Exposure Assessment 101

Glossary of Terms and Supplemental Information

Version 2.0

American Chemistry Council

LRI Long-Range Research Initiative

lri.americanchemistry.com

Foundation for Chemistry RESEARCH & INITIATIVES

foundationforchemistry.org

Contents

Glossary of Terms

Glossary adapted and supplemented from several sources, including CPS, IPCS, USEPA ExpoBox Training, Exposure Science in the 21st Century (NRC).

7Q10 flow: Average stream flow value for the 7-consecutive days lowest- flow over a 10-year period. Used to determine predicted environmental concentrations from E-FAST.

Action Level: The concentration level at which risk is expected if exposures exceed action level values. In an industrial hygiene context, the action level is often used as an initial risk management control point at a concentration below the occupational exposure limit.

Acute toxicity: Adverse effects on any living organism that results from a single dose or single exposure of a chemical; any poisonous effect produced within a short period of time, usually less than 96 hours.

ADD (Average daily dose): The estimate of dose averaged over the number of years of use/exposure to the chemical; used in assessments of risk of non-cancer chronic health effects.

ADR (Acute dose rate): The estimated dose on a given day; used in assessments of the risk of acute toxic effects.

Advection: chemical transport in a medium, e.g., transport in air

Affirmative finding: TSCA requires EPA to review submitters' section 5 notices and make an affirmative finding on the safety of new chemical substances or significant new uses of chemicals with five possible determinations: 1) unreasonable risk, 2) insufficient information to make a reasoned evaluation of risk, 3) absence of sufficient information may present an unreasonable risk, 4) substantial environmental release or substantial exposure, and 5) not likely to present an unreasonable risk.

APDR (Acute potential dose rate): The estimated dose on a given 8-hour working day exposure duration; used in assessments of the risk of acute toxic effects.

Bioconcentration: Process of chemical uptake and elimination in an organism as a result of exposure in its ambient environment only, e.g., exposure to a fish from water only as occurs in a controlled laboratory experiment.

Bioconcentration Factor (BCF; L-water/kg-organism): The steady-state chemical concentration ratio between an organism (e.g., fish) and its surrounding environment (e.g., water) measured under controlled conditions in which dietary exposure is excluded.

Bioaccumulation: Net result of competing rates of chemical uptake and elimination in an organism as occurs in the natural environment.

Bioaccumulation Factor (BAF; L-water/kg-organism): The steady-state chemical concentration ratio between an organism and its surrounding environment including all routes of chemical exposure, i.e., from water and diet.

Bioassay: Testing method that measures the effects of a material on living organisms.

Biodegradable: Ability of a substance to be broken down physically and/or chemically by microorganisms.

Biological Exposure Indices®: are established by the American Conference of Governmental Industrial Hygienists: represent levels of determinants most likely to be observed in samples collected from healthy workers exposed to the same extent as workers with inhalation exposure at the TLV® (Threshold Limit Value® for workplace air concentrations).

Biomagnification: Process in which the chemical activity (or fugacity) in an organism is greater than the chemical activity in its diet.

Biomonitoring Equivalents (BEs): the concentration or range of concentrations of a chemical or its metabolite in a biological medium (blood, urine, or other medium) that is consistent with an existing health-based exposure guideline.

Bounding Estimates: capture highest possible exposure or theoretical upper bound estimate

Carcinogen(ic): Ability of a substance to cause cancer.

Chemical Abstract Service (CAS): Organization which assigns unique numbers to chemical substances submitted to them. CAS Registry Numbers are the unique identifier for a chemical substance, while chemical names may not be unique.

Chemical category: A group of chemicals whose physicochemical and human health and/or ecotoxicological properties and/or environmental fate properties are likely to be similar or follow a regular pattern, usually as a result of structural similarity. From: *Guidance on Grouping of Chemicals, Second Edition, Series on Testing and Assessment No. 194; ENV/JM/MOMO(2014)4.*

Chemical class: The general chemical group to which a chemical belongs (e.g., acid, base, hydrocarbon, etc.).

Chronic Toxicity: Adverse effects on any living organism in which symptoms develop slowly over a period of time (often the life time of the organism) as a result of long-term or ongoing exposures.

Combined exposures: co-exposures, exposures to multiple substances within relevant biological timeframe

Concern concentration (CC) or Concentration of Concern (COC): Reported in parts per billion (ppb) or parts per million (ppm), provides the concentration of a chemical in a stream and indicates the concentration at which harm is more likely to occur to aquatic organisms. COC is determined by dividing the lowest chronic toxicity value by 10.

Default Evaluative: generic "Unit Word" which is representative of typical conditions

Deterministic modeling: provide single point estimates

Direct discharge: Under NPDES permitting, the discharge of chemicals or compounds directly to a surface water body.

Dose: In terms of monitoring exposure levels, the amount of a toxic substance taken into the body over a given period of time.

Dose Response: The manner in which an organism's response to a toxic substance changes as its overall exposure to the substance changes.

EC50 (Effective Concentration 50): Median effective concentration for an effect of interest. In the context environmental risk assessment, it is the concentration of a chemical at which 50% of the test organisms die; a common measure of acute toxicity.

Effluent: The stream flowing out of a facility or water body. The concentrations in its flow are used to estimate potential health effects of the discharge.

Emission rate: the amount of chemical released into a system of interest over a specified period of time.

Empirical models: based upon datasets. Ex. EASE, ECETOC-TRA Worker Module based upon occupational monitoring data

Equilibrium: when two or more compartments are at equal fugacity (or chemical activity); not equal concentrations, e.g., $K_{OW} = \frac{c_O}{c_W}$

Existing Chemical Substance: Any chemical already in commerce when TSCA originally enacted in 1976 or any chemical that has undergone Premanufacture Notice review and is listed on the TSCA Inventory.

Exposure: Contact between an agent and a target (receptor) via inhalation, ingestion, or dermal routes. The route, magnitude, and duration of exposure contributes to the ultimate risk for the organism.

Exposure pathway: the course an agent takes from the source to the target (receptor).

Exposure Scenario: A combination of facts, assumptions and inferences that define a discrete situation where potential exposures may occur. These may include the source, the exposed population, the time frame of exposure, microenvironment(s), and activities. Scenarios are often created to aid exposure assessors in estimating exposure.

Exposure Science: the collection and analysis of quantitative and qualitative information needed to understand the nature of contact between receptors (such as people or ecosystems) and physical, chemical, or biologic stressors.

Farfield Exposures: Receptors exposed to chemicals that were released or used far away (ambient exposure). In the context of industrial hygiene, farfield often refers to exposures outside the immediate proximity of the worker.

Half-life: Time required for one-half of the mass or concentration of a chemical or compound to degrade or be removed from the system.

Harmonic mean: The number of daily flow measurements divided by the sum of the reciprocals of the flows. A value that is more conservative than the arithmetic mean flow value. Used to assess chronic risks to humans.

Hazard: Potential for a substance to cause adverse effects to organisms, for example irritation, liver toxicity, birth defects, etc.

Henry's Law Constant: A measure of the concentration of a chemical in air over its concentration in water.

High end: A plausible estimate of an individual exposure or dose for those persons at the upper end of an exposure or dose distribution, typically above the 90th percentile, but no higher than the individual in the population who has the highest exposure.

Hybrid Models: combination of empirical and mechanistic models

Hydrophilic: Having an affinity for water.

Influent: Stream flowing into a facility or water body.

Indirect discharge: Under NPDES permitting, unlike a direct discharger, an indirect discharger from a nonresidential source pumps effluent to another facility that has a permit to discharge to the stream. Indirect dischargers often pretreat their discharges prior to pumping them to the publicly owned treatment works.

Inter-media exchange: transfer from one compartment to another, e.g., from air to water

IOC: ionizable organic chemical

K_{oa}: Octanol-air partition coefficient - the ratio of a chemical's concentration in the octanol phase to its concentration in air of a two-phase octanol/air system at equilibrium.

K_{oc}: Organic carbon partition coefficient -the ratio of amount of a chemical adsorbed per unit weight of organic carbon to the chemical concentration in solution at equilibrium Is an indication of how the chemical will partition itself between the solid and solution phases of a water-saturated or unsaturated soil.

K_{ow}: Octanol-water partition coefficient -the ratio of a chemical's concentration in the octanol phase to its concentration in the aqueous phase of a two-phase octanol/water system at equilibrium.

LADD (Lifetime average daily dose): The estimated dose to an individual averaged over a lifetime; used in assessments of *carcinogenic* risk.

LC50 (Lethal Concentration 50): Median lethal concentration is the concentration of a chemical at which 50% of the test organisms die; a common measure of acute toxicity. This can reflect the concentration in water or air.

LD50 (Lethal Dose 50): The dose of a toxicant that will kill 50% of test organisms within a designated period of time. The lower the LD50, the more toxic the compound.

Lipophilic: Having an affinity for, or capable of dissolving in, fat and fatty materials.

Loading: The amount of chemical that is discharged to a stream after treatment, reported in kg/day.

Lowest Observed Adverse Effect Level (LOAEL) or Lowest Observed Effect Level (LOEL): Lowest dose at which there was an observed toxic or adverse effect – usually associated with mammalian health data.

Lowest Observed Effect Concentration (LOEC): Lowest concentration which caused observable harm – usually associated with aquatic species data or inhalation toxicity data.

Margin of Exposure: Ratio of an effect level (example given) no-observed-adverse-effect level (NOAEL) obtained from animal toxicology studies to the predicted, or estimated human exposure.

Mechanistic or First Principle models: based upon scientific principles of mass balance and transport (physical-chemical properties, physics).

Milligrams/liter (mg/L): A measure of concentration used in the measurement of fluids that is roughly equivalent to parts per million.

Mode-of-entry: how a chemical enters the system.

Moiety(ies): Compounds formed when a larger compound is subdivided or substructures within a larger molecule.

(M)SDS (Material Safety Data Sheet or Safety Data Sheet): Printed material concerning a hazardous chemical including its physical properties, hazards to personnel, fire and explosive potential safe handling and transportation recommendations, health effects, reactivity, and proper disposal. Originally established for employee safety by OSHA regulation and now incorporated in to international regulation as an SDS.

Mutagenicity: The property of a chemical to cause genetic mutations that are expressed in the next generation but not necessarily in the organism exposed to the mutagen.

Nearfield: Used in CEM & IH Mod to denote breathing zone immediately around user (personal breathing zone).

Nearfield Exposure: Exposure that takes place in the vicinity of a receptor. In the context of industrial hygiene, nearfield refers to exposures within the immediate proximity of the worker.

New Chemical Substance (NCS): Any chemical that is not on the TSCA Inventory.

No Effect at Saturation (NES): In general, when the log K_{ow} is less than or equal to 5.0 for fish and daphnid, or 6.4 for green algae, ECOSAR provides reliable quantitative (numeric) toxicity estimates for acute effects. If the log Kow exceeds those general limits, empirical data indicate that the decreased solubility of these lipophilic chemicals results in "no effects at saturation" during a 48-hour to 96-hour test. For chronic effects, chemicals with a log Kow value >8.0 are expected "no effects at saturation."

No Observed Adverse Effect Level (NOAEL) or No Observed Effect Level (NOEL): Highest dose at which there was not an observed toxic or adverse effect – usually associated with mammalian health data.

No Observed Effect Concentration (NOEC): Concentration which does not cause observable harm – usually associated with aquatic species data or inhalation toxicity data.

NPDES (National Pollutant Discharge Elimination System): is the primary permitting program under the Clean Water Act which requires that dischargers of chemicals to surface waters obtain a permit from EPA. A NPDES permit number is a nine-character number with the two letter State abbreviation beginning the number (e.g., NC0001234).

Occupational Exposure Limit (OEL): Workplace exposure limit for chemicals, intended to protect from adverse health effects in all or most workers over a working life-time. Established as recommended or consensus values by various organizations.

Parts per million(ppm): One ppm is comparable to one drop in the gasoline tank of a full-size car.

Parts per billion (ppb): One ppb is comparable to one kernel of corn in a filled, 45-fool silo, 16 feet in diameter.

Parts per trillion (ppt): One ppt is comparable to one drop in a swimming pool the size of a football field and 43 feet deep.

Permissible Exposure Limit (PEL): Workplace exposure limits for chemicals established by the U.S. Occupational Safety and Health Administration (OSHA).

Point Source: A stationary location or fixed facility such as an industry or municipality that discharges chemicals into air or surface water.

Pollution: Any substances in environmental media that degrade the natural quality of the environment.

Pollution Prevention (P2): The concept stating that it is easier to prevent pollution at the source than to clean up pollution after it has occurred.

Potential Dose Rate(s) PDR(s): Provide an estimate of possible exposure rate to receptor from expected use, usually derived by modeling using default exposure factors.

Potentially exposed or susceptible subpopulations: A group of individuals within the general population identified by the Administrator who, due to either greater susceptibility or greater exposure, may be at greater risk than the general population of adverse health effects from exposure to a chemical substance or mixture, such as infants, children, pregnant women, workers, or the elderly.

POTW (Publicly Owned Treatment Works): A municipal or public service district sewage treatment system.

Predicted Environmental Concentration (PEC): Concentration expected in the water column which aquatic species will be exposed to.

Predicted No Effect Concentration (PNEC): Concentration which does not cause observable harm – usually associated with aquatic species data.

Premanufacture Notice (PMN): A notice to EPA required under Section 5 of TSCA for anyone who plans to manufacture (including import) a new chemical substance for a non-exempt commercial purpose.

Probabilistic Dilution Model (PDM): Addresses aquatic ecological exposures and risks. PDM is used by the General Population and Ecological Exposure from Industrial Releases, and Down-the-Drain modules to calculate concentrations and to predict the number of days per year a chemical's concentration of concern (COC) in an ambient water body will be exceeded by the discharge from a facility.

QSARs: Quantitative Structure Activity Relationships are models that relate a set of "predictor" variables (e.g., structural components) to a response variable (e.g., K_{OW}).

REACH: Registration, Evaluation, Authorisation and Restriction of Chemicals is a European Union regulation dating from 18 December 2006. REACH addresses the production and use of chemical substances, and their potential impacts on both human health and the environment.

Reach: A reach is a stream or river segment identified by EPA and assigned an 11-digit ID number. The first two numbers indicate the hydrologic region of the United States in which the reach is located.

Reaction: chemical transformation in a medium or biological system, e.g., hydrolysis.

Reference Dose (RfD): Estimate of daily oral exposure that is likely to be without a significant increased risk of adverse health effects.

Release: Any spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing into the environment of a hazardous or toxic chemical.

Risk: A measure of the chance that damage to life, health, property, or the environment will occur.

Risk Assessment: A process to determine the increased risk from exposure to environmental chemicals together with an estimate of the severity of impact. Risk assessments use specific chemical information plus risk factors.

SARs: Structure Activity Relationship (SAR) predict the toxicity of chemicals based on their structural similarity to chemicals for which toxicity data are available. SARs express the correlations between a compound's physicochemical properties and its toxicity. SARs measured for one compound can be used to predict the toxicity of similar compounds belonging to the same chemical class. EPA routinely uses to estimate toxicity of chemicals submitted as Premanufacture Notices mandated by Section 5 of the Toxic Substances Control Act (TSCA).

SCREEN3: A single source Gaussian plume model which provides maximum ground-level concentrations for point, area, flare, and volume sources. SCREEN3 is a screening version of the ISC3 model.

Sensitivity Analysis: The computation of the effect of changes in input values or assumptions (including boundaries and model functional form) on the outputs.

Sentinel Exposure: the exposure to a single chemical substance that represents the plausible upper bound of exposure relative to all other exposures within a broad category of similar or related exposures

SIC (SIC) Code: Standard Industrial Classification Code system is a four-digit number that identifies the specific industrial activity. For a complete listing of SIC codes, see Standard Industrial Classification Manual. 1987. Supt. of Documents, U.S. Government Printing Office, Washington, DC. SIC Codes were mostly replaced by the six-digit North American Industry Classification System (NAICS).

Slope Factor: A measure of individual's extra risk (increased likelihood) of developing cancer for each incremental increase in exposure to a chemical.

Steady-state: condition at which concentrations do not significantly change over time.

Stochastic (Probabilistic) modeling: Provides a distribution of estimates based on the chosen inputs.

STP (Sewage treatment plant): A municipal or public service district sewage treatment system.

Toxicity Testing: Biological testing (usually with an invertebrate, fish, or small mammal) to determine the adverse effects, if any, of a chemical substance.

Uncertainty Analysis: Investigates the effects of lack of knowledge or potential errors of the model (e.g. the uncertainty associated with parameter values or model design and output).

Supplemental Information

References and Links to Exposure-Assessment Models

Model Name	Link
AIM	https://www.epa.gov/tsca-screening-tools/analog-identification-methodology-aim-tool
A.I.S.E. REACT	https://www.aise.eu/our-activities/regulatory-context/reach/consumer-safety-exposure-assessment.aspx
AIST-ADMER	www.aist-riss.jp/software/admer/en/index_e.html
AIST-CBAM	https://www.aist-riss.jp/projects/RAM/risk/CBAM_index.htm (Japanese)
ART	https://www.advancedreachtool.com/
CEM	https://www.epa.gov/tsca-screening-tools/cem-consumer-exposure-model-download-and-install-instructions
ChemSteer	https://www.epa.gov/tsca-screening-tools/chemsteer-chemical-screening-tool-exposures-and-environmental-releases
ConsExpo	https://www.rivm.nl/en/consexpo
EASE (UK)	https://www.hse.gov.uk/research/rrpdf/rr136.pdf
EAS-E Suite	
ECETOC TRA	https://www.ecetoc.org/tools/targeted-risk-assessment-tra/
ECOSAR	https://www.epa.gov/tsca-screening-tools/ecological-structure-activity-relationships-ecosar-predictive-model
E-FAST	https://www.epa.gov/tsca-screening-tools/e-fast-exposure-and-fate-assessment-screening-tool-version-2014
EGRET	https://www.esig.org/reach-ges/consumers/

Model Name	Link
EPI Suite™	https://www.epa.gov/tsca-screening-tools/epi-suitetm-estimation-program-interface
EUSES	https://echa.europa.eu/support/dossier-submission-tools/euses
ExpoBox	https://www.epa.gov/expobox
HeatDB	https://www.ecetoc.org/tools/ecetoc-heat-db/
HESI Look up Tables	https://hesiglobal.org/publication/using-exposure-bands-for-rapid-decision-making-in-the-risk21-tiered-exposure-assessment/
IECCU	https://www.epa.gov/tsca-screening-tools/users-guide-and-download-ieccu-indoor-environmental-concentrations-buildings
IH SkinPerm	https://www.aiha.org/public-resources/consumer-resources/topics-of-interest/ih-apps-tools
IHMod	https://www.aiha.org/public-resources/consumer-resources/topics-of-interest/ih-apps-tools
MCCEM	https://www.epa.gov/tsca-screening-tools/multi-chamber-concentration-and-exposure-model-mccem-version-12
OECD	http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=ENV/JM/MONO(2012)1&docLanguage=En
OncoLogic™	https://www.epa.gov/tsca-screening-tools/oncologictm-computer-system-evaluate-carcinogenic-potential-chemicals
PACEM	https://www.rivm.nl/en/consumer-exposure-to-chemical-substances/exposure-models/PACEM
PBT Profiler	https://www.epa.gov/sites/production/files/2015-05/documents/07.pdf
PetroRisk	https://www.concawe.eu/reach/petrorisk/
PROTEX	https://lilienv.weebly.com/protex.html
PROTEX-HT	https://www.eas-e-suite.com
RAIDAR	https://arnotresearch.com/raidar/
RAIDAR-ICE	https://arnotresearch.com/raidar-ice/

Model Name	Link
REACT	https://www.aise.eu/our-activities/regulatory-context/reach/consumer-safety-exposure-assessment.aspx
SEEM	https://cfpub.epa.gov/si/si_public_file_download.cfm?p_download_id=536631&Lab=NCCT
SHEDS-HT	GitHub - HumanExposure/SHEDSHTRPackage: SHEDS-HT R package and default input files
Stoffenmanager	https://stoffenmanager.com/
USETOX	https://usetox.org/
RISKOFDERM	https://echa.europa.eu/documents/10162/19680902/calculator_riskofderm_enl.xls/9e0c3fa8-4764-4a18-95f9-8fbccf3acf2a

References to Websites

Basics Module

Slide	Link	Title
38 (TSCA Terminology)	https://www.regulations.gov/document/EPA-HQ-OPPT-2016-0654-0108	Procedures for Chemical Risk Evaluation Under the Amended Toxic Substances Control Act

Occupational Module

Slide	Link	Title
9 (How to Collect Exposure Data)	https://www.epa.gov/esam	Environmental Sampling and Analytical Methods (ESAM) Program
9 (How to Collect Exposure Data)	https://www.cdc.gov/niosh/nmam/default.html	NIOSH Manual of Analytical Methods (NMAM) 5th Edition
9 (How to Collect Exposure Data)	https://www.osha.gov/dts/sltc/methods/	Sampling and Analytical Methods
9 (How to Collect Exposure Data)	https://www.aihaaccreditedlabs.org/	AIHA Laboratory Accreditation Programs, LLC
14 (Sources of OEL/Benchmarks)	https://www.osha.gov/annotated-pels	Permissible Exposure Limits – Annotated Tables

Slide	Link	Title
14 (Sources of OEL/Benchmarks)	https://www.dir.ca.gov/title8/5155table_ac1.html#_blank	PERMISSIBLE EXPOSURE LIMITS FOR CHEMICAL CONTAMINANTS
14 (Sources of OEL/Benchmarks)	https://www.cdc.gov/niosh/npg/	NIOSH Pocket Guide to Chemical Hazards
14 (Sources of OEL/Benchmarks)	https://portal.acgih.org/s/store#/store/browse/detail/a154W00000BPU38QAH	2019 TLVs and BEIs
14 (Sources of OEL/Benchmarks)	https://echa.europa.eu/information-on-chemicals	ECHA – Information on Chemicals
14 (Sources of OEL/Benchmarks)	https://tera.org/OARS/#reservations	OARS WEEL TABLE
14 (Sources of OEL/Benchmarks)	https://limitvalue.ifa.dguv.de/	GESTIS Database
15 (Sources of Data)	https://www.osha.gov/opengov/healthsamples.html	Chemical Exposure Health Data
15 (Sources of Data)	https://www2a.cdc.gov/hhe/search.asp	Health Hazard Evaluations (HHEs)
15 (Sources of Data)	https://www.epa.gov/tsca-inventory	TSCA Chemical Substance Inventory
29 (ART – Typical Uses)	https://echa.europa.eu/guidance-documents/guidance-on-information-requirements-and-chemical-safety-assessment	Guidance on Information Requirements and Chemical Safety Assessment
79 (IH SkinPerm – Inputs)	https://aiha-assets.sfo2.digitaloceanspaces.com/AIHA/resources/IHSkinPerm.xlsm	IH SkinPerm Download

Consumer Exposure, Part 1 Module

Slide	Link	Title
36 (Child Specific Exposure Resources)	https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=262211	Child-Specific Exposure Scenarios Examples (Final Report)

Environmental Exposure, Part 2 Module

Slide	Link	Title
38-40	www.eas-e-suite.com	Exposure And Safety Estimation (EAS-E) Suite

References to Papers, Figures, and Other References

Basics Module

Slide	Reference	Link	Title
14 (Source-to-Outcome Continuum) 15 (Exposure Pathways)	USEPA 2019; Figure 2-1	https://www.epa.gov/sites/production/files/2020-01/documents/guidelines_for_human_exposure_assessment_final2019.pdf	Source-to-Outcome Continuum
16 (Exposure Pathways) 23 (Environmental Receptors)	Introduction to EUSES, de Knecht, RIVM	https://www.youtube.com/watch?v=0QejiP0Owio	Sources of Release to Environment
17 (Exposure Route: Point of Entry)	USEPA 2019; Figure 2-3	https://www.epa.gov/sites/production/files/2020-01/documents/guidelines_for_human_exposure_assessment_final2019.pdf	External and Internal Exposures
24 (Environmental Exposure)	RAIDAR User Manual	https://arnotresearch.com/raidar/	Environmental Exposure
27 (Emerging Exposure Applications)	Ring et al. 2019	https://pubmed.ncbi.nlm.nih.gov/30516957/	Consensus Modeling of Median Chemical Intake for the U.S. Population Based on Predictions of Exposure Pathways
30, 31 (Tiering Example)	Feld-Cook et al. 2020	https://www.nature.com/articles/s41370-019-0190-x	Exploring the utility of robots in exposure studies

Slide	Reference	Link	Title
34 (Exposure Descriptors) 35 (Bounding Estimates) 36 (High-End Estimates) 37 (Central Tendency Estimates) 57 (Framework for Exposure Evaluation)	USEPA EXA 402	https://www.epa.gov/expobox/exposure-assessment-tutorials	Exposure Assessment Tutorials Risk Assessment Training and Experience (RATE)
41 (Biomonitoring Equivalents (BEs))	Presentation by S. Hayes, L. Aylward Aylward et al. 2008	https://pubmed.ncbi.nlm.nih.gov/22518117/	Biomonitoring Equivalents (BEs)
44 (Inhalation Exposure – Basic Algorithm), 45 (Oral Exposure – Basic Algorithm), 46 (Dermal Exposure – Basic Algorithms)	ExpoBox	https://www.epa.gov/expobox/exposure-assessment-tutorials	Exposure Assessment Tutorials Risk Assessment Training and Experience (RATE)
56 (Cumulative and Aggregate Exposures)	USEPA 2001	https://www.epa.gov/sites/production/files/2015-07/documents/aggregate.pdf	Fig 1. Some Pathways and Routes to be Considered in an Aggregate Exposure and Risk Assessment

New Chemicals Program Module

Slide	Reference	Link	Title
32 (Case Study EPI Suite)	Critical Path Services (CPS), 2017		TSCA compliance risk screening

Slide	Reference	Link	Title
33 (Case Study ECOSAR), 34 (Case Study PBT Profiler), 35 (Case Study AIM), 36 (Case Study OncoLogic), 51 (Case Study Human Health Risk Results)	USEPA, 2013a	https://www.epa.gov/sites/production/files/2015-05/documents/05-iad_discretes_june2013.pdf	Interpretive Assistance Document for Assessment of Discrete Organic Chemicals

Occupational Module

Slide	Reference	Link	Title
5-8, 10-11, 14	Jahn 2015	https://online-ams.aiha.org/amsssa/ecssashop.show_product_detail?p_mode=detail&p_product_serno=887	A Strategy for Assessing and Managing Occupational Exposures
9 (How to Collect Exposure Data)	NIOSH Manual of Analytical Methods (NMAM), Fourth Edition	https://www.cdc.gov/niosh/docs/2003-154/pdfs/7500.pdf	Silica, Crystalline, by XRD
30 (ART - Evaluation)	LeBlanc et al. 2018	https://pubmed.ncbi.nlm.nih.gov/29133136/	Comparison of the near field/far field model and the advanced reach tool (ART) model V1.5: exposure estimates to benzene during parts washing with mineral spirits
30 (ART - Evaluation) 37 (Stoffenmanager - Typical Uses/Evaluation)	Landberg et al. 2017	https://academic.oup.com/annweh/article/61/5/575/3066300?login=true	A Study of the Validity of Two Exposure Assessment Tools: Stoffenmanager and the Advanced REACH Too
30 (ART - Evaluation)	Schinkel et al. 2014	https://pubmed.ncbi.nlm.nih.gov/24449808/	Reliability of the Advanced REACH Tool (ART)

Slide	Reference	Link	Title
56 (HESI Tables – Typical Uses), 57 (HESI Tables – Risk Visualization)	Dellarco et al. 2017	https://pubmed.ncbi.nlm.nih.gov/28266262/	Risk21 Exposure Assessment Framework
64 (ChemSTEER – Typical Uses)	Daniels et al. 2003	https://www.tandfonline.com/doi/abs/10.1080/10473220301430	EPA's Exposure Assessment Tools and Models
71 (IH Mod – Evaluation)	Keil et al.	https://online-ams.aiha.org/amsssa/ecssashop.show_product_detail?p_mode=detail&p_product_serno=889	Mathematical Models for Estimating Occupational Exposure to Chemicals, 2nd Edition
86 (IH SkinPerm – Evaluation)	Tibaldi et al. 2014	https://www.tandfonline.com/doi/abs/10.1080/15459624.2013.831983	Dermal Absorption of Chemicals: Estimation by IH SkinPerm
88 (Scenario 1. 1-bromopropane)	CDC 2002	https://www.cdc.gov/niosh/hhe/reports/pdfs/2000-0410-2891.pdf	HETA #2000-0410-2891 STN Cushion Company Thomasville, North Carolina
91 (Scenario 2. Methylene Chloride)	CDC 1993	https://www.cdc.gov/niosh/hhe/reports/pdfs/1992-0360-2372.pdf	HETA 92-0360-2372
Additional information from presenters	NIOSH co-authors and others (Journal of Occupational and Environmental Hygiene)	https://www.tandfonline.com/toc/uoeh20/12/sup1	State of the Science of Occupational Exposure Limit Methods and Guidance A 10-manuscript series on key aspects of the derivation of occupational exposure limits [OELs] and issues for OEL use and implementation.

Consumer Exposure, Part 1 Module

Slide	Reference	Link	Title
7 (OECD Products and Articles)	OECD 2017	https://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=env/jm/mono(2017)14&doclanguage=en	OECD Products and Articles
10 (Exposure Framework), 11 (Exposure Pathways)	USEPA 2019; Figure 2-1	https://www.epa.gov/sites/production/files/2020-01/documents/guidelines_for_human_exposure_assessment_final2019.pdf	Source-to-Outcome Continuum
13 (Exposure Route: Point of Entry)	USEPA 2019; Figure 2-3	https://www.epa.gov/sites/production/files/2020-01/documents/guidelines_for_human_exposure_assessment_final2019.pdf	External and Internal Exposures
14 (Exposure Scenarios)	ICPS 2004	http://www.inchem.org/documents/harmproj/harmproj/harmproj1.pdf	IPCS Risk Assessment Terminology
15 (Exposure Scenarios)	ECHA 2017	https://echa.europa.eu/documents/10162/13632/illustrative_example_es_part1_introductory_note_en.pdf/b170d34c-6249-4995-babc-204c06315781	An illustrative example of the exposure scenarios to be annexed to the safety data sheet

Slide	Reference	Link	Title
16 (Exposure Scenarios)	USEPA 2012	https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/standard-operating-procedures-residential-pesticide	Example Exposure Scenarios
34 (Child Specific Exposure Resources)	OECD 2019	https://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=ENV/JM/MONO(2019)29&docLanguage=en	Considerations When Assessing Children's Exposure To Chemicals from Products
35 (Child Specific Exposure Resources)	OECD 2019	http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=ENV/JM/MONO(2019)24&doclanguage=en	Estimating Mouthing Exposure in Children – Compilation Of Case Studies
41,42 (Tiering Example)	Feld-Cook et al. 2020	https://www.nature.com/articles/s41370-019-0190-x	Exploring the utility of robots in exposure studies
53 (High Throughput Exposure Approaches), 55 (USEPA SEEM-3)	Ring et al. 2019	https://pubmed.ncbi.nlm.nih.gov/30516957/	Consensus Modeling of Median Chemical Intake for the U.S. Population Based on Predictions of Exposure Pathways

Consumer Exposure, Part 2 Module

Slide	Reference	Link	Title
31 (EGRET Observations)	Zaleski et al., 2014	https://www.nature.com/articles/jes2012128	European solvent industry group generic exposure scenario risk and exposure tool

Slide	Reference	Link	Title
32 (HESI Look-up Tables)	Dellarco et al., 2017	https://pubmed.ncbi.nlm.nih.gov/28266262/	Using exposure bands for rapid decision making in the RISK21 tiered exposure assessment
46 (ConsExpo Models)	National Institute for Public Health and the Environment, ConsExpo Web Consumer Exposure models model documentation	https://www.rivm.nl/bibliotheek/rapporten/2017-0197.pdf	ConsExpo Web Consumer Exposure models model documentation
73(Summary of Models within CEM)	EPA/ICF 2019	https://www.epa.gov/sites/production/files/2019-06/documents/cem_2.1_user_guide.pdf	Consumer Exposure Model (CEM) User Guide
97 (Model Comparison)	Cowan-Ellsberry et al. 2020	https://www.nature.com/articles/s41370-020-0237-z	Perspectives on advancing consumer product exposure models

Environmental Exposure, Part 1 Module

Slide	Reference	Link	Title
16 (Mass Balance) 23 (Spectrum of Multimedia Models)	Wania and Mackay, 1999	https://www.sciencedirect.com/science/article/abs/pii/S0269749199000937	The evolution of mass balance models of persistent organic pollutant fate in the environment
31 (Bioconcentration: Empirical Models)	Mackay 1982	https://pubs.acs.org/doi/pdf/10.1021/es00099a008	Correlation of bioconcentration factors
35 (The Influence of Biotransformation)	Modified from Arnot et al. 2008	https://pubs.acs.org/doi/10.1021/es800106g	Policies for chemical hazard and risk priority setting: can persistence, bioaccumulation, toxicity and quantity information be combined?

Environmental Exposure, Part 2 Module

Slide	Reference	Link	Title
7 (Measured Databases of Properties)	Pontolillo & Eganhouse 2001, USGS	https://pubs.usgs.gov/wri/wri014201/pdf/wri01-4201.pdf	The search for reliable aqueous solubility (Sw) and octanol-water partition coefficient (Kow) data for hydrophobic organic compounds: DDT and DDE as a case study. Water-Resources Investigations Report 01-4201.
10 (Environmental Partitioning phases: "3 solubility (S) approach")	Modified from Mackay 2001	https://www.taylorfrancis.com/books/mono/10.1201/9781420032543/multimedia-environmental-models-donald-mackay	Multimedia Environmental Models: The Fugacity Approach - Second Edition
11 (Least-Squares Adjustment Tool for Harmonizing Physiochemical Properties)	Schnecker et al. 2005	https://pubs.acs.org/doi/pdf/10.1021/es0502526	Least-Squares Adjustment Spreadsheet v1.1
24 (EUSES: Conceptual Overview)	Introduction to EUSES de Knecht, RIVM	https://www.rivm.nl/bibliotheek/rapporten/601900005.pdf	Figures taken from a presentation by Joop de Knecht for this model
33 (PROTEX: Conceptual Overview) 35 (PROTEX-HT: Conceptual Overview) 36 (PROTEX-HT: Example Results)	Li et al. 2018	https://www.sciencedirect.com/science/article/pii/S0160412018304100	Towards a systematic understanding of the dynamic fate of polychlorinated biphenyls in indoor, urban and rural environments
41 (EPA's ECOSEEM: Conceptual Overview)	Ring et al. 2019	https://pubs.acs.org/doi/10.1021/acs.est.8b04056	Consensus Modeling of Median Chemical Intake for the U.S. Population Based on Predictions of Exposure Pathways

Slide	Reference	Link	Title
41 (EPA's ECOSEEM: Conceptual Overview)	Sayre et al. ACS 2019	https://epa.figshare.com/articles/poster/Development_and_evaluation_of_consensus_meta-model_for_estimating_national_concentrations_of_organic_chemicals_in_surface_water/9772604	Poster presentation "Development and evaluation of consensus meta-model for estimating national concentrations of organic chemicals in surface water" (ACS Fall 2019)
44 (Key uncertainties with all models)	Di Guardo et al. 2018	https://pubs.rsc.org/en/content/articlelanding/2018/em/c7em00568g#!divAbstract	Environmental fate and exposure models: Advances and challenges in 21st century chemical risk assessment

References

Basics Module

Exposure Science in the 21st Century: A Vision and a Strategy - National Research Council

Exposure Science: Basic Principles and Applications - Lioy and Weisel

International Program on Chemical Safety (IPCS) Risk Assessment Terminology

Toxic Substances Chemicals Act (TSCA) legislation

New Chemicals Program Module

Chemical categories: https://www.epa.gov/sites/production/files/2014-10/documents/ncp_chemical_categories_august_2010_version_0.pdf

CPS, 2017. Sustainable Futures Workshop, TSCA compliance risk screening, Newark, Delaware, April 25-27, 2017

USEPA's New Chemicals Program: https://www.epa.gov/reviewing-new-chemicals-under-toxic-substances-control-act-tsca

U.S. Environmental Protection Agency (EPA). 2013a. Interpretive Assistance Document for Assessment of Discrete Organic Chemicals, Updated June 2013. https://www.epa.gov/sites/production/files/2015-05/documents/05-iad_discretes_june2013.pdf

U.S. Environmental Protection Agency (EPA). 2013b. Interpretive Assistance Document for Assessment of Polymers, Updated June 2013.

https://www.epa.gov/sites/production/files/2015-05/documents/06-iad_polymers_june2013.pdf

Zaleski, R., Qian, H., Zelenka, M. et al. European solvent industry group generic exposure scenario risk and exposure tool. J Expo Sci Environ Epidemiol 24, 27–35 (2014). https://doi.org/10.1038/jes.2012.128

Occupational Module

All models are wrong. Available: https://en.wikipedia.org/wiki/All_models_are_wrong [accessed 1 January 2021].

Baldwin, P.E.J and A.D. Maynard. (1998). A Survey of Wind Speeds in Indoor Workplaces. Ann occup hyg 42(5) pp. 303-313.

Burton, D. J. 2002. Burton Field Guide for Industrial Hygiene. Fairfax, VA: AIHA Press.

Demou, E., S. Hellweg, M.P. Wilson, S.K. Hammond and T.E. McKone. 2009. Evaluating Indoor Exposure Modeling Alternatives for LCA: A Case Study in the Vehicle Repair Industry. Environmental Science and Technology, 43 (15):5804-5810.

ECHA. 2016. Guidance on information requirements and chemical safety assessment. Chapter R. 14: Occupational exposure assessment.

Jahn S, Bullock W, Ignacio J, eds. 2015. A Strategy for Assessing and Managing Occupational Exposures. 4th ed. AIHA Press:Falls Church, VA.

Jayjock M, Logan P, Mader B, Owens J, Eldridge J, Costello M, et al. 2010. Modeled Comparisons of Health Risks Posed by Fluorinated Solvents in a Workplace Spill Scenario. Ann Occup Hyg 55:202–213; doi:10.1093/annhyg/meq062.

Landberg HE, Axmon A, Westberg H, Tinnerberg H. 2017. A Study of the Validity of Two Exposure Assessment Tools: Stoffenmanager and the Advanced REACH Tool. Ann Work Expo Heal 61:575–588; doi:10.1093/annweh/wxx008.

LeBlanc M, Allen JG, Herrick RF, Stewart JH. 2018. Comparison of the near field/far field model and the advanced reach tool (ART) model V1.5: exposure estimates to benzene during parts washing with mineral spirits. Int J Hyg Environ Health 221:231–238; doi:10.1016/j.ijheh.2017.10.016.

NRC. 1991. Environmental Epidemiology, Volume 1: Public Health and Hazardous Wastes.

Parker S. 2002. McGraw-Hill Dictionary of Scientific and Technical Terms. Sixth Edit. McGraw-Hill.

Savic N, Gasic B, Schinkel J, Vernez D. 2017. Comparing the Advanced REACH Tool's (ART) estimates with Switzerland's occupational exposure data. Ann Work Expo Heal 61:954–964; doi:10.1093/annweh/wxx069.

Tibaldi R, ten Berge W, Drolet D. 2014. Dermal Absorption of Chemicals: Estimation by IH SkinPerm. J Occup Environ Hyg 11:19–31; doi:10.1080/15459624.2013.831983.

Tischer M, Lamb J, Hesse S, van Tongeren M. 2017. Evaluation of tier one exposure assessment models (ETEAM): Project overview and methods. Ann Work Expo Heal 61:911–920; doi:10.1093/annweh/wxx066.

U.S. Environmental Protection Agency (EPA). Exposure Assessment Tools by Tiers and Types - Screening-Level and Refined. Available: https://www.epa.gov/expobox/exposure-assessment-tools-tiers-and-types-screening-level-and-refined [accessed 1 January 2021].

Waters M, McKernan L, Maier A, Jayjock M, Schaeffer V, Brosseau L. Exposure Estimation and Interpretation of Occupational Risk: Enhanced Information for the Occupational Risk Manager. Journal of Occupational and Environmental Hygiene, 2015; 12:S99–S111.

Consumer Exposure, Part 1 Module

Aylward et al. 2020 Exposure to selected preservatives in personal care products: case study comparison of exposure models and observational biomonitoring data. Journal of Exposure Science and Environmental Epidemiology 30:28-41 https://doi.org/10.1038/s41370-018-0104-3 (LRI sponsored)

Cowan-Ellsberry et al. 2020 Perspectives on advancing consumer product exposure models. Journal of Exposure Science & Environmental Epidemiology 30:856–865 https://doi.org/10.1038/s41370-020-0237-z (EAWG sponsored)

ECHA. 2017. An illustrative example of the exposure scenarios to be annexed to the safety data sheet https://echa.europa.eu/documents/10162/13632/illustrative_example_es_part1_introductory_note_en.pdf/b170d34c-6249-4995-babc-204c06315781

U.S. Environmental Protection Agency (EPA). 2014. Child-Specific Exposure Scenarios Examples (Final Report). https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=262211

OECD. 2017. INTERNATIONALLY HARMONISED FUNCTIONAL, PRODUCT AND ARTICLE USE CATEGORIES. http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=env/jm/mono(2017)14&doclanguage=en

OECD. 2019. CONSIDERATIONS WHEN ASSESSING CHILDREN'S EXPOSURE TO CHEMICALS FROM PRODUCTS. https://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=ENV/JM/MONO(2019)29&docLanguage=en

OECD. 2019. ESTIMATING MOUTHING EXPOSURE IN CHILDREN – COMPILATION OF CASE STUDIES. http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=ENV/JM/MONO(2019)24&doclanguage=en

The Practice of Consumer Exposure Assessment, eds. Gerhard Heinemeyer, Matti Jantunen, Pertti Hakkinen, Springer, Cham, Switzerland.

U.S. Environmental Protection Agency (EPA). (2003) Example Exposure Scenarios. National Center for Environmental Assessment, Washington, DC; EPA/600/R-03/036. Available from: National Information Service, Springfield, VA; PB2003-103280 and at http://www.epa.gov/ncea

Consumer Exposure, Part 2 Module

CEM User Manual. https://www.epa.gov/sites/production/files/2019-06/documents/cem_2.1_user_guide.pdf

Cowan-Ellsberry, C., Zaleski, R.T., Qian, H. et al. Perspectives on advancing consumer product exposure models. J Expo Sci Environ Epidemiol 30, 856–865 (2020). https://doi.org/10.1038/s41370-020-0237-z

ECHA. 2017. An illustrative example of the exposure scenarios to be annexed to the safety data sheet https://echa.europa.eu/documents/10162/13632/illustrative_example_es_part1_introductory_note_en.pdf/b170d34c-6249-4995-babc-204c06315781

M. Dellarco, R. Zaleski, B. J. Gaborek, H. Qian, C. A. Bellin, P. Egeghy, N. Heard, O. Jolliet, D. R. Lander, N. Sunger, K. S. Stylianou & J. Y. Tanir (2017) Using exposure bands for rapid decision making in the RISK21 tiered exposure assessment, Critical Reviews in Toxicology, 47:4, 317-341, DOI: 10.1080/10408444.2016.1270255 To link to this article: https://doi.org/10.1080/10408444.2016.1270255

National Institute for Public Health and the Environment, ConsExpo Web Consumer Exposure models model documentation Update for ConsExpo Web 1.0.2, 2017. ConsExpo Web Consumer exposure models Model documentation (rivm.nl)

OECD. 2017. INTERNATIONALLY HARMONISED FUNCTIONAL, PRODUCT AND ARTICLE USE CATEGORIES. http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=env/jm/mono(2017)14&doclanguage=en

OECD. 2019. CONSIDERATIONS WHEN ASSESSING CHILDREN'S EXPOSURE TO CHEMICALS FROM PRODUCTS. https://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=ENV/JM/MONO(2019)29&docLanguage=en

OECD. 2019. ESTIMATING MOUTHING EXPOSURE IN CHILDREN – COMPILATION OF CASE STUDIES. http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=ENV/JM/MONO(2019)24&doclanguage=en

U.S. Environmental Protection Agency (EPA). (2003) Example Exposure Scenarios. National Center for Environmental Assessment, Washington, DC; EPA/600/R-03/036. Available from: National Information Service, Springfield, VA; PB2003-103280 and at http://www.epa.gov/ncea

U.S. Environmental Protection Agency (EPA). 2014. Child-Specific Exposure Scenarios Examples (Final Report). https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=262211

Zaleski, R., Qian, H., Zelenka, M. et al. European solvent industry group generic exposure scenario risk and exposure tool. J Expo Sci Environ Epidemiol 24, 27–35 (2014). https://doi.org/10.1038/jes.2012.128

Environmental Exposure, Part 1 & 2 Modules

Arnot, J. A.; Brown, T. N.; Wania, F.; Breivik, K.; McLachlan, M. S., Prioritizing chemicals and data requirements for screening-level exposure and risk assessment. 2012. *Environ Health Persp*, *120*, (11), 1565-1570.

Arnot, J. A.; Gobas, F. A. P. C. 2004. A food web bioaccumulation model for organic chemicals in aquatic ecosystems. *Environ Toxicol Chem*, *23*, (10), 2343-2355.

Arnot, J. A.; Mackay, D., Policies for chemical hazard and risk priority setting: can persistence, bioaccumulation, toxicity and quantity information be combined? 2008. *Environ Sci Technol*, *42*, (13), 4648-4654.

Birak, P.; Yurk, J.; Adeshina, F.; Lorber, M.; Pollard, K.; Choudhury, H.; Kroner, S. 2001. Travis and Arms revisited: a second look at a widely used bioconcentration algorithm. *Toxicol Indust Health*, *17*, (5-10), 163-175.

Costanza J, Boethling RS, Lynch DG, Arnot JA. 2012. Use of the bioaccumulation factor to screen chemicals for bioaccumulation potential. *Environ Toxicol Chem,* 10:2261-2268.

Di Guardo, A.; Gouin, T.; MacLeod, M.; Scheringer, M. 2018. Environmental fate and exposure models: Advances and challenges in 21st century chemical risk assessment. *Environmental Science: Processes & Impacts*, 20, 58-71.

Fantke, P.; Huijbregts, M.; Margni, M.; Hauschild, M.; Jolliet, O.; McKone, T. E.; Rosenbaum, R. K.; van de Meent, D. 2015. *USEtox®2.0 User Manual (Version 2)*.

Li L, Arnot JA, Wania F. 2018. Towards a systematic understanding of the dynamic fate of polychlorinated biphenyls in indoor, urban and rural environments. *Environ Int* 117, 57-68.

Li, L.; Arnot, J. A.; Wania, F., How are Humans Exposed to Organic Chemicals Released to Indoor Air? 2019. *Environ Sci Technol*, *53*, (19), 11276-11284.

Li, L.; Sangion, A.; Wania, F.; Armitage, J. M.; Toose, L.; Hughes, L.; Arnot, J. A., Development and evaluation of a holistic and mechanistic modeling framework for chemical emissions, fate, exposure, and risk. in review.

Li, L.; Wania, F., Tracking chemicals in products around the world: introduction of a dynamic substance flow analysis model and application to PCBs. 2016. *Environ Int*, *94*, 674-686.

Lowe CN, Williams AJ. 2021. Enabling high-throughput searches for multiple chemical data using the U.S. EPA Comptox Chemicals Dashboard. *J Chem Info Model* 61:565-570.

Mackay D. 2001. Multimedia Environmental Models: The Fugacity Approach - Second Edition. Boca Raton, FL: Lewis Publishers.

Mackay, D.; Di Guardo, A.; Paterson, S.; Cowan, C. E. 1996. Evaluating the environmental fate of a variety of types of chemicals using the EQC model. *Environ Toxicol Chem*, *15*, (9), 1627-1637.

Mansouri, K.; Grulke, C. M.; Judson, R. S.; Williams, A. J. 2018. OPERA models for predicting physicochemical properties and environmental fate endpoints. *J Cheminformatics*, *10*, 10.

McKone, T. E. 1993. *CalTOX, A Multimedia Total Exposure Model for Hazardous-Waste Sites.*; U.S. Department of Energy: Washington, DC..

Pontolillo J, Eganhouse RP. 2001. The search for reliable aqueous solubility (Sw) and octanol-water partition coefficient (Kow) data for hydrophobic organic compounds: DDT and DDE as a case study. Water-Resources Investigations Report 01-4201. U.S. Geological Survey.

Ring, C. L.; Arnot, J. A.; Bennett, D. H.; Egeghy, P. P.; Fantke, P.; Huang, L.; Isaacs, K. K.; Jolliet, O.; Phillips, K. A.; Price, P. S.; Shin, H.-M.; Westgate, J. N.; Setzer, R. W.; Wambaugh, J. F. 2019. Consensus Modeling of Median Chemical Intake for the U.S. Population Based on Predictions of Exposure Pathways. *Environ Sci Technol*, *53*, (2), 719-732.

Rosenbaum, R. K.; Bachmann, T. M.; Gold, L. S.; Huijbregts, M. A. J.; Jolliet, O.; Juraske, R.; Koehler, A.; Larsen, H. F.; MacLeod, M.; Margni, M.; McKone, T. E.; Payet, J.; Schuhmacher, M.; Meent, D.; Hauschild, M. Z. 2008. USEtox—the UNEP-SETAC toxicity model: recommended characterisation factors for human toxicity and freshwater ecotoxicity in life cycle impact assessment. *The International Journal of Life Cycle Assessment*, *13*, (7), 532-546.

Schenker, U.; MacLeod, M.; Scheringer, M.; Hungerbuehler, K. 2005. Improving data quality for environmental fate models: A least-squares adjustment procedure for harmonizing physicochemical properties of organic compounds. *Environ Sci Technol* 2005, *39*, 8434-8441.

Travis, C. C.; Arms, A. D. 1998. Bioconcentration of organics in beef, milk and vegetation. *Environ Sci Technol*, *22*, 271-274.

Turner DB. 1994. Workbook of atmospheric dispersion estimates: An introduction to dispersion modeling. Second edition. Boca Raton, FL, USA: Lewis publishers, CRC Press, Inc.

U.S. EPA *Estimation Programs Interface (EPI) Suite for Microsoft® Windows, Ver. 4.11.*, Released November, 2012; U. S. Environmental Protection Agency: Washington, D.C.

U.S. EPA *Exposure and Fate Assessment Screening Tool (E-FAST)*. 2014. *Version 2.0 Documentation Manual*.; Versar, Inc.: Springfield, VA.

U.S. EPA. 2011. Exposure Factors Handbook: 2011 edition. EPA/600/R-09/052F. Washington, DC:U.S. Environmental Protection Agency.

Ulrich N, Endo S, Brown TN, Watanabe N, Bronner G, Abraham MH, et al. 2017. UFZ-LSER Database v 3.2.1 [internet]. Available: http://www.ufz.de/lserd.

Vermeire, T. G.; Rikken, M.; Attias, L.; Boccardi, P.; Boeije, G.; Brooke, D.; de Bruijn, J.; Comber, M.; Dolan, B.; Fischer, S.; Heinemeyer, G.; Koch, V.; Lijzen, J.; Muller, B.; Murray-Smith, R.; Tadeo, J. 2005. European Union System for the Evaluation of Substances (EUSES): The Second Version. *Chemosphere*, *59*, 473-485.

Wania F, Mackay D. 1999. The evolution of mass balance models of persistent organic pollutant fate in the environment. *Environ Poll*, 100:223-240.

Disclaimer

The views expressed are those of the authors and do not necessarily reflect the official policy or position of the ACC, FCRI, or the authors' employers. Reference to commercial products, services, or links does not imply endorsement by ACC or FCRI, the authors or the authors' employers. Materials and information communicated in this course may not reflect the most current developments in law or regulation; thus, you should not rely on the information or course materials to address specific legal, regulatory or product stewardship matters.

For more information, contact ACC_LRI@icf.com.