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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

US EPA ARCHIVE DOCUMENT

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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CONTENTS

| <u>Chapter</u> | | <u>Page</u> |
|----------------|--|-------------|
| | CONTENTS | vi |
| | FIGURES | xii |
| | TABLES | xiii |
| | LIST OF ACRONYMS | xv |
| | INDEXED LIST OF VARIABLES | xx |
| 1 | INTRODUCTION | 1-1 |
| 1.1 | OBJECTIVE AND DOCUMENT ORGANIZATION | 1-1 |
| 1.2 | BACKGROUND | 1-3 |
| 1.3 | USING THIS DOCUMENT | 1-6 |
| 1.4 | PRIMARY REFERENCE DOCUMENTS | 1-13 |
| 1.5 | RISK NOMENCLATURE | 1-17 |
| 2 | CHARACTERIZING FACILITY EMISSIONS | 2-1 |
| 2.1 | COMPILING BASIC FACILITY INFORMATION | 2-1 |
| 2.2 | IDENTIFYING EMISSION SOURCES & ESTIMATING EMISSION RATES | 2-2 |
| 2.2.1 | Estimating Stack Emission Rates for Existing Facilities | 2-3 |
| 2.2.2 | Estimating Emission Rates for Facilities with Multiple Stacks | 2-13 |
| 2.2.3 | Estimating Stack Emission Rates for Facilities Not Yet Operational | 2-13 |
| 2.2.4 | Estimating Stack Emission Rates for Facilities Previously Operated | 2-14 |
| 2.2.5 | Emissions From Process Upsets | 2-15 |
| 2.2.6 | RCRA Fugitive Emissions | 2-17 |
| 2.2.7 | RCRA Fugitive Ash Emissions | 2-27 |
| 2.2.8 | Cement Kiln Dust (CKD) Fugitive Emissions | 2-28 |
| 2.3 | IDENTIFYING COMPOUNDS OF POTENTIAL CONCERN | 2-31 |
| 2.3.1 | Criteria Pollutants | 2-39 |
| 2.3.2 | Endocrine Disruptors | 2-41 |
| 2.3.3 | Hexachlorobenzene and Pentachlorophenol | 2-42 |
| 2.3.4 | Hydrogen Chloride/Chlorine Gas | 2-43 |
| 2.3.5 | Metals | 2-44 |
| 2.3.6 | Nitroaromatics | 2-57 |
| 2.3.7 | Particulate Matter | 2-58 |
| 2.3.8 | Phthalates | 2-59 |

CONTENTS (contd.)

| <u>Chapter</u> | | <u>Page</u> |
|----------------|---|-------------|
| | 2.3.9 Polychlorinated Biphenyls | 2-61 |
| | 2.3.10 Polychlorinated Dibenzo(p)dioxins and Dibenzofurans | 2-66 |
| | 2.3.11 Polynuclear Aromatic Hydrocarbons | 2-71 |
| | 2.3.12 Radionuclides | 2-74 |
| | 2.3.13 Volatile Organic Compounds | 2-78 |
| 2.4 | ESTIMATING COPC CONCENTRATIONS FOR NON-DETECTS | 2-79 |
| | 2.4.1 Definitions of Commonly Reported Detection Limits | 2-79 |
| | 2.4.2 Using Non-Detect Data In the Risk Assessment | 2-82 |
| | 2.4.3 Statistical Distribution Techniques | 2-85 |
| | 2.4.4 Our Recommendations on Quantifying Non-Detects | 2-85 |
| | 2.4.5 Estimated Maximum Possible Concentration (EMPC) | 2-86 |
| 2.5 | EVALUATING CONTAMINATION IN BLANKS | 2-87 |
| 3 | AIR DISPERSION AND DEPOSITION MODELING | 3-1 |
| 3.1 | DESCRIPTION OF AIR MODELS | 3-3 |
| | 3.1.1 Background on Air Dispersion Models for Risk Assessment | 3-3 |
| | 3.1.2 Preprocessing Programs | 3-7 |
| 3.2 | PARTITIONING OF EMISSIONS | 3-8 |
| | 3.2.1 Vapor Phase Modeling | 3-8 |
| | 3.2.2 Particle Phase Modeling (Mass Weighting) | 3-8 |
| | 3.2.3 Particle-Bound Modeling (Surface Area Weighting) | 3-12 |
| 3.3 | SITE-SPECIFIC INFORMATION NEEDED FOR AIR MODELING | 3-14 |
| | 3.3.1 Surrounding Terrain Information | 3-15 |
| | 3.3.2 Surrounding Land Use Information | 3-16 |
| | 3.3.3 Information on Facility Building Characteristics | 3-20 |
| 3.4 | METEOROLOGICAL DATA PRIMER | 3-22 |
| | 3.4.1 Wind Direction and Wind Speed | 3-23 |
| | 3.4.2 Dry Bulb Temperature | 3-24 |
| | 3.4.3 Opaque Cloud Cover | 3-25 |
| | 3.4.4 Cloud Ceiling Height | 3-25 |
| | 3.4.5 Surface Pressure | 3-26 |
| | 3.4.6 Incoming Short-wave Radiation\Leaf Area Index | 3-26 |
| | 3.4.7 Precipitation Amount and Type | 3-26 |
| | 3.4.8 Upper Air Data (Mixing Height) | 3-27 |
| | 3.4.9 Potential Data Sources | 3-27 |
| 3.5 | METEOROLOGICAL PREPROCESSOR DATA NEEDS | 3-31 |
| | 3.5.1 Monin-Obukhov Length | 3-32 |
| | 3.5.2 Anemometer Height | 3-33 |
| | 3.5.3 Surface Roughness Length at Measurement Site | 3-33 |

CONTENTS (contd.)

| <u>Chapter</u> | | <u>Page</u> |
|----------------|---|-------------|
| | 3.5.4 Surface Roughness Length at Application Site | 3-33 |
| | 3.5.5 Noon-Time Albedo | 3-34 |
| | 3.5.6 Bowen Ratio | 3-35 |
| | 3.5.7 Anthropogenic Heat Flux | 3-37 |
| | 3.5.8 Fraction of Net Radiation Absorbed at the Ground | 3-38 |
| 3.6 | ISCST3 MODEL INPUT FILES | 3-39 |
| | 3.6.1 COntrol Pathway | 3-42 |
| | 3.6.2 SOurce Pathway | 3-47 |
| | 3.6.3 REceptor Pathway | 3-52 |
| | 3.6.4 MEteorological Pathway | 3-55 |
| | 3.6.5 Terrain Grid (TG) Pathway | 3-56 |
| | 3.6.6 OUtput Pathway | 3-57 |
| 3.7 | ISCST3 MODEL EXECUTION | 3-58 |
| 3.8 | USING MODEL OUTPUT | 3-58 |
| | 3.8.1 Unit Rate Output vs. COPC-Specific Output | 3-60 |
| | 3.8.2 ISCST3 Model Output | 3-61 |
| | 3.8.3 Using Model Output to Estimate Media Concentrations | 3-62 |
| 3.9 | MODELING FUGITIVE EMISSIONS | 3-64 |
| 3.10 | MODELING ACUTE RISK | 3-67 |
| 4 | EXPOSURE SCENARIO IDENTIFICATION | 4-1 |
| 4.1 | CHARACTERIZING THE EXPOSURE SETTING | 4-3 |
| | 4.1.1 Current and Reasonable Potential Future Land Use | 4-4 |
| | 4.1.2 Water Bodies and their Associated Watersheds | 4-7 |
| | 4.1.3 Special Population Characteristics | 4-10 |
| 4.2 | RECOMMENDED EXPOSURE SCENARIOS | 4-11 |
| | 4.2.1 Farmer | 4-15 |
| | 4.2.2 Farmer Child | 4-18 |
| | 4.2.3 Resident | 4-18 |
| | 4.2.4 Resident Child | 4-19 |
| | 4.2.5 Fisher | 4-19 |
| | 4.2.6 Fisher Child | 4-20 |
| | 4.2.7 Acute Receptor Scenario | 4-21 |
| 4.3 | SELECTING EXPOSURE SCENARIO LOCATIONS | 4-21 |

CONTENTS (contd.)

| <u>Chapter</u> | | <u>Page</u> |
|----------------|--|-------------|
| 5 | ESTIMATING MEDIA CONCENTRATIONS | 5-1 |
| 5.1 | CALCULATING COPC CONCENTRATIONS IN AIR FOR DIRECT INHALATION | 5-2 |
| 5.2 | CALCULATING COPC CONCENTRATIONS IN SOIL | 5-3 |
| | 5.2.1 Calculating Cumulative Soil Concentration (C_s) | 5-4 |
| | 5.2.2 Calculating the COPC Soil Loss Constant (k_s) | 5-7 |
| | 5.2.3 Calculating the Deposition Term (D_s) | 5-19 |
| | 5.2.4 Site-Specific Parameters for Calculating Cumulative Soil Concentration ... | 5-19 |
| 5.3 | CALCULATING COPC CONCENTRATIONS IN PRODUCE | 5-22 |
| | 5.3.1 Aboveground Produce Concentration Due to Direct Deposition (P_d) | 5-24 |
| | 5.3.2 Aboveground Produce Concentration Due to Air-to-Plant Transfer (P_v) ... | 5-32 |
| | 5.3.3 Produce Concentration Due to Root Uptake (P_r) | 5-35 |
| 5.4 | CALCULATING COPC CONCENTRATIONS IN BEEF AND DAIRY PRODUCTS | 5-37 |
| | 5.4.1 Forage and Silage Concentrations Due to Direct Deposition (P_d) | 5-39 |
| | 5.4.2 Forage and Silage Concentrations Due to Air-to-Plant Transfer (P_v) | 5-42 |
| | 5.4.3 Forage, Silage, and Grain Concentrations Due to Root Uptake (P_r) | 5-43 |
| | 5.4.4 Beef Concentration Resulting from Plant and Soil Ingestion (A_{beef}) | 5-43 |
| | 5.4.5 COPC Concentration In Milk Due to Plant and Soil Ingestion (A_{milk}) | 5-49 |
| 5.5 | CALCULATING COPC CONCENTRATIONS IN PORK | 5-53 |
| | 5.5.1 Fraction of Plant Type i Grown on Contaminated Soil and Eaten by the Animal (Swine) (F_i) | 5-54 |
| | 5.5.2 Quantity of Plant Type i Eaten by the Animal (Swine) Each Day (Q_{pi}) ... | 5-55 |
| | 5.5.3 Concentration of COPC in Plant Type i Eaten by the Animal (Swine) (P_i) . | 5-56 |
| | 5.5.4 Quantity of Soil Eaten by the Animal (Swine) Each Day (Q_s) | 5-56 |
| | 5.5.5 Average Soil Concentration Over Exposure Duration (C_s) | 5-57 |
| | 5.5.6 Soil Bioavailability Factor (B_s) | 5-57 |
| | 5.5.7 Metabolism Factor (MF) | 5-57 |
| 5.6 | CALCULATING COPC CONCENTRATIONS IN CHICKEN AND EGGS | 5-57 |
| | 5.6.1 Fraction of Plant Type i Grown on Contaminated Soil and Eaten by the Animal (Chicken) (F_i) | 5-59 |
| | 5.6.2 Quantity of Plant Type i Eaten by the Animal (Chicken) Each Day (Q_{pi}) .. | 5-59 |
| | 5.6.3 Concentration of COPC in Plant Type i Eaten by the Animal (Chicken) (P_i) | 5-60 |
| | 5.6.4 Quantity of Soil Eaten by the Animal (Chicken) Each Day (Q_s) | 5-60 |
| | 5.6.5 Average Soil Concentration Over Exposure Duration (C_s) | 5-61 |
| | 5.6.6 Soil Bioavailability Factor (B_s) | 5-61 |
| 5.7 | CALCULATING COPC CONCENTRATIONS IN DRINKING WATER AND FISH | 5-61 |
| | 5.7.1 Total COPC Load to the Water Body (L_T) | 5-64 |

CONTENTS (contd.)

| <u>Chapter</u> | | <u>Page</u> |
|----------------|--|-------------|
| | 5.7.2 Universal Soil Loss Equation - USLE | 5-69 |
| | 5.7.3 Sediment Delivery Ratio (<i>SD</i>) | 5-70 |
| | 5.7.4 Total Water Body COPC Concentration (C_{wtot}) | 5-71 |
| | 5.7.5 Concentration of COPC in Fish (C_{fish}) | 5-85 |
| | 5.8 USING SITE-SPECIFIC vs. DEFAULT PARAMETER VALUES | 5-89 |
| 6 | QUANTIFYING EXPOSURE | 6-1 |
| | 6.1 INHALATION EXPOSURE PATHWAYS | 6-2 |
| | 6.1.1 Soil Inhalation Resulting from Dust Resuspension | 6-3 |
| | 6.2 INGESTION EXPOSURE PATHWAYS | 6-4 |
| | 6.2.1 Body Weight | 6-5 |
| | 6.2.2 Food (Ingestion) Exposure Pathways | 6-6 |
| | 6.2.3 Soil (Ingestion) Exposure Pathway | 6-13 |
| | 6.2.4 Water (Ingestion) Exposure Pathways | 6-14 |
| | 6.3 DERMAL EXPOSURE PATHWAYS | 6-17 |
| | 6.3.1 Dermal Exposure to Soil | 6-17 |
| | 6.3.2 Dermal Exposure to Water | 6-18 |
| | 6.4 EXPOSURE FREQUENCY | 6-19 |
| | 6.5 EXPOSURE DURATION | 6-19 |
| | 6.6 AVERAGING TIME | 6-21 |
| 7 | CHARACTERIZING RISK AND HAZARD | 7-1 |
| | 7.1 QUANTITATIVELY ESTIMATING CANCER RISK | 7-3 |
| | 7.2 QUANTITATIVELY ESTIMATING NONCANCER HAZARD | 7-5 |
| | 7.3 TARGET LEVELS | 7-10 |
| | 7.4 ESTIMATING ACUTE EXPOSURE FROM DIRECT INHALATION | 7-10 |
| | 7.4.1 Existing Hierarchical Approaches for Acute Inhalation Exposure | 7-10 |
| | 7.4.2 Our Recommended Hierarchical Approach | 7-12 |
| | 7.4.3 Characterizing Potential Health Effects from Acute Exposure | 7-14 |
| 8 | INTERPRETING UNCERTAINTY FOR HUMAN HEALTH RISK ASSESSMENT | 8-1 |
| | 8.1 UNCERTAINTY AND LIMITATIONS OF THE RISK ASSESSMENT PROCESS | 8-1 |
| | 8.2 TYPES OF UNCERTAINTY | 8-2 |

CONTENTS (contd.)

| <u>Chapter</u> | | <u>Page</u> |
|----------------|---|-------------|
| 8.3 | QUALITATIVE ESTIMATES OF UNCERTAINTY | 8-5 |
| 8.4 | QUANTITATIVE ESTIMATES OF UNCERTAINTY | 8-5 |
| 8.5 | RISK ASSESSMENT UNCERTAINTY DISCUSSION | 8-7 |
| 9 | COMPLETING THE RISK ASSESSMENT REPORT AND FOLLOW-ON ACTIVITIES .. | 9-1 |
| 9.1 | CONCLUSIONS | 9-1 |
| 9.2 | ACTIVITIES FOLLOWING RISK ASSESSMENT COMPLETION | 9-2 |
| | REFERENCES | R-1 |

APPENDICES

| | | |
|-----|--|--|
| A | CHEMICAL-SPECIFIC DATA | |
| A-1 | CHEMICALS OF POTENTIAL INTEREST | |
| A-2 | CHEMICAL-SPECIFIC PARAMETER VALUES | |
| B | ESTIMATING MEDIA CONCENTRATION EQUATIONS AND VARIABLE VALUES | |
| B-1 | SOIL INGESTION EQUATIONS | |
| B-2 | PRODUCE INGESTION EQUATIONS | |
| B-3 | ANIMAL PRODUCTS INGESTION EQUATIONS | |
| B-4 | DRINKING WATER AND FISH INGESTION EQUATIONS | |
| B-5 | DIRECT INHALATION EQUATION | |
| B-6 | ACUTE EQUATION | |
| C | RISK CHARACTERIZATION EQUATIONS | |

FIGURES

| <u>Figure</u> | | <u>Page</u> |
|---------------|---|-------------|
| 1-1 | HUMAN HEALTH RISK ASSESSMENT PROCESS | 1-10 |
| 2-1 | EXAMPLE FACILITY PLOT MAP | 2-18 |
| 2-2 | EXAMPLE EMISSIONS INVENTORY | 2-19 |
| 2-3 | COPC IDENTIFICATION | 2-32 |
| 2-4 | PHASE ALLOCATION AND SPECIATION OF MERCURY IN AIR | 2-47 |
| 3-1 | SOURCES OF METEOROLOGICAL DATA | 3-28 |
| 3-2 | EXAMPLE INPUT FILE FOR "PARTICLE PHASE" | 3-40 |
| 4-1 | ISCST3 GRID NODES AND LAND USE DESIGNATIONS | 4-23 |
| 5-1 | COPC CONCENTRATION IN AIR FOR DIRECT INHALATION | 5-2 |
| 5-2 | COPC CONCENTRATION IN SOIL | 5-3 |
| 5-3 | COPC CONCENTRATION IN PRODUCE | 5-24 |
| 5-4 | COPC CONCENTRATION IN BEEF AND DAIRY PRODUCTS | 5-38 |
| 5-5 | COPC CONCENTRATION IN PORK | 5-53 |
| 5-6 | COPC CONCENTRATION IN CHICKEN AND EGGS | 5-58 |
| 5-7 | COPC LOADING TO THE WATER BODY | 5-63 |
| 5-8 | COPC CONCENTRATION IN FISH | 5-86 |

TABLES

| <u>Table</u> | <u>Page</u> |
|--|-------------|
| 2-1 EXAMPLE CALCULATION TOTAL FUGITIVE EMISSION RATES FOR EQUIPMENT IN WASTE FEED STORAGE AREA | 2-22 |
| 2-2 EXAMPLE CALCULATION SPECIATED FUGITIVE EMISSIONS FOR EQUIPMENT IN WASTE FEED STORAGE AREA | 2-24 |
| 2-3 SOCFI AVERAGE EMISSION FACTORS | 2-25 |
| 2-4 QUALITATIVE EFFECTS OF PHYSICAL & CHEMICAL CONDITIONS ON METHYLATION | 2-54 |
| 2-5 TOXICITY EQUIVALENCY FACTORS FOR COPLANAR PCBs | 2-64 |
| 2-6 SLOPE FACTORS FOR PCBs | 2-65 |
| 2-7 PCDD/PCDF TOXICITY EQUIVALENCY FACTOR VALUES | 2-69 |
| 2-8 RELATIVE POTENCY FACTORS FOR CLASS B2 CARCINOGEN PAHs | 2-70 |
| 3-1 HYPOTHETICAL PARTICLE SIZE DISTRIBUTION DATA TO SUPPORT EXAMPLE CALCULATIONS | 3-10 |
| 3-2 URBAN LAND USE TYPES | 3-17 |
| 3-3 SURFACE ROUGHNESS HEIGHTS | 3-19 |
| 3-4 <i>L</i> VALUES FOR VARIOUS LAND USES | 3-32 |
| 3-5 ALBEDO OF NATURAL GROUND COVERS FOR LAND USE TYPES AND SEASONS | 3-34 |
| 3-6 DAYTIME BOWEN RATIOS BY LAND USE, SEASON, AND PRECIPITATION CONDITIONS | 3-36 |
| 3-7 ANTHROPOGENIC HEAT FLUX (Q_f) AND NET RADIATION (Q_*) FOR SEVERAL URBAN AREAS | 3-38 |
| 3-8 ISCST3 INPUT FILE SECTIONS | 3-41 |
| 3-9 DRY DEPOSITION VELOCITY ESTIMATES AVAILABLE IN LITERATURE | 3-43 |
| 3-10 ISCST3 AIR PARAMETER OUTPUT | 3-59 |

TABLES (contd.)

| | | |
|-----|---|------|
| 4-1 | RECOMMENDED EXPOSURE SCENARIOS FOR A HUMAN HEALTH RISK ASSESSMENT | 4-13 |
| 6-1 | MEAN CONSUMPTION RATES FOR RECOMMENDED EXPOSURE SCENARIOS | 6-4 |
| 6-2 | COOKING-RELATED WEIGHT LOSSES FOR VARIOUS HOME-PRODUCED FOODS | 6-11 |
| 6-3 | EXPOSURE DURATION VALUES | 6-21 |

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 |

US EPA ARCHIVE DOCUMENT

INDEXED LIST OF VARIABLES

| Variable | Units | Definition | [Sections]/ Equations |
|-----------------------|---------------------------------------|---|--|
| γ | unitless | Empirical constant | used to generate R_p |
| 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 |
| A_h | m ² | Area planted | used to estimate Y_p |
| A_{hi} | m ² | Area planted to i th crop | see A_h |
| A_I | m ² | Impervious watershed area receiving COPC deposition | 5-31; 5-32; 5-33; 5-36C; B-4-9; B-4-10 |

INDEXED LIST OF VARIABLES (contd.)

| 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 |

INDEXED LIST OF VARIABLES (contd.)

| Variable | Units | Definition | [Sections]/ Equations |
|------------------------|---|--|---|
| Br_{grain} | unitless ($\mu\text{g COPC/g DW plant}$)/($\mu\text{g COPC/g soil}$) | Plant-soil bioconcentration factor for COPC in grain | 5-20A; [A2.4.3]; A-2-14B; B-3-9 |
| $Br_{rootveg}$ | unitless ($\mu\text{g COPC/g FW plant}$)/($\mu\text{g COPC/g soil}$) | 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 ($\text{mg COPC/kg lipid tissue}$)/($\text{mg COPC/kg sediment}$) | COPC air-to-plant biotransfer factor for aboveground produce ($\mu\text{g COPC/g DW plant}$)/($\mu\text{g COPC/g air}$)—unitless | 5-18; [A2.4.4]; A-2-15A&B; B-2-8 |
| $Bv_{forage/silage}$ | unitless ($\mu\text{g COPC/g DW plant}$)/($\mu\text{g COPC/g air}$) | 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 | $\mu\text{g/m}^3$ | 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 ($\mu\text{g/m}^3$) | 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} | $\text{mg COPC/kg FW tissue}$ | Concentration of COPC in fish | [5.7.5]; 5-48; 5-49; 5-50; B-4-28; C-1-4 |
| Chv | $\mu\text{g-s/g-m}^3$ | Unitized hourly air concentration from vapor phase | B-6-1 |
| Chp | $\mu\text{g-s/g-m}^3$ | Unitized hourly air concentration from particle phase | B-6-1 |
| $Chpb$ | $\mu\text{g-s/g-m}^3$ | Unitized hourly air concentration from particle-bound phase | |

INDEXED LIST OF VARIABLES (contd.)

| Variable | Units | Definition | [Sections]/ Equations |
|-------------|--|---|--|
| C_s | mg COPC/kg soil | Average soil concentration over exposure duration | [5.2.1]; 5-1C&D; 5-20A&B; 5-22; 5-24; 5-25; 5-26; 5-32; 5-33; B-1-1; B-2-1; B-2-9; B-2-10; B-3-1; B-3-9; B-3-10; B-3-11; B-3-12; B-3-13; B-3-14; B-4-1; B-4-10; B-4-11 |
| 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-day) ⁻¹ | Cancer slope factor | 7-2; [A2.6.2]; C-1-7 |
| $C_{s,tD}$ | mg COPC/kg soil | Soil concentration at time tD | [5.2.1]; 5-1E; B-1-1; B-2-1; B-3-1; B-4-1; C-3-1 |
| 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 |
| C_{yp} | μg-s/g-m ³ | Unitized yearly average air concentration from particle phase | [3.8.3.2]; B-5-1 |
| C_{yv} | 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 |
| C_{yww} | 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 |
| d_{bs} | m | Depth of upper benthic sediment layer | 5-35; 5-36A; 5-43; 5-45; 5-47; B-4-15; B-4-16; B-4-18; B-4-22; B-4-23; B-4-25 |
| D_{mean} | | Mean particle size density for a particular filter cut size | 3-1 |
| D_s | mg COPC/kg soil-yr | Deposition term | [5.2.3]; 5-1C, D&E; 5-36C; B-1-1; B-2-1; B-3-1; B-4-1 |
| 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 |
| D_w | cm ² /s | Diffusivity of COPC in water | 5-41A&B; [A2.3.5]; A-2-2B; B-4-20 |

INDEXED LIST OF VARIABLES (contd.)

| Variable | Units | Definition | [Sections]/ Equations |
|-------------|-------------------|--|--|
| $Dydp$ | $s/m^2\text{-yr}$ | Unitized yearly average dry 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 |
| $Dydv$ | $s/m^2\text{-yr}$ | Unitized yearly average dry 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 |
| $Dytwp$ | $s/m^2\text{-yr}$ | 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 |
| $Dywp$ | $s/m^2\text{-yr}$ | 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 |
| $Dyww$ | $s/m^2\text{-yr}$ | 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 |
| $Dytwv$ | $s/m^2\text{-yr}$ | 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 |
| F_w | 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 |

INDEXED LIST OF VARIABLES (contd.)

| 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 ⁶¹ | 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 |
| k_p | yr ⁻¹ | Plant surface loss coefficient | [5.3.1.2]; 5-14; B-2-7; B-3-7 |
| k_s | 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; |
| k_{se} | 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 |
| k_{sg} | 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 |
| k_{sl} | 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 |
| k_{sr} | 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 |
| k_{sv} | 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>i</i>) | |
| $Q_{i(adj)}$ | g/s | Adjusted emission rate of COPC (<i>i</i>) | |
| $Qcp_{i(adj)}$ | g/s | Adjusted emission rate of Table A-1 carcinogenic COPC (<i>i</i>) | |
| Qcp_i | g/s | Emission rate of Table A-1 carcinogenic COPC (<i>i</i>) | |
| Q_f | W/m ² | Anthropogenic heat flux | [3.5.7] |
| Qp_i | kg DW/day | Quantity of plant type <i>i</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 |
| Q_s | 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 |

US EPA ARCHIVE DOCUMENT

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 |
| J_{Sf} | unitless | Entropy of fusion [$J_{Sf}/R = 6.79$] | A-2-11 |
| SF | $(\text{mg/kg-day})^{-1}$ | 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 | : 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 |

INDEXED LIST OF VARIABLES (contd.)

| 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 |
| Y_h | kg DW | Dry harvest yield | |
| Y_{h_i} | kg DW | Harvest yield of <i>i</i> th crop | |
| Y_p | 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 |
| Y_{p_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 | |