Office of Solid Waste
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Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities

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Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities

U.S. EPA, OFFICE OF SOLID WASTE

U.S. ENVIRONMENTAL PROTECTION AGENCY

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DISCLAIMER

This document provides guidance to EPA regional and state RCRA hazardous waste programs, as well as to facilities subject to RCRA requirements and the general public. More specifically, this guidance document conveys how EPA generally intends to exercise its discretion in implementing RCRA statutory and regulatory provisions concerning combustion facilities subject to RCRA. EPA designed this guidance to explain and clarify national policy on issues related to EPA's obligation to ensure that operating permits granted to combustion facilities contain conditions necessary to protect human health and the environment.

The statutory provisions and EPA regulations discussed in this handbook contain legally binding requirements. This guidance itself does not substitute for those provisions, nor is it a regulation itself. Thus, this guidance does not impose legally binding requirements on EPA, states, or the regulated community, and may not apply to a particular situation based on the specific circumstances of the combustion facility. EPA and state regulators base their permitting decisions on the statute and regulations as applied to the specific combustion facility and retain their discretion to use approaches on a case-by-case basis that differ from those recommended in this guidance where appropriate. Therefore, interested parties are free to raise questions and concerns about the substance of this guidance document and the appropriateness of the application of recommendations to a particular situation. Because this guidance is not a regulation, EPA and state regulators will consider such questions and concerns when implementing the recommendations (for example, during the comment period provided on draft combustion permits). Whether the recommendations in this Handbook are appropriate in a given situation will depend on facility-specific circumstances.

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LIST OF ACRONYMS

:g	Microgram
:m	Micrometer
ACGIH	American Conference of Governmental Industrial Hygienists
ADD	Average daily dose
AEFA	Average emission factor approach
AEGL	Acute inhalation exposure guidelines
AERMOD	American Meteorological Society/EPA Regulatory Model
Ah	Aryl hydrocarbon
AHH	Aryl hydrocarbon hydroxylase
AIEC	Acute inhalation exposure criteria
AIHA	American Industrial Hygiene Association
APCD	Air pollution control device
APCS	Air pollution control system
ARE	Acute reference exposure
Acute REL	Acute reference exposure level
ASTM	American Society for Testing and Materials
atm	Atmosphere
ATSDR	Agency for Toxic Substances and Disease Registry
AWFCO	Automatic waste feed cutoff
BaP	Benzo(a)pyrene
BAF	Bioaccumulation factor
BBS	Bulletin board service
BCF	Bioconcentration factor
BEHP	Bis(2-ethylhexyl) phthalate
BIF	Boiler and industrial furnace
BPIP	Building profile input program check
BSAF	Sediment bioaccumulation factor
Btu	British thermal unit
BW	Body weight
CAA	Clean Air Act
CALPUFF	California Puff Model
CARB	California Air Resources Board
CAS	Chemical Abstracts Service
CFR	Code of Federal Regulations
CKD	Cement kiln dust
CLP	Contract Laboratory Program
cm	Centimeters
COPC	Compound of potential concern
CRQL	Contract required quantitation limit
CSV	Unspeciated chromatographical semivolatiles
CWA	Clean Water Act

LIST OF ACRONYMS (contd.)

DEHP	Diethylhexylphthalate
dL	Decaliter
DNA	Deoxyribonucleic acid
DNOP	Di(n)octyl phthalate
DOE	Department of Energy
DRE	Destruction and removal efficiency
DW	Dry weight of soil or plant/animal tissue
EPACA	U.S. Environmental Protection Agency Correlation Approach
EQL	Estimated quantitation limit
ERPG	Emergency response planning guidelines
ESP	Electrostatic precipitator
FW	Fresh weight (or whole/wet weight) of plant or animal tissue
g	Grams
GAQM	Guideline to Air Quality Models
GC	Gas chromatography
GEP	Good engineering practice
GRAV	Unspeciated gravimetric compounds
H3TD	Hierarchy of Human Health Toxicity Data
HEAST	Health Effects Assessment Summary Tables
HI	Hazard index
HQ	Hazard quotient
IARC	International Agency for Research on Cancer
IDL	Instrument detection limit
IEU/BK	Integrated exposure uptake/biokinetic
IPM	Insoluble polystyrene microspheres
IUPAC	International Union of Pure and Applied Chemistry
IRIS	Integrated Risk Information System
ISC-PRIME	Industrial Source Complex-Plume Rise Model Enhancements
ISCSTDFT	Industrial Source Complex Short Term Draft
ISCST3	Industrial Source Complex Short Term 3
K	Kelvin
kg	Kilogram
LADD	Lifetime average daily dose
L	Liter
lb	Pound
LCD	Local climatological data annual summary with comparative data
m	Meters
MACT	Maximum achievable control technology

LIST OF ACRONYMS (contd.)

MDL	Method detection limit
MEHP	Monoethylhexyl phthalate
mg	Milligram
Mg	Megagram
MIR	Maximum individual risk
MJ	Megajoule
mL	Milliliter
MPRM	Meteorological processor for regulatory models
MPTER	Air quality model for multiple point source gaussian dispersion algorithm with terrain adjustments
MRL	Minimum risk level
NCDC	National Climatic Data Center
NC DEHNR	North Carolina Department of Environment, Health, and Natural Resources
NCEA	National Center for Environmental Assessment
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NIOSH	National Institute of Occupational Safety and Health
NRC	Nuclear Regulatory Commission
NRC COT	National Research Council Committee on Toxicology
NTP	National Toxicology Program
NWS	National Weather Service
OAQPS	Office of Air Quality Planning and Standards
OEHHA	Office of Environmental Health Hazard Assessment
ORD	Office of Research and Development
OSHA	U.S. Occupational Safety and Health Administration
OSW	Office of Solid Waste
OSWER	Office of Solid Waste and Emergency Response
PAH	Polynuclear aromatic hydrocarbon
PCB	Polychlorinated biphenyl
PCDD	Polychlorinated dibenzo(p)dioxin
PCDF	Polychlorinated dibenzofuran
PCRAMMET	Personal computer version of the meteorological preprocessor for the old RAM program
PDF	Probability density function
pg	Picogram
PIC	Product of incomplete combustion
PM	Particulate matter
PMD	Portable monitoring device
PM10	Particulate matter less than 10 micrometers in diameter
POHC	Principal organic hazardous constituent
ppb	Parts per billion
ppm	Parts per million
ppmv	Parts per million by volume
ppt	Parts per trillion

LIST OF ACRONYMS (contd.)

PQL	Practical quantitation limit
PU	Polyurethane
QA	Quality assurance
QAPjP	Quality assurance project plan
QC	Quality control
RCRA	Resource Conservation and Recovery Act
RfC	Reference concentration
RfD	Reference dose
RME	Reasonable maximum exposure
RPF	Relative potency factor
RTDM	Rough terrain diffusion model
RTDMDEP	Rough terrain diffusion model deposition
s	Second
SAMSON	Solar and Meteorological Surface Observational Network
SCAPA	Subcommittee on Consequence Assessment and Protective Actions
SCRAM	Support Center for Regulatory Air Models
SF	Slope factor
SLERA	Screening level ecological risk assessment
SOCMI	Synthetic Organic Chemical Manufacturing Industries
SQL	Sample quantitation limit
SRA	Screening ranges approach
SVOC	Semivolatile organic compound
SW-846	U.S. Environmental Protection Agency Test Methods for Evaluating Solid Waste
TCDD	Tetrachlorodibenzo(p)dioxin
TDA	Toluenediamine
TDI	Toluene diisocyanate
TEELs	Temporary emergency exposure limits
TEF	Toxicity equivalent factor
TEQ	Toxicity equivalent quotient
TG	Terrain grid
TIC	Tentatively identified compound
TLV	Threshold limit value
TOC	Total organic carbon
TOE	Total organic emissions
TSD	Treatment, storage, and disposal
TTN	Technology transfer network
TWA	Time-weighted average
U/BK	Uptake/biokinetic
USCA	Unit-Specific Correlation Approach
USDA	U.S. Department of Agriculture

LIST OF ACRONYMS (contd.)

U.S. EPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
USLE	Universal soil loss equation
UTM	Universal transverse mercator
VOC	Volatile organic compound
WHO	World Health Organization

INDEXED LIST OF VARIABLES

Variable	Units	Definition	**[Sections]**/ Equations
γ	unitless	Empirical constant	used to generate *Rp*
λ_z	unitless	Dimensionless viscous sublayer thickness	5-41B; 5-42B; B-4-20; B-4-21
μ_a	g/cm-s	Viscosity of air	5-42B; B-4-21
μ_w	g/cm-s	Viscosity of water corresponding to water temperature	5-41B; B-4-20
ρ_a	g/cm^3 or g/m^3	Density of air	5-18; 5-41-B; 5-42B; B-2-8; B-3-8; B-4-20; B-4-21
ρ_s	kg/L	Bed sediment density	used to generate θ_{bs}
ρ_{soil}	g/cm^3	Solids particle density	5-7a; B-1-6; B-2-6; B-3-6; B-4-6
ρ_w	g/cm^3	Density of water corresponding to water temperature	5-41B; B-4-20
θ	unitless	Temperature correction factor	5-40; B-4-19
θ_{bs}	unitless	Bed sediment porosity	5-36B; 5-37; 5-47; B-4-16; B-4-25
θ_{sw}	mL water/cm^3 soil	Soil volumetric water content	**[5.2.4.4]**; 5-4; 5-5A; 5-7A; 5-7C; 5-32; 5-33; B-1-3; B-1-4; B-1-5; B-1-6; B-2-3; B-2-4; B-2-5; B-2-6; B-3-3; B-3-4; B-3-5; B-3-6; B-4-3; B-4-4; B-4-5; B-4-6; B-4-10; B-4-11
θ_v	cm^3/cm^3	Soil void fraction	5-7B; 5-7C
a	unitless	Empirical intercept coefficient	5-34; B-4-14
A_{beef}	mg COPC/kg FW tissue	Concentration of COPC in beef	**[5.4.4]**; 5-22; B-3-10
$A_{chicken}$	mg COPC/kg FW tissue	Concentration of COPC in chicken meat	**[5.6.1]**; 5-26; B-3-14
ADD	mg COPC/kg BW-day	Average daily dose	6-1
ADD_{infant}	pg COPC/kg BW infant/day	Average daily dose for infant exposed to contaminated breast milk	C-3-2
ADD_{mat}	pg COPC/kg BW mother/day	Average daily dose (mother)	
AEF	kg/hr-source	Applicable average emission factor for the equipment type	
A_{egg}	mg COPC/kg FW tissue	Concentration of COPC in eggs	**[5.6.1]**; C-1-3
Ah	m^2	Area planted	used to estimate Yp
Ahi	m^2	Area planted to *i*th crop	see *Ah*
A_I	m^2	Impervious watershed area receiving COPC deposition	5-31; 5-32; 5-33; 5-36C; B-4-9; B-4-10

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Variable	Units	Definition	**[Sections]**/ Equations
A_L	m^2	Total watershed area receiving COPC deposition	5-32; 5-33; 5-34; 5-36C; 5-43; B-4-10; B-4-11;B-4-14; B-4-22
A_{milk}	mg COPC/kg FW tissue	Concentration of COPC in milk	**[5.4.5]**; 5-24; B-3-11
A_{pork}	mg COPC/kg FW tissue	Concentration of COPC in pork	**[5.5.1]**; 5-25; B-3-12
AT	days	Averaging time	**[6.5]**; 6-1; C-1-7; C-1-8; C-3-1
A_W	m^2	Water body surface area	**[4.1.2]**; 5-29; 5-30; 5-35; 5-36C; 5-43; B-4-8; B-4-12; B-4-15; B-4-22
b	unitless	Empirical slope coefficient	5-34; B-4-14
Ba_{beef}	day/kg FW tissue	Biotransfer factor for beef	5-22; **[A2.5.1]**; A-2-16; B-3-10
$Ba_{chicken}$	day/kg FW tissue	Biotransfer factor for chicken	5-26; **[A2.5.3]**; B-3-14
Ba_{egg}	day/kg FW tissue	Biotransfer factor for eggs	5-26; **[A2.5.3]**; A-2-18; B-3-13
BAF_{fish}	L/kg FW tissue	Bioaccumulation factor for fish	5-49; **[A2.5.4]**; B-4-27
Ba_{milk}	day/kg FW tissue	Biotransfer factor for milk	5-24; **[A2.5.1]**; A-2-17; B-3-11
Ba_{pork}	day/kg FW tissue	Biotransfer factor for pork	5-25; **[A2.5.2]**; B-3-12
BCF_{fish}	unitless (mg COPC/kg FW tissue)/(mg COPC/kg dissolved water)	Bioconcentration factor for fish	5-48; **[A2.5.4]**; B-4-26
BD	g soil/cm^3 soil	Soil bulk density	**[5.2.4.2]**; 5-4; 5-5A; 5-7A; 5-11; 5-32; 5-33; B-1-1; B-1-3; B-1-4; B-1-5; B-1-6; B-2-1; B-2-3; B-2-4; B-2-5; B-2-6; B-3-1; B-3-3; B-3-4; B-3-5; B-3-6; B-4-1; B-4-3; B-4-4; B-4-5; B-4-6; B-4-10; B-4-11
Br_{ag}	unitless	Plant-soil bioconcentration factor for aboveground produce	5-20A; **[A2.4.3]**; A-2-14A; B-2-9
Br_{forage}	unitless (µg COPC/g DW plant)/(µg COPC/g soil)	Plant-soil bioconcentration factor for forage	5-20A; **[A2.4.3]**; A-2-14B; B-3-9

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Variable	Units	Definition	**[Sections]**/ Equations
Br_{grain}	unitless (µg COPC/g DW plant)/(µg COPC/g soil)	Plant-soil bioconcentration factor for COPC in grain	5-20A; **[A2.4.3]**; A-2-14B; B-3-9
$Br_{rootveg}$	unitless (µg COPC/g FW plant)/(µg COPC/g soil)	Plant-soil bioconcentration factor for COPC in belowground produce	5-20B; **[A2.4.2]**; A-2-13; B-2-10
Bs	unitless	Soil bioavailability factor	**[5.4.4.6]**; 5-22; 5-24; 5-25; 5-26; B-3-10; B-3-11; B-3-12; B-3-13; B-3-14
BSAF	unitless	Biota-to-sediment accumulation factor	**[5.75]**; 5-50; **[A2.5.4.3]**; B-4-28
Bv_{ag}	unitless (mg COPC/kg lipid tissue)/(mg COPC/kg sediment)	COPC air-to-plant biotransfer factor for aboveground produce (µg COPC/g DW plant)/(µg COPC/g air)—unitless	5-18; **[A2.4.4]**; A-2-15A&B; B-2-8
$Bv_{forage/silage}$	unitless (µg COPC/g DW plant)/(µg COPC/g air)	Air-to-plant biotransfer factor for forage and silage	5-18; **[A2.4.4]**; A-2-15A&B; B-3-8
C	unitless	USLE cover management factor	5-33A; B-4-13
C_a	µg/m^3	Total COPC air concentration	**[6.1]**; 7-1; 7-5; B-5-1; C-2-1; C-2-2; C-3-1
C_{acute}		Acute air concentration (µg/m^3)	7-9; B-6-1; C-4-1
$Cancer\ Risk_i$	unitless	Individual lifetime risk through indirect exposure to COPC carcinogen *i*	7-3; C-1-7
$Cancer\ Risk_{inh(i)}$	unitless	Individual lifetime cancer risk through direct inhalation of COPC carcinogen *i*	C-2-1
C_{BS}	g sediment/cm^3 water	Bed sediment concentration (or sediment bulk density)	5-36A; 5-37; 5-43; 5-47; B-4-16; B-4-22; B-4-25
C_d	unitless	Drag coefficient	5-41B; 5-42B; B-4-20;
C_{dw}	mg COPC/L water	Dissolved phase water concentration	**[5.7.4.9]**; 5-46; 5-48; 5-49; B-4-24; B-4-26; B-4-27; C-1-5
C_{fish}	mg COPC/kg FW tissue	Concentration of COPC in fish	**[5.7.5]**; 5-48; 5-49; 5-50; B-4-28; C-1-4
Chv	µg-s/g-m^3	Unitized hourly air concentration from vapor phase	B-6-1
Chp	µg-s/g-m^3	Unitized hourly air concentration from particle phase	B-6-1
Chpb	µg-s/g-m^3	Unitized hourly air concentration from particle-bound phase	

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C_{sb}	mg COPC/kg sediment	Concentration sorbed to bed sediment	**[5.7.4.10]**; 5-47; 5-50; B-4-25; B-4-28
CSF	$(mg/kg\text{-}day)^{-1}$	Cancer slope factor	7-2; **[A2.6.2]**; C-1-7
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C_{wctot}	mg COPC/L water column	Total COPC concentration in water column	**[5.7.4.8]**; 5-45; 5-46; B-4-23; B-4-24
C_{wtot}	g COPC/m^3 water body (or mg/L)	Total water body COPC concentration including water column and bed sediment	**[5.7.4]**; 5-35; 5-45; 5-47; B-4-15; B-4-23; B-4-25
Cyp	µg-s/g-m^3	Unitized yearly average air concentration from particle phase	**[3.8.3.2]**; B-5-1
Cyv	µg-s/g-m^3	Unitized yearly average air concentration from vapor phase	**[3.8.3.1]**; 5-18; B-2-8; B-3-8; B-5-1
Cywv	µg-s/g-m^3	Unitized yearly (water body and watershed) average air concentration from vapor phase	**[3.8.3.1]**; 5-30; B-4-12
D_a	cm^2/s	Diffusivity of COPC in air	5-7A; 5-42B; **[A2.3.5]**; A-2-2A; B-1-6; B-2-6; B-3-6; B-4-6; B-4-21
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d_{wc}	m	Depth of water column	**[4.1.2]**; 5-35; 5-36A; 5-45; 5-47; B-4-15; B-4-16; B-4-18; B-4-23; B-4-25
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Dytwp	s/m^2-yr	Unitized yearly (water body or watershed) average total (wet and dry) deposition from particle phase	**[3.8.3.2]**; 5-29; 5-31; B-4-1; B-4-8; B-4-9
Dywp	s/m^2-yr	Unitized yearly average wet deposition from particle phase	**[3.8.3.2]**; 5-11; 5-14; B-1-1; B-2-1; B-2-7; B-3-1; B-3-7
Dywv	s/m^2-yr	Unitized yearly average wet deposition from vapor phase	**[3.8.3.2]**; 5-11; 5-14; B-1-1; B-2-1; B-2-7; B-3-1; B-3-7
Dytwv	s/m^2-yr	Unitized yearly (water body or watershed) average total (wet and dry) deposition from vapor phase	**[3.8.3.2]**; 5-29; 5-31; B-4-1; B-4-8; B-4-9
d_z	m	Total water body depth	5-36A; 5-39; 5-41A; B-4-16; B-4-18; B-4-20
ED	yr	Exposure duration	6-1; C-1-7; C-1-8; C-3-1; C-3-2
EF	days/yr	Exposure frequency	6-1; C-1-7; C-1-8; C-3-1
ER	unitless	Soil enrichment ratio	5-33; B-1-3; B-2-3; B-3-3; B-4-3; B-4-11
E_v	cm/yr	Average annual evapotranspiration	5-5A; B-1-5; B-2-5; B-3-5; B-4-5
f_{bs}	unitless	Fraction of total water body COPC concentration in benthic sediment	**[5.7.4.1]**; 5-36B; 5-38; 5-47; B-4-16; B-4-17; B-4-25
F_i	unitless	Fraction of plant type *i* grown on contaminated soil and eaten by the animal	5-22; 5-24; 5-25; 5-26; B-3-10; B-3-11; B-3-12; B-3-13B-3-14
f_{lipid}	unitless	Fish lipid content	5-50; B-4-28
Fw	unitless	Fraction of COPC wet deposition that adheres to plant surfaces	5-14; B-2-7; B-3-7
f_{wc}	unitless	Fraction of total water body COPC concentration in the water column	**[5.7.4.1]**; 5-35; 5-36A; 5-38; 5-45; B-4-15; B-4-16; B-4-17; B-4-23

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Variable	Units	Definition	**[Sections]**/ Equations
F_v	unitless	Fraction of COPC air concentration in vapor phase	**[3.2]**; 5-11; 5-14; 5-18; 5-29; 5-30; 5-31; B-1-1; B-2-1; B-2-7; B-2-8; B-3-1; B-3-7; B-3-8; B-4-1; B-4-8; B-4-9; B-4-12; B-5-1; B-6-1
H	atm-m^3/mol	Henry's Law constant	5-7A; 5-30; 5-40; **[A2.3.4]**; A-2-1; B-1-6; B-2-6; B-3-6; B-4-6; B-4-12; B-4-19
HI	unitless	Hazard index	7-6; 7-7; C-1-11
HI_j	unitless	Hazard index for exposure pathway j	C-1-10
HQ	unitless	Hazard quotient	7-5; C-1-8
HQ_i	unitless	Hazard quotient for COPC i	7-6
$HQ_{inh(i)}$	unitless	Hazard quotient for direct inhalation of COPC	C-2-2; C-2-4
I	cm/yr	Average annual irrigation	5-5A; B-1-5; B-2-5; B-3-5; B-4-5
I_i	mg/day	Daily intake of COPC (i) from animal tissue	**[6.2.2]**; C-1-3
k	unitless	von Karman's constant	5-41B; 5-42B; B-4-20; B-4-21
K	ton/acre	USLE erodibility factor	5-33A; B-4-13
k_b	yr^{G1}	Benthic burial rate constant	**[5.7.4.7]**; 5-38; 5-43; 5-44; B-4-17
Kd_{bs}	cm^3 water/g bottom sediment	Bed sediment/sediment pore water partition coefficient	5-36B; 5-47; **[A2.3.8]**; A-2-8C; B-4-16; B-4-25;
Kd_{ij}	unitless	Partition coefficient for COPC i associated with sorbing material j	
Kd_s	cm^3 water/g soil	Soil-water partition coefficient	5-4; 5-5A; 5-7A; 5-20B; 5-32; 5-33; **[A2.3.8]**; A-2-8A; B-1-3; B-1-4; B-1-5; B-1-6; B-2-3; B-2-4; B-2-5; B-2-6; B-2-10; B-3-3; B-3-4; B-3-5; B-3-6; B-4-3; B-4-4; B-4-5; B-4-6; B-4-10; B-4-11
Kd_{sw}	L water/kg suspended sediment	Suspended sediments/surface water partition coefficient	5-36A; 5-39; 5-46; **[A2.3.8]**; A-2-8B; B-4-16; B-4-18; B-4-24
K_G	m/y	Gas phase transfer coefficient	**[5.7.4.6]**; 5-40; 5-42A&B; B-4-19; B-4-21

INDEXED LIST OF VARIABLES (contd.)

Variable	Units	Definition	**[Sections]**/ Equations
K_L	m/yr	Liquid phase transfer coefficient	**[5.7.4.5]**; 5-40; 5-41A&B; B-4-19; B-4-20
K_{oc}	mL water/g soil	Soil organic carbon-water partition coefficient	**[A2.3.7]**; A-2-4; A-2-5; A-2-6; A-2-7;
K_{ow}	unitless (mg COPC/L octanol)/(mg COPC/L octanol)	Octanol-water partition coefficient	**[A2.3.6]**; A-2-4; A-2-5; A-2-6; A-2-7; A-2-12A&B; A-2-14A&B; A-2-15A; A-2-16; A-2-17; A-2-19
kp	yr^{-1}	Plant surface loss coefficient	**[5.3.1.2]**; 5-14; B-2-7; B-3-7
ks	yr^{-1}	COPC soil loss constant due to all processes	**[5.2.2]**; 5-1C, D&E; B-1-1; B-1-2; B-2-1; B-2-2; B-3-1; B-3-2; B-4-1; B-4-2;
kse	yr^{-1}	COPC loss constant due to soil erosion	**[5.2.2.2]**; 5-2A; B-1-2; B-1-3; B-2-2; B-2-3; B-3-2; B-3-3; B-4-2; B-4-3
ksg	yr^{-1}	COPC loss constant due to biotic and abiotic degradation	**[5.2.2.1]**; 5-2A; **[A2.3.9]**; A-2-9; B-1-2; ; B-2-2; B-3-2; B-4-2
ksl	yr^{-1}	COPC loss constant due to leaching	**[5.2.2.4]**; 5-2A; 5-5A; B-1-2; B-1-5; B-2-2; B-2-5; B-3-2; B-3-5; B-4-2; B-4-5
ksr	yr^{-1}	COPC loss constant due to surface runoff	**[5.2.2.3]**; 5-2A; 5-4; B-1-2; B-1-4; B-2-2; B-2-4; B-3-2; B-3-4; B-4-2; B-4-4
ksv	yr^{-1}	COPC loss constant due to volatilization	**[5.2.2.5]**; 5-2A; 5-7A; B-1-2; B-1-6; B-2-2; B-2-6; B-3-2; B-3-6; B-4-2; B-4-6
k_v	yr^{-1}	Water column volatilization rate constant	**[5.7.4.3]**; 5-38; 5-39; B-4-17; B-4-18
K_v	m/yr	Overall COPC transfer rate coefficient	**[5.7.4.4]**; 5-30; 5-39; 5-40; B-4-12; B-4-18; B-4-19
k_{wt}	yr^{-1}	Overall total water body dissipation rate constant	**[5.7.4.2]**; 5-35; 5-38; B-4-15;B-4-17
L	m	Monin-Obukhov Length	**[3.5.1]**
LADD	mg COPC/kg BW-day	Lifetime average daily dose	7-2

INDEXED LIST OF VARIABLES (contd.)

Variable	Units	Definition	**[Sections]**/ Equations
L_{DEP}	g/yr	Total (wet and dry) particle phase and vapor phase COPC direct deposition load to water body	**[5.7.1.1]**; 5-28; 5-29; B-4-7; B-4-8
L_{dif}	g/yr	Vapor phase COPC diffusion load to water body	**[5.7.1.2]**; 5-28; 5-30; B-4-7; B-4-12
leak rate	kg/hr	Emission rate from the individual item of equipment	**[2.2.6.1]**
L_E	g/yr	Soil erosion load	**[5.7.1.5]**; 5-28; 5-33; B-4-7; B-4-11
L_R	g/yr	Runoff load from pervious surfaces	**[5.7.1.4]**; 5-28; 5-32; B-4-7; B-4-10
L_{RI}	g/yr	Runoff load from impervious surfaces	**[5.7.1.3]**; 5-28; 5-31; B-4-7; B-4-9
L_T	g/yr	Total COPC load to the water body including deposition, runoff, and erosion	**[5.7.1]**; 5-28; B-4-7; B-4-15
LS	unitless	USLE length-slope factor	5-33A; B-4-13
M_{skin}	g	Mass of a thin (skin) layer of below ground vegetable	5-19
$M_{vegetable}$	g	Mass of the entire vegetable	5-19
MF	unitless	Metabolism factor	**[5.4.4.7]**; 5-22; 5-24; 5-25; B-3-10; B-3-11; B-3-12
MW	g/mole	Molecular weight	**[A2.3.1]**; A-2-1
OC_{sed}	unitless	Fraction of organic carbon in bottom sediment	5-50; B-4-28
p°_L	atm	Liquid phase vapor pressure of chemical	A-2-11
p°_S	atm	Solid phase vapor pressure of chemical	A-2-11
P	cm/yr	Average annual precipitation	5-5A; B-1-5; B-2-5; B-3-5; B-4-5
PF	unitless	USLE supporting practice factor	5-33A; B-4-13
Pd	mg COPC/kg DW	Aboveground exposed produce concentration due to direct (wet and dry) deposition onto plant surfaces	**[5.3.1]**; 5-14; 5-23; B-2-7; B-3-7; C-1-2
P_i	mg/kg DW	Total COPC concentration in plant type *i* ingested by the animal	**[5.4.4.3]**; 5-22; 5-23; 5-24; 5-25; 5-26; 5-27; B-3-10; B-3-11; B-3-12; B-3-13; B-3-14
Pr	mg COPC/kg DW	Aboveground exposed and protected produce concentration due to root uptake	**[5.3.3]**; 5-20A&B; 5-23; 5-27; B-2-9; B-3-9; C-1-2
Pr_{bg}	mg COPC/kg DW	Belowground produce concentration due to root uptake	B-2-10; C-1-2
Pv	mg COPC/kg DW	Concentration of COPC in plant due to air-to-plant transfer	**[5.3.2]**; 5-18; 5-23; B-2-8; B-3-8; C-1-2

INDEXED LIST OF VARIABLES (contd.)

Variable	Units	Definition	**[Sections]**/ Equations
Q	g/s	COPC emission rate	5-11; 5-14; 5-18; 5-29; 5-30; 5-31; B-1-1; B-2-1; B-2-7; B-2-8; B-3-1; B-3-7; B-3-8; B-4-1; B-4-8; B-4-9; B-4-12; B-5-1; B-6-1
Q_i	g/s	Emission rate of COPC *(i)*	
$Q_{i(adj)}$	g/s	Adjusted emission rate of COPC *(i)*	
$Qcp_{i(adj)}$	g/s	Adjusted emission rate of Table A-1 carcinogenic COPC *(i)*	
Qcp_i	g/s	Emission rate of Table A-1 carcinogenic COPC *(i)*	
Q_f	W/m^2	Anthropogenic heat flux	**[3.5.7]**
Qp_i	kg DW/day	Quantity of plant type *i* ingested by the animal each day	**[5.4.4.2]**; 5-22; 5-24; 5-25; 5-26; B-3-10; B-3-11; B-3-12; B-3-13; B-3-14
Qs	kg/day	Quantity of soil ingested by the animal each day	
Q_*	W/m^2	Net radiation absorbed	**[3.5.8]**
r	unitless	Interception fraction—the fraction of material in rain intercepted by vegetation and initially retained	
R	atm-m^3/mol-K	Universal gas constant	5-7A; 5-30; 5-40; A-2-11; B-1-6; B-2-6; B-3-6; B-4-6; B-4-12; B-4-19
RCF	(µg COPC/g DW plant)/(µg COPC/mL soil water)	Root concentration factor	5-20B; **[A2.4.1]**; A-2-12A&B; A-2-13; B-2-10
RO	cm/yr	Average annual surface runoff from pervious surfaces	5-4; 5-5A; 5-32; B-1-4; B-1-5; B-2-4; B-2-5; B-3-4; B-3-5; B-4-4; B-4-5; B-4-10
REL		California EPA Air Toxics Hot Spots Program acute reference exposure levels	**[7.4.2]**
RF	yr^{-1}	USLE rainfall (or erosivity) factor	5-33A; B-4-13
RfC		Inhalation reference dose	7-5; **[A2.6.1]**; C-2-2
RfD	mg COPC/kg body weight/day	Oral reference dose	7-5; **[A2.6.1]**; C-1-8
Rp	unitless	Interception fraction of the edible portion of plant	**[5.3.11]**; 5-14; B-2-7; B-3-7
S	mg COPC/L water	Solubility of COPC in water	**[A2.3.3]**; A-2-1

INDEXED LIST OF VARIABLES (contd.)

Variable	Units	Definition	**[Sections]**/ Equations
SD	unitless	Sediment delivery ratio	**[5.7.3]**; 5-33; 5-34; 5-36C; 5-43; B-1-3; B-2-3; B-3-3; B-4-3
ΔSf	unitless	Entropy of fusion [$\Delta S_f/R$ = 6.79]	A-2-11
SF	$(mg/kg\text{-}day)^{-1}$	Slope factor	
S_T	cm^2/cm^3 air	Whitby's average surface area of particulates (aerosols)	A-2-11
T_a	K	Ambient air temperature	**[3.4.2]**; 5-7A; A-2-11; B-1-6; B-2-6; B-3-6; B-4-6
T_1	yr	Time period at the beginning of combustion	5-1D; B-1-1; B-2-1; B-3-1; B-4-1
T_2	yr	Length of exposure duration	5-1C&D; B-1-1; B-2-1; B-3-1; B-4-1
tD	yr	Time period over which deposition occurs (time period of combustion)	5-1C, D&E; B-1-1; B-2-1; B-3-1; B-4-1
T_m	K	Melting point of chemical	**[A2.3.2]**
Tp	yr	Length of plant exposure to deposition per harvest of edible portion of plant	**[5.3.1.3]**; 5-14; 5-16; 5-21; B-2-7; B-3-7
tp_i	yr	Length of plant's exposure to deposition per harvest of the edible portion of the *i* th plant group	5-13
Total Cancer Risk	unitless	Individual lifetime cancer risk through indirect exposure to all COPC carcinogens	7-3; 7-4; C-1-9
Total Cancer $Risk_{inh}$	unitless)	Total individual lifetime cancer risk through direct inhalation of all COPC carcinogens	C-2-3
TSS	mg/L	Total suspended solids concentration	5-36A; 5-36C; 5-39; 5-43; 5-46; B-4-16; B-4-18; B-4-22; B-4-24
T_{wk}	K	Water body temperature	5-30; 5-40; B-4-12; B-4-19;
$t_{1/2}$	days	Half-time of COPC	5-15
u	m/s	Current velocity	5-41A; B-4-20
URF	$\mu g/m^3$	Unit risk factor	7-1; C-2-1
Vf_x	m^3/yr	Average volumetric flow rate through water body	5-35; 5-36C; 5-43; B-4-15; B-4-22;
VG_{ag}	unitless	Empirical correction factor for aboveground produce (forage and silage)	**[5.3.2.1; 5.4.2.1]**; 5-18; B-2-8; B-3-8
$VG_{rootveg}$	unitless	Empirical correction factor for below ground produce	5-19; 5-20B; B-2-10
Vp	atm	Vapor pressure of COPC	**[A2.3.3]**; A-2-1
W	m/s	Average annual wind speed	**[3.4.1]**; 5-41B; 5-42B; B-4-20; B-4-21
W_b	m/yr	Rate of burial	5-44

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Variable	Units	Definition	**[Sections]**/ Equations
X_e	kg/m^2-yr	Unit soil loss	**[5.7.2]**; 5-33; 5-33A; 5-36C; 5-43; B-1-3; B-2-3; B-3-3; B-4-3; B-4-11; B-4-13; B-4-22
Yh	kg DW	Dry harvest yield	
Yh_i	kg DW	Harvest yield of *i*th crop	
Yp	kg DW/m^2	Yield or standing crop biomass of edible portion of plant (productivity)	**[5.3.1.4; 5.4.1.4]**; 5-14; B-2-7; B-3-7
Yp_i	kg DW/m^2	Yield or standing crop biomass of the edible portion of the plant (productivity)	5-13
Z_s	cm	Soil mixing zone depth	**[5.2.4.1]**; 5-4; 5-5A; 5-7A&B; 5-11; B-1-1; B-1-3; B-1-4; B-1-5; B-1-6; B-2-1; B-2-3; B-2-4; B-2-5; B-2-6; B-3-1; B-3-3; B-3-4; B-3-5; B-3-6; B-4-1; B-4-3; B-4-4; B-4-5; B-4-6
0.01	kg cm^2/mg-m^2	Units conversion factor	
10^{-6}	g/µg	Units conversion factor	
10^{-6}	kg/mg	Units conversion factor	
0.31536	m-g-s/cm-µg-yr	Units conversion factor	
365	days/yr	Units conversion factor	
907.18	kg/ton	Units conversion factor	
0.1	g-kg/cm^2-m^2	Units conversion factor	
0.001	g/mg	Units conversion factor	
100	mg-cm^2/kg-cm^2	Units conversion factor	
1000	mg/g	Units conversion factor	
4047	m^2/acre	Units conversion factor	
1×10^3	g/kg	Units conversion factor	
3.1536×10^7	s/yr	Units conversion factor	