Hot Spots Exposure Assessment and Stochastic Analysis Document

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What is the Air Toxics Hot Spots Program?

- Stationary sources in CA report emissions of specified list of chemicals to ARB and Air Pollution Control Districts.
- Facilities are prioritized by Districts (high, medium, low concern).
  - Based on emissions estimates, distance to nearest receptor, information on potency of toxicants, and worst case meteorology.
- High concern facilities must conduct risk assessment to estimate public health impacts to surrounding population from facility emissions.

What is the Air Toxics Hot Spots Program?

- **Risk management activities by the local air districts can be prioritized based on the results of risk assessments.**
- **ARB uses the results of risk assessments to determine the need for and to design air toxics control measures that apply to certain types of industrial activities (e.g. chrome plating).**

OEHHA's role

- Statute requires risk assessments be conducted in accordance with guidelines developed by OEHHA.
  - OEHHA created Technical Support Documents to lay out underlying science and methods - first adopted in 1999 – 2000.
- OEHHA revised Technical Support Documents after passage of SB 25 requiring more explicit consideration of infants and children – both exposure and potential sensitivities relative to adults.
  - Noncancer and cancer dose-response assessment guidance approved following SRP Review in 2008 and 2009.
- OEHHA also reviews risk assessments sent by Districts.
- The Exposure Guidelines are undergoing your review now.

Hot Spots Exposure Guidelines Need to be:

- Practical to apply yet as comprehensive as possible
- Adaptable to many different scenarios and types of facilities
- Useful to compare potential health impacts/risks across facilities.
- Protective of public health.

Why the Revision?

- **OEHHA is mandated to adequately consider infants and children in evaluating toxicity of chemicals in all programs.**
- **Revision of the exposure assessment guidance prompted by the recognition of greater risks for early-in-life exposure.**
- **Revisions incorporate the latest scientific data on exposure and fate and transport into the model.**
  - **large body of literature on exposure and fate published since the last version of the exposure guidelines.**
- **Presentation focuses on the major changes to the document.**

Revisions to Exposure & Stochastic Analysis Document

- Need exposure variates for different age ranges.
- Cancer risk for exposures from third trimester to < 2 years weighted 10 X (OEHHA, 2009).
- Cancer risk for exposures from age 2 to <16 years weighted 3 X (OEHHA, 2009).
- Exposure is greater early in life because of behavioral, physiological differences, therefore risk are separately calculated for each age range and then summed.
  - Hence the need for exposure variates corresponding to specific age groupings.

Cancer Risk Calculation

- Cancer risk to be calculated for residential exposure duration of 9, 30, and 70 years.
- Requires incorporation of age-specific exposures, for example:
  - Calculation of Cancer Risk from Third Trimester to Age 30:

  CR = [ADD third trimester X CPF X 10 (ASF) X 0.3/70 years] + [ADD age 0 to <2 X CPF X 10 (ASF) X 2/70] +

  [ADD age 2 < 16 X CPF X 3 X 14/70] +

  [ADD age 16 < 30 X CPF X 1 (ASF) X 14/70 years]
- Where ADD =Average Daily Dose
- CPF= Cancer Potency Factor
- ASF=Age Sensitivity Factor
- Need exposure variates for third trimester, 0<2, 2<9, 9<16, 16 <30, 30<70.

Pathways Evaluated Under Hot Spots

- Inhalation*
- Dermal**
- Soil ingestion**
- Mother's milk**
- Home grown produce***
- Home raised meat (chicken, beef, pork)***
- Home raised eggs***
- Angler caught fish***
- Cow's milk (home raised)***
- Drinking water from local surface waters (not reservoirs)***

*All chemicals

**All chemicals subject to deposition

***Chemicals subject to deposition, particular pathways in accordance with physical-chemical properties, at sites with a completed pathway.

Exposure Assessment and Stochastic Analysis Revisions

- Only nonvolatile or semivolatile chemicals are evaluated in the Hot Spots for the noninhalation pathways—most chemicals are only evaluated using the inhalation pathway.
- Non and semi-volatiles include some important toxicants such as PAHs, dioxins and furans, mercury, lead and hexavalent chromium.
- Thus, we have exposure variates for all significant pathways of exposure that can occur with airborne deposition.

Tiered Approach to Risk Assessment

- Facilities have the option of presenting alternative site specific RA.
- OEHHA provided guidance for this in OEHHA, 2000.
- Same as previous guidelines:
  - Tier I point estimate approach uses OEHHA recommended point estimates
  - Tier II point estimate approach uses justified site specific point estimates
  - Tier III stochastic approach uses OEHHA recommended distributions
  - Tier IV stochastic approach uses justified site specific distributions

Tiered Approach to Risk Assessment

- **Most of the OEHHA distributions and point estimates are revised based on newer data.**

- **There is now a stochastic approach for the dermal pathway, whereas in the previous document there was only a point estimate approach.**

Sidebar on SB-352

- SB-352 requires a risk assessment for proposed school site within 100 yards of a busy roadway.
- SB-352 specified the use of the Hot Spots risk assessment procedures, but the current guidance only specifies 24 hour breathing rates and 8-hour worker breathing rates.
- Revised Exposure Assessment and Stochastic Analysis document has 1 hour breathing rates at various activity levels that can be used to estimate a breathing rate during a school day with different activities (e.g. sports, classroom).

Chapter 2: Air Dispersion Modeling
Changes in Air Modeling Procedures

- **Aermod has been endorsed by USEPA and is now recommended for Hot Spots risk assessments.**
- **There is an option for spatial averaging for the residential and worker MEI.**
  - **There can be a rapid fall off in concentration with point sources in close proximity to an offsite worker or resident MEI.**
  - **Averaging the concentration over a small area, such as small lot or the workplace area where the worker moves about may make more sense is some cases.**
  - **Spatial averaging is at the discretion of the District or ARB.**

Chapter 3: Breathing Rates

Chronic exposure breathing rates.

- For long-term daily residential continuous exposure for various age ranges.

8-hour breathing rates for cancer risk.

- For exposure only during facility operations of about 8 hours/day: Off-site workers, schools and neighborhoods.

1-hour breathing rates.

- Proposed school sites near major roads (SB-352).

Breathing Rates
Chronic Exposure

Three evaluated approaches for estimating long-term breathing rates.

All are indirect measures of breathing rate:

1. **Energy (food) intake – calories consumed related to oxygen breathed in to convert calories to energy.**
2. **Metabolic Equivalent approach – Reflects the proportional increase in basal metabolic rate during specific activities.**
3. **Doubly-labeled water – measures CO_2 production from body –an indirect measure of metabolic rate.**

Breathing Rates
Energy (food) Intake Approach

Arcus-Arth & Blaisdell (2007)

- Based on large 2-day food intake survey of children and adults - Continuing Survey of Food Intake of Individuals (CSFII) - by USDA in 2000
- Advantages
  - Large study
  - Individual data on food intake, age, body wt.
  - Nationally representative data for age groups
- Disadvantage
  - Only 2 days of data – may overestimate upper and lower percentiles

Breathing Rates
Metabolic Equivalent Approach

US EPA (2009)

- Based on separate national surveys of activity patterns and body weights by age.
- Advantages
  - Large study.
  - Nationally representative data for age groups.
- Disadvantage
  - Does not consider limits on maximum activity values – may overestimate upper percentiles.

Breathing Rates
Doubly-Labeled Water Approach

Brochu et al. (2006a,b)

- Collection of individual data from numerous studies; estimates CO_2 production and thus, total energy expenditure over 1-3 weeks.
- OEHHA developed distributions based on individual data from Brochu.

Breathing Rates
Doubly-Labeled Water Approach

- Advantages
  - Most accurate for long term breathing rate estimates
  - Large database
- Disadvantage
  - Not representative of the population
  - Different ages not sampled equally

Summary of Breathing Rates

Mean Breathing Rates in L/kg/day

	3rd Tri	0<2 Yrs	2<9 Yrs	2<16 Yrs	16<30 Yrs	16-70 Yrs
CSFII	200	752	595	481	200	165
MET	221	1125	597	449	221	219
DLW	222	567	482	423	222	206
Previous Values		Ages 0-9 452			Ages 0 -70 232	

Summary of Breathing Rates

95th Percentile Breathing Rates in L/kg/day

	3rd Trim	0<2 Yrs	2<9 Yrs	2<16 Yrs	16<30 Yrs	16-70 Yrs
CSFII	377	1241	975	868	377	307
MET	296	1372	776	595	296	299
DLW	302	713	628	626	302	286
Previous Values		Ages 0-9 581			Ages 0-70 381	

Proposed Long-Term Breathing Rates

- No “gold standard” method for determining breathing rates representative of the population.
- Each method has its advantages and disadvantages.
  - We chose an average of the CSFII and DLW methods, for which we had individual (raw) data to develop distributions for OEHHA age groups.
  - Used Monte Carlo simulation to combine data and develop a stochastic distribution of breathing rates

Proposed Long-Term Breathing Rates

Proposed point estimates

	3rd Trim-ester	0<2 Yrs	2<9 Yrs	2<16 Yrs	16<30 Yrs	16-70 Yrs
		L/kg-day				
Mean	210	658	535	452	210	185
95th	335	1092	861	745	335	290
		L/day				
Mean		6243	10,700	13,255	15,025	13,919
95th		11,197	16,384	22,581	23,462	22,867

Proposed 8-Hour Breathing Rates

- Based on US EPA (2009) MET minute ventilation rates: Sedentary, light and moderate activities
- Represents breathing rates that can occur during an 8-hour period

Age (yr)	0<2	2<9	2<16	16<30	16-70
	Sedentary & Passive Activities (L/kg-8 hr)				
Mean	197	101	82	34	34
95th	250	139	115	43	43
	Moderate Intensity Activities (L/kg-8 hr)				
Mean	893	466	379	173	168
95th	1152	638	523	235	230

Proposed 1-Hour Breathing Rates
for SB-352 purposes

- Based on US EPA (2009) minute ventilation rates: sedentary, light, moderate, high intensity activities
- Represents breathing rates over a 1-hr period

Age (yr)	0<2	2<6	6<11	11<16	16-70
	Sedentary & Passive Activities (L/kg-60 min)				
Mean	25	17	10	6	4
95th	31	23	14	8	5
	Moderate Intensity Activities (L/kg-60 min)				
Mean	112	76	44	28	21
95th	144	103	62	39	29

Chapter 4: Soil Ingestion

- **The USEPA (2008) Child-specific Exposure Factors Handbook approach for soil ingestion rate, based on nine peer reviewed studies is recommended.**
- **Body weight data from the individual studies are not available, therefore age-specific body weight recommendations from Chapter 10 were used to provide soil ingestion rates in terms of mg/kg BW*day.**
- **Data on variability insufficient to recommend a distribution for stochastic analysis.**

Proposed Soil Ingestion Rates

	mg/day		mg/Kg BW*day	
Age	Mean	95th	Mean	95th
3rd Tri	50	200	0.66	2.64
0<2	150	400	15.5	41.2
2<9	100	400	4.57	18.3
2<16	100	400	2.7	10.8
16<30	50	200	0.66	2.64
16<70	50	200	0.63	2.5

Chapter 5: Mother's Milk Pathway

- **We have added polycyclic aromatic hydrocarbons (PAHs) and lead to the list of chemicals evaluated in the mother's milk pathway**
- **We have updated the mother's milk pathway model for dioxins and furans, and PCBs**
- **Re-evaluated intake rates for breast-fed infants (very small change from previous recommendations)**

Chapter 6: Dermal Exposure, Previous OEHHA, 2000 Dermal Dose Equation

Dermal Dose = (Cs × SA × SL × EF × ABS × ED) / (BW × AT × $1x10^6$)

where:

Dermal Dose = exposure dose through dermal absorption in mg/kg-d

Cs = average concentration of chemical in soil (µg/kg)

SA = surface area of exposed skin (m^2)

SL = soil loading on skin (g/m^2-d)

EF = exposure frequency (d/yr)

ABS = fraction of chemical absorbed across skin

ED = exposure duration (yrs):

BW = body weight (kg)

AT = averaging time (days), to assess carcinogenic risk

Dermal Exposure Assessment
Proposed Dermal Dose Equation

Reduce the dermal-dose equation to the following:

$$\text{Dermal dose} = ADL * Cs * ABS * ED / AT * 1x10^{6}$$

Where:

ADL = annual dermal load (mg soil / kg BW – yr)

$$ADL = (BSA / BW)* [(SL_b)(SA_b\%_b)] * EF$$

Where :

BSA/BW	**= total body surface area / body weight (cm^2/kg)**
SL_b	**= daily soil loading on a specific body part (mg/cm^2-d)**
$SA\%_b$	**= percent surface area of the exposed specific body part**
EF	**= exposure frequency (d/yr)**

Dermal Exposure Assessment
Proposed Dermal Dose Equation

Advantage:

- **Determined the high end estimate of the three variates combined instead of using the high end from each one multiplied together.**
- **Proper method of estimating overall variability from several sources/estimating overall high end point estimates.**
- **Distributional information that previously was separate is now integrated into one distribution**
- **Simplifies calculation for risk assessors**

Dermal Exposure Assessment
California Climate Regions

OEHHA developed ADLs for different climates because climate affects surface area exposed and exposure frequency.

1) Warm – areas that have warm to hot climates throughout the year (L.A.)

2) Mixed – Hot summers / cold winters (Central valley, mountain regions)

3) Cold – coastal areas (San Francisco, Eureka)

The Districts should be consulted concerning appropriate ADL for a particular location.

Dermal Exposure Assessment
Annual Dermal Load Table

- **Annual Dermal Load (ADL) in g soil / kg BW-yr**

	Children (0<2 yr)	Children (2<9 yr)	Children (2<16 yr)	Adults (16<30, 16-70 yr)	Off-Site Worker
Warm climate					
Mean	3.6	7.5	6.4	1.2	2.6
95 th Percentile	4.3	9.1	8.5	2.6	5.0
Mixed climate					
Mean	2.1	6.6	5.7	1.1	2.6
95 th Percentile	2.9	8.7	8.1	2.4	5.0
Cold climate					
Mean	1.2	3.1	2.8	0.7	2.6
95 th Percentile	1.9	5.2	5.1	2.1	5.0

Dermal Exposure Assessment
Updated Dermal Absorption Factors (ABS)

ABS expressed as %, or fraction, absorbed across skin

Dermal dose = ADL * Cs * ABS * ED / AT * $1x10^6$

- **Reviewed chemical-specific dermal absorption data in the literature**
- **ABS takes into account: Soil type, lipophilicity of chemical, soil organic content, soil aging of chemical, soil time on skin**
- **A few increased (Pb, 1% to 3%), a few decreased (Hg 10% to 4%), others remained the same (PCBs 14%, PAHs 13%)**

Chapter 7: Home-Raised Produce, Meat, Milk, and Eggs

- Used Data for the 1999-2000 NHANES dataset to estimate consumption rates for leafy, exposed, protected and root home raised produce, home-raised chicken, beef, pork, eggs, and cow's milk.
- Survey conducted for one day, therefore, typical intake for individuals may not be captured.
- Thus high end consumption rates may be overestimated but these are the best available data.
- Fate and transport parameters for determining food concentrations revised (e.g. root uptake factors).

Chapter 8: Water consumption

- **The Hot Spots program includes a surface water drinking pathway.**
- **So far this pathway has not been used in a Hot Spots risk assessment, but is available if needed.**
- **Data from the USEPA Office of Water (2004), and USEPA's Child-specific Exposure Factors Handbook (2008), were combined for various age ranges.**

Proposed Water Consumption Rates (ml/kg BW*day)

Age Range	Mean	95th Percentile
Third Trimester	18	47
0<2 Years	113	196
2<9 Years	26	66
2<16 Years	24	61
16<30 Years	18	47
16<70 Years	18	45

Chapter 9: Fish Consumption of Angler-Caught Fish - Overview

- **The fish consumption rate is needed for assessment of potential health risks to individuals consuming fish from waters impacted by facility emissions.**
- **In the Hot Spots program, generally limited to freshwater bodies including lakes and ponds.**
- **OEHHA reviewed existing and new studies for angler caught fish consumption estimates of Californians.**
- **Fish pathway is rarely invoked in the Hot Spots program.**

Fish Consumption
Key Study

- **Proposed fish consumption based on San Francisco Bay Seafood Consumption Study published in 2000, by Cal. Dept. of Public Health**
- **Replaces fish consumption estimate based on Santa Monica Bay Seafood Consumption Study from 1994**
  - **Advantage of the California marine surveys: ethnically diverse population.**
  - **Disadvantage: marine fish consumption, not freshwater fish consumption.**

Proposed Children's Fish Consumption Rates

	0<2 Yrs	2<9 Yrs	2<16 Yrs	9-Year Scenario
	Proposed rate in g/day			Previous in g/day
Mean	2.1	7.9	13.3	8.7
95th	6.6	25.4	42.9	24.3
	Proposed rate in g/kg-day			Previous in g/kg-day
Mean	0.18	0.36	0.36	0.48
95th	0.58	1.16	1.16	1.35

Proposed Fish Consumption Rates for Adults

	16<30 Yrs	16<70 Yrs	30- & 70 Year Scenarios
	Proposed rate in g/day		Previous in g/day
Mean	28.8	28.8	30.5
95th	92.4	92.4	85.2
	Proposed rate in g/kg-day		Previous in g/kg-day
Mean	0.38	0.36	0.48
95th	1.22	1.16	1.35

Chapter 10: Body Weights
Overview

Most variates in the Exposure Document already incorporate body weight into the analysis.

In a few cases, such as fish consumption, body weight information is not provided, so the body weight variate can be useful.

- **Key study: *National Health and Nutrition Examination Surveys.***
  - **the most current information on body weight of the U.S. population.**
  - **A continuous survey since 1999.**

Proposed Body Weight Point Estimates

- **Body weight point estimates in kg**

Age (years)	Proposed Mean	Previous Mean
0<2	9.7	
2<9	21.9	18 (0-9 years)
2<16	37.0	
16<30	75.9	
16-70	80.0	63 (0-70 years)

Chapter 11

- Chapter contains information on a variety of topics, including:
  - Residential exposure duration.
  - Time at home for residents.
  - Job tenure for offsite workers.
  - Individual vs. population risk.

Residential Exposure Duration

- OEHHA is proposing a 30 year residency exposure duration which is around the 90th or 95th percentile for residence time.
- Data were obtained on California residence time from the American Community Surveys (2000-2009).
- These data are generally consistent with nationwide data.
- OEHHA recommends that a 9 year and 70 year scenario also be included which are the mean and lifetime residency exposure duration, respectively.

Worker Exposure Duration

- **Risk to offsite workers near a facility is included in the Hot Spots program.**
- **Risk to offsite workers is evaluated using the same health values as for the public.**
- **Workers employed at the facility being evaluated are covered by Cal OSHA, using occupational health standards.**
- **The length of time that a worker is on the job with a specific employer (i.e., job tenure) determines the exposure duration.**

Worker Exposure Durations
Key Study

- **Census Bureau's Survey of Income and Program Participation (SIPP).**
- **The SIPP sample is a multistage-stratified sample of the U.S. civilian non-institutionalized population.**
- **Workers asked when they started working for a current or most recent past employer, and when they stopped working for that same employer.**
- **Current job tenure data covers 1996-2008.**

Worker Exposure Duration
Proposed Job Exposure Duration

- Previous OEHHA recommendation:
  - 40 years for employment tenure
- Proposed OEHHA recommendation:
  - 25 years for employment tenure
  - Represents a reasonable estimate of the 95th percentile of employment duration from the SIPP.
- Supported by other less rigorous surveys that asked questions regarding length of employment with a specific employer.

Individual vs. Population Risk

- **There is a need to more clearly separate individual cancer risk (e.g., for the MEI) and population wide risk.**
- **Past Hot Spots risk assessments focused on lifetime cancer risk to the maximally exposed individual (MEI) exposed 24/7 to facility emissions at the maximum impact point.**
- **A small facility (A) may have a small zone of impact (footprint) with few people impacted at a relatively higher cancer risk (above "acceptable"); risk management would be triggered.**
- **A large facility (B) with extensive but dilute emissions may have a large footprint with many people exposed at an "acceptable" cancer risk; risk management would not be triggered.**

Individual vs. Population Risk

- **Some risk assessments reported cancer burden calculations which are opaque to the general public**
- **OEHHA recognizes the need for more focus on population wide risks to capture the example where many people are exposed to "acceptable" cancer risk**
- **We recommend reporting the number of people exposed within cancer risk isopleths of 10^{-6} and higher to give a clearer indication of the population wide health impacts from facility emissions.**

Activity Patterns

- Previous exposure to the residential MEI was assumed to be 24 hours a day for 70 years.
- The Air Resources Board and OEHHA determined from survey data the fraction of time spent at home (includes vacation).
  - Ages 0<2 0.85
  - Ages 2<16 0.72
  - Ages 16<70 0.73
- The issue with considering time away from the residence is that it is not known where the person is when away, and therefore if the person was still exposed to facility emissions.
- For purposes of estimating cancer risk from a specific facility, recommend that there is no exposure from the facility when away from the residence unless there is a school within the 1 x 10^{-6} isopleth.

Summary

- **The updated draft Exposure Assessment Guidelines incorporates new data on exposure parameters published after the 2000 version.**
- **Updates air dispersion modeling, includes spatial averaging.**
- **The age ranges for exposure variates accommodate assessment of greater risk from early-in-life exposure to carcinogens.**
- **Population risk emphasized more.**
- **Residential and worker exposure duration based on newer data.**