption Factors

	Part 201 Value	Update	Source/Reference/ Dates	Comments/Notes /Issues
Gastrointestinal absorption efficiency value (ABS _{gi})		1.0	MDEQ, 2015/USEPA RAGS-E, 2004	
ABS _{gi} details		MDEQ, 2015/USEPA RAGS-E, 2004		
Skin absorption efficiency value (AE _d)		0.1	MDEQ, 2015	
AE _d details				
Ingestion Absorption Efficiency (AE _i)		1.0	MDEQ, 2015	
AE _i Details				
Relative Source Contribution for Water (RSC _w)		0.2	MDEQ, 2015	
Relative Source Contribution for Soil (RSC _s)		1.0	MDEQ, 2015	
Relative Source Contribution for Air (RSC _A)		1.0	MDEQ, 2015	
Others				

(D) Rule 57 Water Quality Values and GSI Criteria

Current GSI value (µg/L)	200 (X)
Updated GSI value (µg/L)	200 (X)
Rule 57 Drinking Water Value (µg/L)	12

	Rule 57 Value (µg/L)	Verification Date
Human Non-cancer Values- Drinking water source (HNV-drink)	19	07/1997
Human Non-Cancer Values- Non-drinking water sources (HNV-Non-drink)	510	07/1997
Wildlife Value (WV)	NA	NA
Human Cancer Values for Drinking Water Source (HCV-drink)	12	07/1997
Human Cancer values for non-drinking water source (HCV-Non-drink)	310	07/1997
Final Chronic Value (FCV)	200	09/2011
Aquatic maximum value (AMV)	950	09/2011
Final Acute Value (FAV)	1900	09/2011

Sources:

1. MDEQ Surface Water Assessment Section Rule 57 [website](#)
2. MDEQ Rule 57 [table](#)

(E) Target Detection Limits (TDL)

	Value	Source
Target Detection Limit – Soil ($\mu\text{g}/\text{kg}$)	50	MDEQ, 2015
Target Detection Limit – Water ($\mu\text{g}/\text{L}$)	1	MDEQ, 2015
Target Detection Limit – Air (ppbv)	9.70E-01	MDEQ, 2015
Target Detection Limit – Soil Gas (ppbv)	3.20E+01	MDEQ, 2015

CHEMICAL UPDATE WORKSHEET ABBREVIATIONS:

CAS # - Chemical Abstract Service Number.

Section (A) Chemical-Physical Properties**Reference Source(s):**

CRC	Chemical Rubber Company Handbook of Chemistry and Physics, 95th edition, 2014-2015
EMSOFT	USEPA Exposure Model for Soil-Organic Fate and Transport (EMSOFT) (EPA, 2002)
EPA2001	USEPA (2001) Fact Sheet, Correcting the Henry's Law Constant for Soil Temperature. Office of Solid Waste and Emergency Response, Washington, D.C.
EPA4	USEPA (2004) User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings. February 22, 2004.
EPI	USEPA's Estimation Programs Interface SUITE 4.1, Copyright 2000-2012
HSDB	Hazardous Substances Data Bank
MDEQ	Michigan Department of Environmental Quality
NPG	National Institute for Occupational Safety and Health Pocket Guide to Chemical Hazards
PC	National Center for Biotechnology Information's PubChem database
PP	Syracuse Research Corporation's PhysProp database
SCDM	USEPA's Superfund Chemical Data Matrix
SSG	USEPA's Soil Screening Guidance: Technical Background Document, Second Edition, 1996
USEPA/EPA	United States environmental protection agency's Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment). July, 2004.

W9 USEPA's User Guide for Water9 Software, Version 2.0.0, 2001

Basis/Comments:

EST	estimated
EXP	experimental
EXT	extrapolated
NA	not available or not applicable
NR	not relevant

Section (B) Toxicity Values/Benchmarks**Sources/References:**

ATSDR	Agency for Toxic Substances and Disease Registry
CALEPA	California Environmental Protection Agency
CAL DTSC	California Department of Toxic Substances Control
CAL OEHHA	CAEPA Office of Environmental Health Hazard Assessment
CCD	MDEQ Chemical Criteria Database
ECHA	European Chemicals Agency (REACH)
OECD HPV	Organization for Economic Cooperation and Development HPV Database
HEAST	USEPA's Health Effects Assessment Summary Tables
IRIS	USEPA's Integrated Risk Information System
MADEP	Massachusetts Department of Environmental Protection
MDEQ/DEQ	Michigan Department of Environmental Quality
DEQ-CCD/AQD	MDEQ Air Quality Division
DEQ-CCD/RRD	MDEQ Remediation and Redevelopment Division
DEQ-CCD/WRD	MDEQ Water Resources Division
MNDOH	Minnesota Department of Health

NJDEP	New Jersey Department of Environmental Protection
NYDEC	New York State Department of Environmental Conservation
OPP/OPPT	USEPA's Office of Pesticide Programs
PPRTV	USEPA's Provisional Peer Reviewed Toxicity Values
RIVM	The Netherlands National Institute of Public Health and the Environment
TCEQ	Texas Commission on Environmental Quality
USEPA	United States Environmental Protection Agency
USEPA OSWER	USEPA Office of Solid Waste and Emergency Response
USEPA MCL	USEPA Maximum Contaminant Level
WHO	World Health Organization
WHO IPCS	International Programme on Chemical Safety (IPCS/INCHEM)
WHO IARC	International Agency for Research on Cancers
NA	Not Available.
NR	Not Relevant.

Toxicity terms:

BMC	Benchmark concentration
BMCL	Lower bound confidence limit on the BMC
BMD	benchmark dose
BMDL	Lower bound confidence limit on the BMD
CSF	Cancer slope Factor
CNS	Central nervous system
IURF or IUR	Inhalation unit risk factor
LOAEL	Lowest observed adverse effect level
LOEL	Lowest observed effect level
MRL	Minimal risk level (ATSDR)
NOAEL	No observed adverse effect level
NOEL	No observed effect level

RfC	Reference concentration
RfD	Reference dose
p-RfD	Provisional RfD
aRfD	Acute RfD
UF	Uncertainty factor
WOE	Weight of evidence

Section (C) Chemical-specific Absorption Factors

MDEQ	Michigan Department of Environmental Quality
USEPA RAGS-E	United States Environmental Protection Agency's Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment). July, 2004.

Section (D) Rule 57 Water Quality Values and GSI Criteria

GSI	Groundwater-surface water interface
NA	A value is not available or not applicable.
ID	Insufficient data to derive value
NLS	No literature search has been conducted