8 Water Intake Rates

8.1 Introduction

Surface water can serve as a source of domestic water in some locations, particularly rural areas. Airborne contaminants from facilities can deposit directly on surface water bodies, thus exposing humans to contaminants through water consumption. Hot Spots facilities having non-municipal surface bodies of water, which are within the facility's zone of impact and which are used as a source of drinking water, need to include the water pathway in their risk assessments. Note that this pathway is rarely invoked for typical facilities in the Air Toxics Hot Spots program. Hot Spots risk assessments do not include municipal or commercial water sources. Municipal water is excluded because surface reservoirs are generally so large that contaminants from a single source become highly diluted once they enter the surface water body. Further, the level of some contaminants in municipal water may be reduced by water treatment processes typically used for municipal water supplies.

OEHHA does not recommend water pathway algorithms for municipal water source evaluation because the simple model used in the Hot Spots program is not adequate for this purpose. In these guidelines, the algorithm for calculating the water concentration of contaminants only includes that amount of chemical that directly deposits onto the surface of the water and not amounts that deposit onto surface soil and then enter the water body via runoff. It is assumed that contaminants initially deposited onto the water body surface remain suspended in the water column.

Water can be consumed by individuals through various forms of foods and beverages. For Hot Spots program risk assessments, the assessment only considers plain drinking water, water added for reconstituting foods and beverages, and water absorbed by food during cooking. This is because these foods and beverages could be made with water from a non-municipal surface water body. The risk assessment does not include water from commercial food or drink, or water that occurs naturally in fresh foods (e.g., water in an apple). The reasons for these exclusions are given in the paragraph above.

8.2 Recommendations

8.2.1 Point Estimate Approach

Currently there are no water intake distributions specific for California residents. However, OEHHA's derived water intake rate distributions provide a reasonable basis for exposure assessments of the California population. Chemical specific properties such as volatility may influence alternate route exposures via tap water, e.g., by bathing, showering, flushing toilets, etc. In the Air Toxics "Hot Spots" program, these exposure routes are currently not considered. However, they are treated in Superfund risk assessments where ground water contamination is a larger issue. The following recommendations are based on currently available data. Depending on the nature of the analysis, one or more of the recommendations may apply.

For ages involving infants, OEHHA recommends using intake rates based on reconstituted formula intake. This is to protect the sizable subpopulation of infants who typically receive significant amounts of water through reconstituted formula. Breastfed infants, particularly during the first 6 months of age, are essentially non-consumers of water, and should not be included in the derivation of water intake rates designed to protect exposed infants.

For cancer risk assessment, the cancer risk estimates for exposures in the third trimester and from 0<2 years are weighted by an age sensitivity factor of 10 and exposures for the 2<16 year age groups are weighted by an age sensitivity factor of 3 (OEHHA, 2009). These age groups do not completely fit the 0-9, 0-30, and 0-70 year exposure duration scenario age groups. In order to properly weight for these periods and evaluate risk over each of the exposure duration scenarios, water intake rates specific for the third trimester, 0<2, 2<9, 2<16, 16-30, and 16-70 year age groups are needed. For example, for the 9 year scenario, intake rates are needed for the third trimester, the period from 0<2 year (for which the cancer risk will be weighted 10X), and for the 2-9 year period (for which the cancer risk will be weighted 3X). Likewise, for the 30 year exposure scenario, water intake rates are needed for the third trimester, 0<2 year, 2<16 year, and 16-30 year periods. Similarly, for the 70 year exposure scenario, water intake rates are needed for the third trimester, 0<2, 2<16, and 16-70 year periods. OEHHA has derived water intake rates for these additional age groups using the steps and methods outlined in Section 8.2.9 ("OEHHA Derived Water Intake Rates") below.

Table 8.1 presents recommended point estimate water intake rates for Air Toxics Hot Spots risk assessments. The derivation is described below in section 8.4.13.

8.2.2 The Stochastic Approach

When using distributions it is appropriate to truncate them to avoid impossibly large or small values. For drinking water ingestion, the minimum should be set to zero while the maximum should be set to the maximum value listed in Table 8.11.

Recommended water intake rates for stochastic analyses are presented in Table 8.2.

Table 8.1 Recommended Point Estimate Tap Water Intake Rates (ml/kg-day)

Point Estimates				
Using Mean Values	**For the Age Period**	**9-year scenario**	**30-year scenario**	**70-year scenario**
	3rd trimester	18	18	18
	0<2 years	113	113	113
	2<9 years	26	-	-
	2<16 years	-	24	24
	16-30 years	-	18	-
	16-70 years	-	-	18
Using 95th-percentile values	**For the Age Period**	**9-year scenario**	**30-year scenario**	**70-year scenario**
	3rd trimester	47	47	47
	0<2 years	196	196	196
	2<9 years	66	-	-
	2<16 years	-	61	61
	16-30 years	-	47	-
	16-70 years	-	-	45

Table 8.2 Recommended Distributions of Tap Water Intake Rates (ml/kg-day) for Stochastic Risk Assessment

	9-year scenario	**30-year scenario**	**70-year scenario**
0<2 years	**Max Extreme** Likeliest = 93 Scale = 35	**Max Extreme** Likeliest = 93 Scale = 35	**Max Extreme** Likeliest = 93 Scale = 35
2<9 years	**Weibull** Location = 0.02 Scale = 29 Shape = 1.3		
2<16 years		**Gamma** Location = 0.19 Scale = 15.0 Shape = 1.6	**Gamma** Location = 0.19 Scale = 15.0 Shape = 1.6
16-30 years		**Gamma** location=0.49 scale=13.6 shape=1.26	
16-70 years			**Beta** min=0.17 max=178 alpha=1.5 beta= 12.9

8.2.3 Recommended Water Intake Rates for Lactating Subpopulations

OEHHA also recommends water intake rates specific for lactating subpopulations. These recommendations are presented in Table 8.18 in Section 8.5.2. In the point estimate approach, the mean and 95th percentile intake rate for lactating women should be used for the drinking water exposure of a mother when evaluating contaminant concentrations in breast milk. For stochastic analyses, OEHHA recommends using the percentile data for the lactating subpopulations in Table 8.18 and fitting each to distributional models using the procedure outlined in Sections 8.4.13 and 8.4.14. Although the same study derived water intake rates for pregnant women, we utilized the water intake rates for adults ages for the third trimester as they were slightly more health protective than the values derived for pregnant women by U.S. EPA (2004) and presented in Section 8.5.2 below.

8.2.4 Recommended Water Intake Rates for High Activity Levels / Hot Climates

For groups who may be highly physically active or who may live or work in hot climates, OEHHA recommends using the 95th percentile value in Table 8.1 for the age group for which the sensitive endpoint has been identified. For stochastic analyses, OEHHA recommends using the distributions for 9-year or 30-year scenarios in Table 8.2.

8.3 Water Intake Algorithm

The equation to calculate contaminant concentration in surface water for the Air Toxics "Hot Spots" risk assessment model is:

$$Cw = GLC * Dep\text{-}rate * 86{,}400 * SA * 365 / (WV * VC) \qquad \textbf{(Eq. 8-1)}$$

where: Cw = Average concentration in water (µg/kg)

GLC = Ground-level concentration of the pollutant (µg/m^3)
Dep-rate = Vertical rate of deposition (m/sec) (0.02 meters/second for controlled, or 0.05 meters/second for uncontrolled, sources.)
86,400 = Seconds per day conversion factor (sec/d)
SA = Water surface area (m^2)
365 = Days per year (d/yr)
WV = Water volume (kg) (1L = 1 kg)
VC = Number of volume changes per year

Site-specific values for SA, WV, and VC are needed for evaluating the surface water exposure pathway and can be estimated from data collected on-site or public data sources. The equation assumes that all material deposited into the water remains in the water column and that the deposition rate remains constant for a 9, 30 or 70-year exposure duration.

Estimating the daily oral dose of contaminants via the water intake pathway requires information on typical daily water intake of individuals. Typical water intake varies among individuals. Characterizing this inter-individual variability allows more accurate estimates of average and high end intake as well as characterizing a range of exposures to the population.

Water intake can be classified as tap water or total water. Tap water is water consumed directly from the tap (i.e., plain drinking water) as well as water used to reconstitute beverages (e.g., coffee, OJ) or foods (e.g., baby cereal), and water absorbed during cooking of foods (e.g., cooked oatmeal) in the home or at a food service establishment (e.g., school, restaurant). “Total water” consists of tap water, plus water found naturally in foods (e.g., in a fresh apple), and water that is in commercial beverages (e.g., soft drinks) and foods (e.g., canned spaghetti). The term “direct” is used by the USEPA (2008) to describe tap water consumed from the tap. The term “indirect” is used to describe tap water used to make foods or beverages. Water in purchased items such as canned soup and intrinsic water in items such as lettuce were not included in the indirect category.

For the Hot Spots program, we are interested in tap water intake rates of consumers. We use tap water intake rates because tap water does not include water from commercial sources and from fresh foods. Commercial food and beverages are excluded because they are almost certainly prepared using water from municipal sources. In addition, commercial food and drink are typically from diverse sources resulting in minimization of the likelihood of a person being exposed from a single source (i.e., facility) from commercial products. Water in fresh foods is excluded because it does not come from a local water source. We use consumer-only data because consumers are the population being exposed. Thus, for example, data from non-consumers, such as individuals who exclusively drink bottled water, would be excluded from the data we use to quantify tap water intake rates.

The sources for tap water are municipal (public) water, household wells or cisterns, and household or public springs. The Hot Spots program water pathway risk assessments apply to water obtained from non-municipal surface water sources impacted by a given facility’s emissions. Because non-municipal surface water is delivered via the tap (faucet) to consumers, and because most studies that have measured water consumption do not specify non-municipal surface water sources, we will use “tap” water data for the estimation of intake rates.

For stochastic evaluation of exposures from the water pathway, probability distributions reflecting variability within the population are needed. There are intake data that are available in ml/kg-day. By normalizing water intake by body weight, the variability associated with the correlation between water intake and body weight is reduced.

Historically, when estimating exposures via drinking water, risk assessors assumed that children ingest 1 liter/day of water, while adults ingest 2 liters/day (NAS, 1977). These values have been used in guidance documents and regulations issued by the U.S. Environmental Protection Agency (U.S. EPA). The purpose of this section is to briefly assess data on water intake rates for use in stochastic types of exposure assessments that employ distributions of water intake. In addition, point estimates of intake can be identified from the distribution and used in the point estimate approach (Tier 1 and 2).

The algorithm for determining dose from surface drinking water sources is:

$$DOSEwater = 1 \times 10^{-6} * Cw * WIR * ABSwa * Fdw * EF \qquad \textbf{(Eq. 8-2)}$$

where: DOSEwater = daily oral dose of contaminant, mg/kg-d

1×10^{-6} = conversion factor (1 mg/1000 µg) (1L/1000 ml)

Cw = Concentration of contaminant in drinking water, µg/L

WIR = Water intake rate for receptor of concern in ml/kg BW-day

ABSwa = GI tract absorption factor (default = 100%)

Fdw = Fraction of drinking water from contaminated source (default = 100%)

EF = Exposure frequency (days/year)

In practice, the GI tract absorption factor (ABSwa) is only used if the cancer potency factor itself includes a correction for absorption across the GI tract. It is inappropriate to adjust a dose for absorption if the cancer potency factor is based on applied rather than absorbed dose. The Fdw variate is always 1 (i.e., 100%) for Tier 1 risk assessments. This variate may only be adjusted under Tier 2-4 risk assessments. The exposure frequency (EF) is set at 350 days per year (i.e., per 365 days) following U.S. EPA (1991).

For cancer risk, the risk is calculated for each age group using the appropriate age sensitivity factors (ASF) and the chemical-specific cancer potency factor (CPF), expressed in units of $(mg/kg\text{-}day)^{-1}$.

$$RISKwater = DOSEwater * CPF * ASF * ED/AT \qquad \textbf{(Eq. 8-3)}$$

Exposure duration (ED) is the number of years within the age groupings. In order to accommodate the use of the ASFs (see OEHHA, 2009), the exposure for each age grouping must be separately calculated. Thus, the DOSEwater and ED are different for each age grouping. The ASF, as shown below, is 10 for the third trimester and infants 0<2 years of age, is 3 for children age 2<16 years of age, and is 1 for adults 16 to 70 years of age.

ED = Exposure duration (years):

0.25 yrs for third trimester	(ASF = 10)
2 yrs for 0<2 age group	(ASF = 10)
7 yrs for 2<9 age group	(ASF = 3)
14 yrs for 2<16 age group	(ASF = 3)
14 yrs for 16<30 age group	(ASF = 1)
54 yrs for 16-70 age group	(ASF = 1)

AT, the averaging time for lifetime cancer risks, is 70 years in all cases. To determine lifetime cancer risks, the risks are then summed across the age groups:

$$\text{RISKwater}_{(\text{lifetime})} = \text{RISKwater}_{(\text{3rdtri})} + \text{RISKwater}_{(0<2\ \text{yr})} + \text{RISKwater}_{(2<16\ \text{yr})} + \text{RISKwater}_{(16\ \text{yr onward})} \qquad \textbf{(Eq. 8-4)}$$

As explained in Chapter 1, we also need to accommodate cancer risk estimates for the average (9 years) and high-end (30 years) length of time at a single residence, as well as the traditional 70 year lifetime cancer risk estimate. For example, assessing risk for a 9 year residential exposure scenario assumes exposure during the most sensitive period, from the third trimester to 9 years of age and would be presented as such:

$$\text{RISKwater}_{(\text{9-yr residency})} = \text{RISKwater}_{(\text{3rdtri})} + \text{RISKwater}_{(0<2\ \text{yr})} + \text{RISKwater}_{(2<9\ \text{yr})} \qquad \textbf{(Eq. 8-5)}$$

For the 30-year residential exposure scenario, risk for the 2<16 and 16<30 age groups would be added to risks for exposures in the third trimester and ages 0<2 years. For the 70 year lifetime risk, Eq 8-4 would apply.

8.4 Water Intake Rate Studies

Water intake rates have been estimated through the collection of empirical (measured or self-reported) intake data. Some studies have modeled these data by fitting them to distributions. Both U.S. EPA and Cal/EPA (OEHHA) have reviewed and made recommendations for water intake rates in their exposure guidelines. In this section (8.4) we will present background on the major studies that have collected or modeled water intake rate data as well as summarize U.S. EPA (Exposure Factors Handbooks) and OEHHA (Air Toxics “Hot Spots” Program Exposure and Stochastic guidelines) exposure guidelines. We review and present water intake values in ml/kg-day because these rates are needed for Equation 8.2 (above). The studies and guidelines are presented chronologically, below. We also describe and present the estimates derived by OEHHA for the current guidelines.

It is important to note that currently available water intake data were collected over short-term periods (one to three days). These data do not reflect long-term typical water intake rates because repeated measures are not available on the same individual over long periods. Therefore, the variability of currently available estimates includes both intra- and inter-individual variability. These two types of variability cannot be separately evaluated with the current data. The average long term intake is better estimated by such data than high end intake.

8.4.1 Canadian Ministry of National Health and Welfare (1981)

The Canadian Ministry of National Health and Welfare (1981) study was conducted in the summer of 1977, the winter of 1978, and involved 970 individuals in 295 households. Interview and questionnaire techniques were used to determine per capita intake of tap water in all beverages (water, tea, coffee, reconstituted milk, soft drinks, homemade alcoholic beverages, etc.). Patterns of water intake were analyzed with respect to age, sex, season, geographical location, and physical activity. Average daily intake rates by age group are presented in Table 8.3 (below). OEHHA did not use data from the Canadian study because the overall climate of Canada tends to be colder than California, the estimates are not likely representative of the current demographics of the U.S. population, and the raw data necessary to determine distributional characteristics were not available.

Table 8.3 Average Daily Water Intake (ml/kg-day) from the Canadian Ministry of National Health and Welfare (1981)

Age	Females	Males	Both sexes
<3 years	53	35	45
3-5 years	49	48	48
6-17 years	24	27	26
18-34 years	23	19	21
35-54 years	25	19	22
55+ years	24	21	22
All Ages	24	21	22

8.4.2 Ershow and Cantor (1989), Ershow et al. (1991)

The Ershow and Cantor (1989) and Ershow et al. (1991) studies analyzed drinking water intake rates using the 1977-1978 Nationwide Food Consumption Survey (NFCS) data. Tap water intakes include tap water consumed as plain water and tap water added, while at home or at restaurants, in the preparation of food and beverages. There were approximately 20,000 study participants. Data were analyzed by age group, sex, season, and geographic region (including the Western Region), and separately for pregnant women, lactating women, and breast-fed children. Intakes were normalized to body weight using self-reported body weights. Because the Western Region estimates of the NFCS most closely reflect intake patterns of California, the Western Region estimates were recommended in the prior version of the Air Toxics Hot Spots Program Exposure Guidelines (OEHHA, 2000).

The Western Region estimates are presented by age group in Table 8.4. These estimates are based on about 16 percent of the total data set. Note that the traditional assumption of 2 liters daily water intake for a 70 kg body weight person corresponds to approximately the 75th percentile on Ershow and Cantor's distribution (28 ml/kg-day, see Table 8.4). Table 8.5 summarizes the intake estimates for pregnant women, lactating women, and breast-fed children of the Ershow and Cantor study. Though the Ershow and Cantor (1989) and Ershow et al. (1991) studies presented extensive analyses of the NFCS data, more recent intake data that more closely reflect current water intake patterns are now available.

Table 8.4 Tap Water Intake Rates (ml/kg-day) of the Western Region, from Ershow and Cantor (1989) [1]

	Mean (SD)	50%	75%-ile	90%-ile	95%-ile
All Ages	24 (17)	21	30	43	54
< 1 year	53 (51)	39	67	106	141
1-10 years	39 (24)	34	49	70	88
11-19 years	18 (11)	17	24	32	39
20-64 years	21 (12)	19	27	37	44
65+ years	23 (10)	21	28	37	42

[1] Pregnant and lactating women, and breast-fed children excluded

Table 8.5 Tap Water Intake Rates (ml/kg-day) for Control, Pregnant and Lactating Women, and Breast-fed Children, from Ershow et al. (1991) [1]

	Mean (SD)	50%	75%-ile	90%-ile	95%-ile
Control [1]	19 (11)	17	24	33	29
Pregnant	18 (10)	16	24	35	40
Lactating	21 (10)	21	27	35	37
Breast-fed	22 (25)	12	38	56	60

[1] Control = women 15-49 years age who were not pregnant or lactating

8.4.3 Roseberry and Burmaster (1992)

Roseberry and Burmaster fit lognormal distributions to the datasets of Ershow and Cantor (1989) (discussed above). In tabulating the data they adjusted the data that were originally collected in 1977-78 to better represent the U.S. age group distribution of 1988. Although this study provided distributions of water intake, which is an essential component of stochastic analyses, OEHHA chose to not use these estimates because more recent water intake data are available. Further, the estimates are not normalized to body weight so they cannot be used or compared to the water estimates recommended in this document.

8.4.4 Levy et al. (1995)

Levy et al. (1995) evaluated fluoride intake of infants at 6 weeks, and 3, 6, and 9 months of age. At 6 weeks age, the sample size was 124, while at 9 months of age it was 77. Mothers were asked to record the average number of ounces of water per day over the past week that the infant consumed as plain water or that were used to make formula, juices and other beverages, baby food, cereal, and other foods consumed by the infant. These amounts were used to determine water intake. However, we did not use data from this study because only the mean and range were reported and because results were given as ounces per day, and were not normalized to body weight.

8.4.5 Exposure Factors Handbook (U.S. EPA, 1997)

The U.S. EPA's Exposure Factors Handbook (EFH) (U.S. EPA, 1997) reviewed water intake studies conducted before 1997 and made recommendations for water intake rate values in U.S. EPA risk assessments. The EFH (1997) used three key studies as the basis for their water intake recommendations: Canadian Ministry of National Health and Welfare (1981), Ershow and Cantor (1989), and Roseberry and Burmaster (1992) (see above). These studies were selected based on the applicability of their survey designs to exposure assessment of the entire United States population. U.S. EPA recommended 21 ml/kg-day as the average tap water intake rate for adults. This value is the population-weighted mean of the data from the Canadian Ministry of National Health and Welfare (1981) and Ershow and Cantor (1989). For the high-end adult value, U.S. EPA averaged the 90^{th} percentile values from the same two studies to obtain a value of 34.2 ml/kg-day. The U.S. EPA recommended using the estimates of Roseberry and Burmaster (1992) for a characterization of the lognormal distribution of water intake estimates. However, U.S. EPA cautioned against using Roseberry and Burmaster (1992) for post-1997 estimates since these distributions reflect 1978 data adjusted to the U.S. age distribution of 1988. In addition to intake rates for adults, U.S. EPA also provided a table of intake rates for children, by age category, also from Ershow and Cantor (1989) and the Canadian Ministry of National Health and Welfare (1981).

OEHHA chose to not use the U.S. EPA (1997) estimates for these Hot Spots Exposure and Stochastic Guidelines because more recent data are available and different age groupings are needed for the Hot Spots risk assessment.

It should be noted that the USEPA released an external review draft of an updated Exposure Factors Handbook in 2009. The final version of the Exposure Factors Handbook was released in October, 2011 (U.S. EPA, 2011).

8.4.6 OEHHA (2000) Exposure Assessment and Stochastic Analysis Guidance

The previous version of the Hot Spots Exposure and Stochastic guidance (2000) recommended the "Western Region" water intake values of Ershow and Cantor (1989), which are presented in Table 8.4 (above). The Western Region was considered more applicable to California than the entire U.S. due to climate and lifestyle (e.g., physical activity) factors.

OEHHA (2000) provided point and distributional recommendations for the 9-, 30-, and 70-year exposure durations used with that guidance. For the 9-year scenario, OEHHA simulated a distribution using the tap water distributions presented by Ershow and Cantor (1989) for children <1 year of age and for children 1 to 10 years of age using Crystal Ball®. This distribution is presented below in Table 8.6. The distribution was fit to a lognormal parametric model with an arithmetic mean and standard deviation of 40.3 ± 21.6, μ ± is exp(3.57 ±0.50). The Anderson Darling Statistic is 0.65.

Table 8.6 OEHHA (2000) Tap Water Intake Rates Fit to a Lognormal Model for the 9-year Scenario (ml/kg-day) [1]

mean	SD	Percentiles										
		5	10	20	30	40	50	60	70	80	90	95
40	22	16	19	23	27	31	35	40	46	54	68	81

[1] Derived by OEHHA from data of ages 0-10 years from Ershow and Cantor (1989) fit to a lognormal distribution. Results presented in OEHHA Exposure Assessment and Stochastic Analysis Guidelines (2000)

For the 30- and 70-year scenarios, OEHHA used data for all ages of females from Ershow and Cantor (1989) to fit to a lognormal distribution with a mean of 24.0 and standard deviation (SD) of 17.2. The female mean was chosen because it is slightly higher than the male mean. Estimates of the fit to a lognormal model distribution are presented in Table 8.7, below.

Table 8.7 OEHHA (2000) Tap Water Intake Rates Fit to a Lognormal Distribution for the 30- and 70-year Scenarios (ml/kg-day) [1]

mean	SD	Percentiles										
		5	10	20	30	40	50	60	70	80	90	95
24	17	7	9	12	14	17	20	23	31	34	45	56

[1] Derived by OEHHA using data of females of all ages from Ershow and Cantor (1989) fit to a lognormal distribution. Results presented in OEHHA Exposure Assessment and Stochastic Analysis Guidelines (2000)

The OEHHA (2000) Exposure and Stochastic Guidance recommended using the mean and 95th percent-ile values from Table 8.6 and 8.7 (above) for each of the 9-, 30-, and 70-year scenarios. These recommended point values are presented in Table 8.8, below.

Table 8.8 Previously Recommended Point-Value Estimates for Daily Water Intake Rates (ml/kg-day) for the Exposure and Stochastic Guidelines of OEHHA (2000)

	9-year scenario (children)	30- and 70-year scenario
Average	40	24
High-end	81	54

For stochastic analyses using the OEHHA (2000) Exposure and Stochastic Guidance, the distributional values presented in Tables 8.6 and 8.7 (above) and fit to a lognormal distribution were recommended.

8.4.7 U.S. EPA Office of Water (2004)

The Office of Water, U.S. EPA, derived estimated water intakes using data from the Continuing Survey of Food Intake of Individuals (CSFII) 1994-1996, 1998 dataset. The CSFII 1994-1996, 1998 (hereafter referred to as CSFII) is a nationwide survey that collected data on food and beverage intakes for two 24-hour non-consecutive periods, 3-10 days apart, on approximately 20,000 individuals during the years 1994-1996 and 1998. The Office of Water estimated the amount of water consumed by each individual, including both direct and indirect water intake. Direct water intake is water consumed as plain water from the tap, while indirect water intake is water used to prepare beverages and foods, either at home or at a food service establishment.

Two-day average water intakes for each participant were used in the analyses. Results are presented by water source (tap, bottled, other sources, or all water sources), type of water (direct, indirect or both), consumption type (consumer-only or combined consumer plus non-consumer ("per capita")), and in units of L/day or L/kg-day. Fine and broad age groups were analyzed. This report provides the most recent published analysis of water intake rates that are representative of the U.S. population. The report includes results for both combined and separate analyses of direct and indirect water intakes. However, the Office of Water (2004) intake estimates are from data that is the average of two non-consecutive days of intake and thus do not reflect a person's long-term typical intake. The combined direct plus indirect, community water intake rates by age group from the Office of Water (2004) report are presented in Table 8.9, below. For all ages, the mean and 95th percentile water intake rates were 17 and 44 ml/kg-d.

Table 8.9 Direct + Indirect, Community Water Intake Rates From U.S. EPA (2004) Table IV-8 (ml/kg-day)

			Percentiles							
Age in Years	**Sample Size**	**Mean**	**5**	**10**	**25**	**50**	**75**	**90**	**95**	**99**
0<0.5	414	95	5	7	37	91	133	184	221	294
0.5<0.9	534	53	3	5	12	47	81	112	129	186
0<2	1828	44	2	4	11	28	62	109	137	215
1-3	3230	26	2	4	9	20	35	53	68	110
4-6	2715	22	1	3	8	18	31	47	63	91
0<6	6410	30	2	4	9	21	38	67	93	162
7-10	956	16	1	3	6	13	22	33	40	59
11-14	736	13	1	2	5	10	17	27	36	54
15-19	771	12	1	1	4	9	16	26	32	62
20+	8459	16	1	3	7	13	22	32	39	62
20-24	637	15	1	2	5	11	18	31	39	80
25-54	4512	16	1	3	7	13	21	32	40	65
55-64	1383	17	1	3	8	14	23	32	38	58
65+	1927	18	2	5	10	16	24	32	37	53
All Ages	17,815	17	1	3	7	13	22	33	44	77

8.4.8 U.S. EPA Child-Specific Exposure Factors Handbook (2008)

The U.S. EPA Child-Specific Exposure Factors Handbook (CEFH) provides exposure factor recommendations, including recommended water intake rate values for exposure assessments that are specific for infants and children.

The U.S. EPA (2008) undertook an analysis of the CSFII 1994-1996, 1998 dataset to derive water intake rates specific for the CEFH age groups. U.S. EPA (2008) defined direct water as water consumed as a beverage. They defined indirect as water used to make beverages or foods. In their analysis, the U.S. EPA did not differentiate between direct and indirect water resulting in intake estimates for combined direct plus indirect water.

The U.S. EPA (2008) presented separate analyses of water intake by water source (i.e., community, bottled, other sources, and all sources). The U.S. EPA (2008) presented both ml/day and ml/kg-day intake rate values, and mean, minimum, maximum, and eleven percentile bins of intake estimates. No recommendations for fitted distributions for water intake rates were made in the CEFH (U.S. EPA, 2008). Both per capita and consumer only water consumption rates were presented.

8.4.9 CEFH Table 3-19

Of the tables in CEFH (U.S. EPA, 2008), Table 3-19 provides water intake estimates that were of the most relevance to OEHHA because these rates are for combined direct plus indirect community water intake. The table includes percentile values for consumer-only rates. Table 3-19 is presented in Table 8.10, below. OEHHA chose to use the estimates for some of these age groups in deriving OEHHA-specific age group water intake rates (see Section 8.4.13, below). This information is also published in Kahn and Stralka (2009).

Table 8.10 Table 3-19 U.S. EPA CEFH (2008). Consumer-only, Direct plus Indirect, Community Water Intake Rates By Age Group for U.S. Infants and Children (ml/kg-day)

	Sample Size	Mean	50th	90th	95th	99th
0<1 month	37	137	138	235	238	263
1<3 months	108	119	107	228	285	345
3<6 months	269	80	77	148	173	222
6<12 months	534	53	47	112	129	186
1<2 years	880	27	20	56	75	109
2<3 years	879	26	21	52	62	121
3<6 years	3703	24	19	49	65	97
6<11 years	1439	17	13	35	45	72
11<16 years	911	13	10	26	34	54
16>18 years	339	12	9	24	32	58
18<21 years	361	13	10	29	35	63

* Source of Data: USDA Continuing Survey of Food Intakes by Individuals (CSFII), 1994-96, 1998

8.4.10 Michaud et al. (2007)

Michaud et al. (2007) investigated the relationship between total fluid intake and bladder cancer. Participants were asked via questionnaire about the volume and frequency of specific beverages during the 5 years prior to the study interview. The researchers calculated total fluid intake by multiplying the volume and frequency of each beverage and summing the result. Because the fluid intake included fluids from commercial beverages, and because water absorbed into foods during cooking was not included, we did not use these intakes. Further, intakes were only given as ml/day and results were reported as quintiles so only intervals of intake were reported (e.g., 29 ml/day, 29-40 ml/day, 41-55 ml/day, etc.).

8.4.11 Barraj et al. (2008)

Barraj et al. (2008) collected drinking water consumption data over a 7-day period on a nationwide sample of persons of all ages during two ‘waves’ (survey periods meant to represent winter and summer seasons). Diaries were used to record frequency and amounts of plain drinking water consumed. The final dataset contained data from 4198 individuals from 2154 households. The response rate was 33 percent and 36 percent for wave 1 and wave 2, respectively. The proportion of study participants by age-sex groups and U.S. region was comparable to those of the U.S. 2000 census, with the exception of women over 50 years of age. The proportion of whites in the study was greater than the U.S. census. Results included 24-hour drinking water consumption rates, number of occasions of drinking water, amount per occasion, and inter- and intra-individual variability in water consumption patterns. This study was restricted to plain drinking water, while we are interested in water used for reconstituting food and beverages and water absorbed during cooking, in addition to plain drinking water. Therefore we cannot use these data to quantify water intake rates. Nonetheless, the study did evaluate inter- and intra-individual variability in daily water intake (ounces per day) and found that inter-individual variability was greater than intra-individual variability. There were significant day-to-day differences in water intake (ounces per day) in “wave 1” (summer) for women 13-49 years of age and men 20-49 years of age, and in “wave 2” (winter/early spring) for children 0-5 and boys 13-19 years of age. There was also a significant weekend effect.

8.4.12 Kahn and Stralka (2009)

Kahn and Stralka (2009) published in a peer-reviewed journal the water intake rates that they had derived for the U.S. EPA, Office of Drinking Water (2004) report. This publication will not be discussed here because the methodology and results are presented in Section 8.4.7, above. However, we make note of this publication and that it has been reviewed for these guidelines.

8.4.13 OEHHA Derived Water Intake Rates for Hot Spots Program Age Groups and Exposure Duration Scenarios

OEHHA chose to use water intake estimates from the Office of Water, U.S. EPA (2004) and USEPA’s CEFH (U.S. EPA, 2008) Table 3-19 as the basis for OEHHA’s water intake rate recommendations (with the exception of the infant age group, see below). Both the Office of Water (2007) and U.S. EPA (2008) CEFH Table 3.19 intake estimates are representative of demographics (e.g., age, sex, income, etc.) of the U.S. population because they have been weighted using the data-specific sample and variance weights. The rates are in ml/kg-day, which is the unit of measure specified for the current Hot Spots program guidance (see Equation 8.1, above). The Office of Water report and U.S. EPA (2008) CEFH Table 3.19 include consumer-only tap (community) water intake rates, which are of particular relevance for OEHHA because water consumed from local surface water bodies is likely to be made available to consumers via the tap at home. Though more recent water intake data are now available (NHANES 1999-2004), the NHANES water intake data are limited because information on whether the water was from the tap or not was not collected, and the water source (e.g., municipal, bottled, etc.) is not specified for several of the years. Further, although direct intake rates are in the NHANES dataset, to obtain the indirect intake rates that OEHHA needs would require calculations using recipe code books and other data manipulation. Thus, the Office of Water and U.S. EPA (2008) CEFH Table 3.19 rates, which are based on 1994-1996 and 1998 data, are the most recent derivation of direct and indirect water intake rates that are representative of the population.

It should be noted, though, that the Office of Water (2004) and U.S. EPA (2008) CEFH Table 3.19 intake rates are not available on a state-by-state basis. Thus, the rates used by OEHHA are not specific to California and therefore may differ from those of the California population due to different climate and lifestyle factors. However, it is likely that the rates would not be substantially different overall since there are other areas of the U.S. with climate and lifestyle patterns similar to those of California. Further, the California population represents a significant fraction (over 10%) of the national population and thus would have contributed some weight to the CSFII survey.

Because the age groups in the Office of Water report (2004) and U.S. EPA (2008) CEFH Table 3.19 differ from the age groups and exposure duration scenarios to be used for Hot Spots risk assessments, OEHHA derived water intake rates specific for the Hot Spots program ages. Table 8.11, below, lists the data sources used to derive water intake rates for the Hot Spots program.

Table 8.11 Data Used to Derive Water Intake Rates for Hot Spots Program Age Groups and Exposure Duration Scenarios

Hot Spots Age Group	Derived by OEHHA [1]	CEFH Revised Table 3-19 (2008)	Office of Water (2004)
0<2 years	0<1 year [1]	1<2 years	
2-9 years		2<3 years 3<6 years 6<11 years	
2<16 years		2<3 years 3<6 years 6<11 years 11<16 years	
16-30 years		16<21 years	20-24 years 25-54 years [2]
16-70 years		16<21 years	20-24 years 25-54 years 55-64 years [3]
>=16 years		16<21 years	20-24 years 25-54 years 55-64 years 65+ years
Hot Spots Exposure Duration	**Derived by OEHHA [1]**	**CEFH Table 3-19 (2008)**	**Office of Water (2004)**
9-year	0<1 year [1]	1<2 years 2<3 years 3<6 years 6<11 years	
30-year	0<1 year [1]	1<2 years 2<3 years 3<6 years 6<11 years 11<16 years 16<21 years	20-24 years 25-54 years [2]
70-year	0<1 year [1]	1<2 years 2<3 years 3<6 years 6<11 years 11<16 years 16<21 years	20-24 years 25-54 years 55-64 years [3]

[1] Using intakes of water in reconstituted formula consumed by infants in CSFII 1994-1996, 1998
[2] Because intake rates are relatively stable after 16 years of age, the 25-54 year age group was used to represent the 25-30 year age group but with population size adjusted to the 25-30 year age group
[3] Because intake rates are relatively stable between the 55-64 year and 65+ year age groups (mean of 17 vs. 18 and 95%-ile of 38 vs. 37, for the 55-64 and 65+ year age groups, respectively), OEHHA chose to use the 55-64 year age group to represent the 65-70 year age group and adjust for the additional 65-70 years of age population.

For the derivation of Hot Spots program age groups and exposure duration scenarios, OEHHA used Crystal Ball version 7.2 (Oracle, 2008) to find the best fit for distributions, to simulate values of distributions, and to identify distributional parameters (mean, scale, location, etc.). Crystal Ball was also used to derive percentiles and summary statistics. In identifying the best fit for a distribution, the Anderson-Darling test, one of three goodness-of-fit tests available in Crystal Ball, was used because it gives extra weight to the tails of the distribution, which the other goodness-of-fit tests do not. The tails of the distribution are of particular interest to OEHHA because the right tail defines high-end intake rates.

OEHHA did not use the Office of Water (2004) or U.S. EPA (2008) CEFH Table 3.19 water intake estimates for infant (0<1 year of age) intake rates. Instead, OEHHA derived water intake rates of infants consuming reconstituted formula. The reasons for this are described below in Section 8.5.1. OEHHA used data from the CSFII 1994-1996, 1998 dataset to derive infant water intake rates. To identify infants who received reconstituted formula, the food description provided for the formula consumed by each infant was reviewed. Breast-fed infants were excluded from analysis. To calculate the amount of water consumed by each infant, the amount of reconstituted formula consumed was multiplied by the percent of indirect water in each type of reconstituted formula (these values were obtained from Appendix-D of the U.S. EPA Office of Drinking Water report (2004)). Two outliers were identified and excluded from analyses. Sample weights were available in the dataset in order to weight each individual’s intake according to the number of infants in the population that he/she represented (see USDA, 2000 for a more detailed description). Each infant’s water intake was paired with her/his sample weight in Crystal Ball (version 7.2) to derive a distribution of intakes representative of the population. The Anderson-Darling goodness-of-fit test was used to find the best fit distribution for the weighted data. This weighting and best fit procedure was conducted for each infant age group (0<1, 1<2, 0<3, 3<6, and 0<12 months of age).

The OEHHA–derived water intake rates for these infant age groups are used in conjunction with other data to derive Hot Spots program age group and exposure duration scenario water intake rates (as outlined in Table 8.11, above). By doing so, the Hot Spots program water intake rates reflect intake rates of the truly exposed infants (those receiving reconstituted formula). The results are presented in Table 8.12, below, along with the Office of Water (2004) or U.S. EPA (2008) CEFH Table 3.19 estimates (direct plus indirect consumer-only community water intake rates) for comparison.

Table 8.12 Water Intake Rates of Infants by Age Group (ml/kg-day) – Derived by OEHHA (2008) or U.S. EPA (2004 or 2008)

Study	Age in Months	Sample Size	Mean	50%-ile	90%-ile	95%-ile	99%-ile
OEHHA CSFII [2]	0<1	45	184	171	253	300	466
U.S. EPA Table 3-19 [3]	0<1	37	137	155	236	269	269
OEHHA CSFII [2]	1<2	61	134	113	294	301	375
OEHHA CSFII [2]	0<3	137	122	113	206	294	375
U.S. EPA Table 3-19 [3]	0<3	108	119	107	247	289	375
OEHHA CSFII [2]	0<6	467	127	123	200	237	333
U.S. EPA (2004) [3]	0<6	414	95	91	184	221	294
OEHHA CSFII [2]	0<12	906	142	148	213	228	276
U.S. EPA (2004) [3]	0<12	948	71	62	145	185	261

[1]N = sample size. However, results have been weighted to adjust sample to the population.
[2]OEHHA analyses include water intake only from reconstituted formula
[3]U.S. EPA (2008) includes any direct or indirect intake of community water by consumers-only

A limitation of using intake data from infants receiving reconstituted formula is that the intakes do not include water added to food and non-formula drink, which results in possible underestimation of water intake. This limitation is likely only applicable to the second half of infancy when infants typically receive supplemental food and drink in addition to formula. A second limitation to the OEHHA derived infant intake rates are that the source of water (e.g., tap) used to reconstitute the formula is unknown. However, it is probable that a large fraction of infants are fed reconstituted formula prepared with tap water (see Section 8.5.1, below, for results of Levallois et al. 2007).

The Office of Water (2004) mean estimates are lower than the OEHHA mean estimates because they include data from infants who may have been almost exclusively (i.e., received an insignificant amount of calories from other non-milk food or drink), or exclusively, breast-fed. The 90th-, 95th-, and 99th-percentile estimates are similar among the analyses because these values likely represent infants who are exclusively fed formula reconstituted with water. These values support the consistency of results among analyses, and indicate that some infants consuming reconstituted formula may have very high water intake rates.

To estimate intake rates for the Hot Spots 0<2 year age group, the percentiles of the distribution and associated intake values for the 0<1 year age group (OEHHA derived, see Table 8.12, above) were entered into Crystal Ball and used to characterize the probability distribution of the intake rates. The best fit for the distribution was identified using the Anderson Darling goodness-of-fit test. The parameters for the modeled distribution were then derived using the empirical minimum and maximum to truncate unrealistically low and high values. This process (characterizing the probability distribution) was repeated for the water intake values of the 1<2 year age group of the CEFH Table 3-19 (2008). Table IV-8 of the Office of Water (2004) provided data on the population size of each age group (0<1 year and 1<2 years) relative to the full age group (0<2 years).

The population proportion was multiplied by 60,000 to give the number of infants for each age group in a hypothetical population of 60,000 infants. The Latin Hypercube method of Monte Carlo simulation in Crystal Ball was then used to generate simulated values for the 0<1 year age group based on the calculated number of infants in the hypothetical population. The same simulation procedure was applied to the 1<2 year age group distribution. The simulated values were then combined into one dataset. The best fit for the distribution of the combined values was characterized using the empirical minimum and maximum values for truncation to eliminate potentially unrealistic extreme values. The parameters of the combined (0<2 year age group) distribution were identified and summary statistics calculated.

To derive distributions for the other Hot Spots age groups and exposure duration scenarios, the above described procedure was also used. That is, using the data outlined in Table 8.11 for each Hot Spots program age group and exposure duration scenario, the probability distribution was characterized, population proportions were calculated (using Office of Water Table IV-8), and values proportional to population size were simulated. The simulated values were then combined, the best fit for the resultant distribution was identified, and parameters and summary statistics for the distribution were found. It may be noted that when calculating population proportions, the age groups of Table IV-8 of the Office of Water (2004) did not always fit the CEFH Table 3-19 age groups. In these cases, some approximations were required.

Values for the OEHHA derived Hot Spots age groups and exposure duration scenarios are presented in Table 8.13, below.

Table 8.13 OEHHA Derived Consumer-only Water Intake Rates (ml/kg-day) for Hot Spots Program Age Groups and Exposure Duration Scenarios[1]

Age	Mean	50th	Variance	90th	95th	99th	Max
Third Trimester	18	14	218	38	47	67	117
0<1 year [2]	143	149	3240	213	228	276	491 [5]
0<2 years [2]	113	106	1915	172	196	247	491 [4]
2-9 years [3]	26	22	414	54	66	92	190 [5]
2<16 years [3]	24	19	362	49	61	88	152
>=16 years [3]	19	16	208	38	47	67	135 [5]
16-30 years [3]	18	14	218	38	47	67	117
16-70 years [3]	18	15	191	37	45	62	116
Duration							
0-9 year [2]	45	25	3052	102	152	288	491
0-30 year [2]	28	15	1219	59	87	177	450
0-70 year [2]	23	14	886	51	73	141	442

[1]OEHHA recommends the mean and 95th percentiles as the average and high end point estimate values.

[2]Includes the OEHHA derived 0<1 year of age group water intake rates derived from the water in reconstituted formula for infants in CSFII

[2]OEHHA derived – data sources are **c**onsumer-only, direct + indirect, community water intake rates from Office of Water (2004) and U.S. EPA CEFH (2008) Table 3.19.

[4]Right tail outliers deleted

[5]fit distribution has maximum of infinity

8.4.14 Fitted Distributions of OEHHA Derived Water Intake Rates

The steps involved in deriving water intake rates specific for the Hot Spots program age group and exposure duration scenarios are described above, and briefly discussed here. OEHHA characterized the probability distributions for certain age group datasets from the Office of Water (2004) or Table 3-19 (2008) using Crystal Ball version 7.2 (Oracle, 2008). The best fit distributional type (e.g., gamma) was then found using the Anderson-Darling goodness-of-fit test. The parameters of the best fit distribution were then determined. Distributions were combined as listed in Table 8.11 to provide age groups matching the age groups needed for the Air Toxics Hot Spots program. The distributions were combined proportionate to population size which was approximated using the population numbers in U.S. EPA (2004). The mean and percentiles were calculated for the combined age group distributions using Crystal Ball 7.2 (Oracle, 2008) and the results are presented in Table 8.13, above. The combined age group distributions were characterized using Crystal Ball to find the best fit distribution, the Anderson-Darling statistic for that fit, and the parameters that fit that distribution. The distributional characteristics and values are presented in Table 8.14, below.

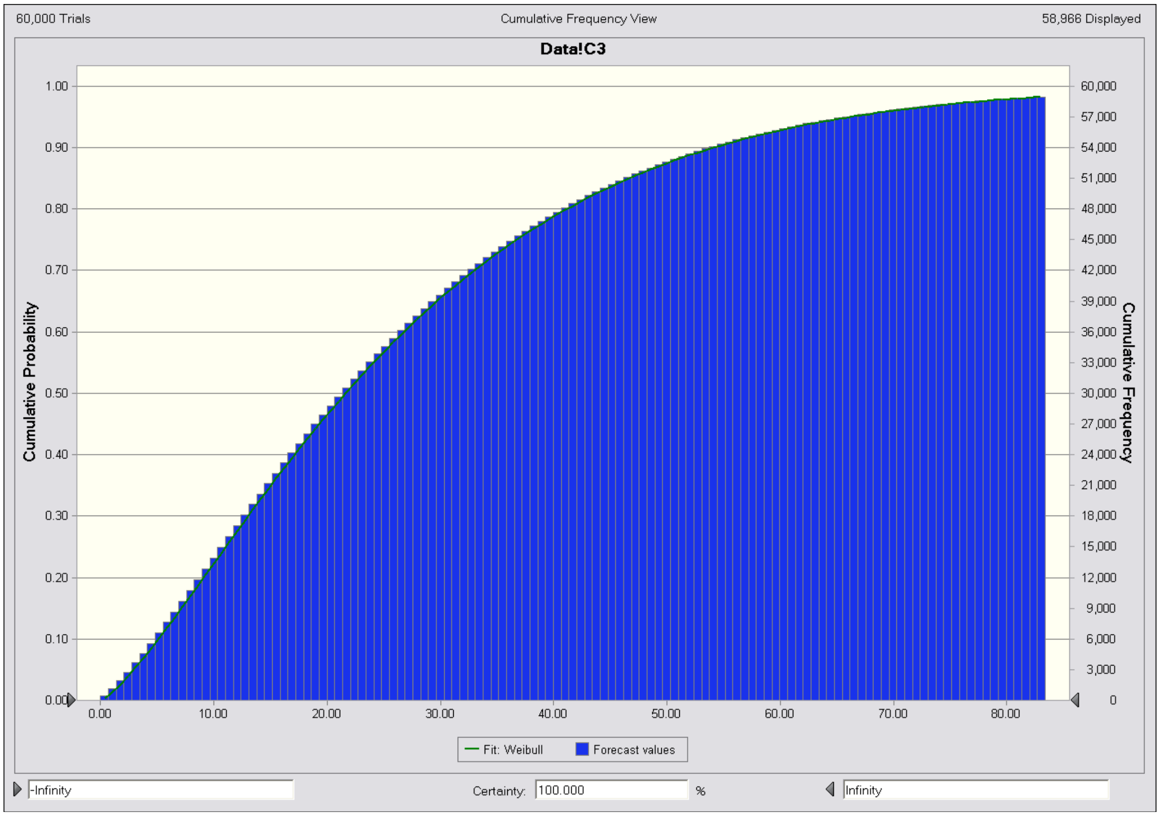
Table 8.14 Recommended Distributions of OEHHA Derived Water Intake Rates for Stochastic Analysis (ml/kg-day)

Age	Best Fit [1]	A-D statistic [2]	Parameters of Distribution [3]
0<1 year	Beta	23.2	Min = 60 Max = 264 Alpha = 4.1 Beta = 2.5
0<2 years [5]	Max Extreme	1.06	Likeliest = 93 Scale = 35
2<9 years	Weibull	0.01	Location = 0.02 Scale = 29 Shape = 1.3
2<16 years [6]	Gamma	0.11	Location = 0.19 Scale = 15.0 Shape = 1.6
≥16 years [6]	Gamma	0.52	Location = 0.17 Scale = 10.7 Shape = 1.8
16-30 year[7]	Gamma	10.6	location=0.49, scale=13.6, shape=1.26
16-70 year	Beta	1.09	min=0.17, max=178, alpha=1.5beta= 12.9
Duration			
0-9 year scenario	Lognormal	2.7	Mean = 45 SD = 70
0-30 year scenario	Lognormal	0.31	Mean = 26 SD = 39
0-70 year scenario	Lognormal	0.04	Mean = 23 SD = 29

[1]Best Fit refers to the distribution found to best fit the empirical data according to the Anderson-Darling goodness-of-fit test
[2]A-D statistic = Anderson-Darling statistic
[3]Parameters of Distribution refers to the parameters of the best fit distribution
[4]Taken directly from U.S. EPA CEFH (2008) Table 3.19.
[5]0<2 year age group derived by combining water in reconstituted formula only for 0<12 month ages from CSFII and the 1<2 year age group from U.S. EPA CEFH (2008) Table 3.19
[6]OEHHA analyses that derived alternate age groups using U.S. EPA (2004) and U.S. EPA CEFH (2008) Table 3.19.
[7]This distribution is recommended for the third trimester also.

To give a graphical example of the OEHHA derived distributions, the cumulative probability of the 2-9 year of age distribution (best fit) is shown below, in Figure 8.1.

Figure 8.1. Cumulative Probability Distribution for Water Intake Rates (ml/kg-day) for 2-9 Years of Age



8.5 Special Subpopulations of Concern

8.5.1 Infants

Infants may be more sensitive and exposed (on a body weight basis) to some toxicants than non-infant children and adults. Further, infants have unique nutritional needs, necessitating the feeding of milk or milk substitutes through at least three, and more commonly through four to six months of age. For the first 4-6 months, infants who are fed breast milk typically receive little, if any, other fluid. This is primarily because continued lactation is dependent on continued nursing. If nursing is reduced or discontinued for any length of time, the milk production quickly ceases. Thus, breast-fed infants tend to receive breast milk as their sole source of fluid and nutrition during the first half of infancy.

On the other hand, infants who are not breast-fed receive formula. The Ross Mothers Survey (Ross Products Division, Abbott, 2003) reported that in 2003, 44 percent, 18 percent, and 10 percent of infants were exclusively breastfed (no other liquids) in the hospital (i.e., soon after birth), at 6 months of age, and at 12 months of age, respectively. This suggests that the percent of infants who receive at least some formula may be up to 56 percent soon after birth and 82 percent at 6 months of age.

Formula can be bought ready-to-feed or in a form requiring the addition of water before it can be fed to the infant (i.e., powder or concentrated liquid). OEHHA analyzed the CSFII 1994-1996, 1998 and NHANES (National Health and Nutrition Examination Survey) 1999-2004 dataset to assess the proportion of infants who received reconstituted formula, relative to all types of formula. The food code descriptions were reviewed to identify the type of formula each infant received, including reconstituted formula. The results are presented in Table 8.15, below. These results provide evidence that a large fraction of formula-fed infants receive reconstituted formula, especially so for the youngest ages. These results also suggest that there may be a trend over time toward greater consumption of reconstituted formula relative to ready-to-feed formula.

Table 8.15 Percent of formula-fed infants consuming reconstituted formula

Age	CSFII	NHANES
0 < 1 month	82% (45 / 55) [1]	94% (31 / 32)
0<6 months	71% (467 / 658)	87% (398 / 457)
0<12 months	75% (906 / 1201)	87% (886 / 1013)

[1] ( ) = # receiving reconstituted formula / # receiving any type formula

Additionally, a study of 2-month old infants in rural Canada (with a sample size of approximately 300) found that 91 percent of formula-fed infants received formula reconstituted with water (Levallois et al., 2007). This is consistent with the results in Table 8.15, above. Because OEHHA is particularly interested in tap water intake rates, it is important to note that, of the Canadian infants receiving reconstituted formula, 60 percent received formula reconstituted with tap water.

Because the majority of formula-fed infants receive formula that has been reconstituted with water, which is often tap water (60 percent per Levallois et al., 2007), during the first half of infancy, the infant population is dichotomized into infants who receive little, or no, tap water (breast-fed infants) and infants who receive significant amounts of tap water every day (reconstituted formula fed infants).

While the infant's diet during first half of infancy typically consists almost exclusively of breast milk or formula, infant diet during the second half is much more varied and includes the gradual introduction of food and non-milk beverages. (The term 'second half of infancy' is used loosely here because the age at which food and non-milk drink is introduced varies but is typically between 4-6 months of age). Nonetheless, during this second half of infancy, the dichotomization of infants into two groups based on water intake rates continues, though the difference between the groups may be somewhat less pronounced.

The American Academy of Pediatrics (AAP, 1997) recommends that infants be exclusively breast-fed through 6 months of age and continue to receive breast milk as their sole source of milk while being introduced to solid food through 12 months. Thus, breast-fed infants may begin to receive some food and drink prepared with water but often not until at least 6 months of age. Further, breast-fed infants frequently continue to receive breast milk as a significant source of fluid and nutrition for several months past the introduction of supplemental food and drink. For formula-fed infants, because the accepted medical recommendation is to not feed cow's milk until at least 12 months of age, formula-fed infants typically continue to receive formula as their sole milk source. Like breast-fed infants, formula-fed infants may increase their intake of food and non-formula drink prepared with water during this period. Both breast-fed and formula-fed infants tend to decrease their consumption of breast milk or formula, respectively, while their consumption of food and drink prepared with water is likely to increase. Thus, during the second half of infancy, overall water intake of breast-fed infants likely increases, though probably not dramatically, while intake of formula-fed infants likely varies considerably between infants but with the potential for some infants to have even greater intake rates than during the first half of infancy.

The above information supports the existence of a sizable subpopulation of infants who are exclusively (or almost exclusively) fed formula reconstituted with water, which is often tap water, for the first 4-6 months and thereafter receive significant quantities of tap water through 12 months of age. These infants could receive significant tap water intake over the first year of life. In the past few years, there has been heightened awareness of the probable increased susceptibility of infants and children to some environmental toxicants. Therefore, it is prudent to identify subpopulations of infants who may be the most highly exposed. For the water pathway, reconstituted formula-fed infants can have a very high rate of tap water intake over the first year of life. Thus, water intake rates representative of this subpopulation (reconstituted formula fed infants) should be used for assessments of infants to exposures via the water pathway.

In risk assessment, we are interested in the dose to those who are exposed; in the case of the water pathway, those who consume water. With water intake, some individuals may not consume water on one or more days, or consume insignificant amounts of water (e.g., breast-fed infants). For the 'consumer-only' groups of infants in the Office of Water report, (U.S. EPA, 2004), only mean (average) values were given and these were only for the 0<6 and 0<12 month ages (i.e., relatively broad age groups for infants). In Table 3-19, consumer-only rates include percentiles of the distribution and the ages are stratified into narrower age groups (i.e., 0<1, 1<3, 3<6, and 6<12 months of age).

Of interest to OEHHA are rates of direct plus indirect community water intakes for narrow age groups of consumer-only infants. With such rates, both central tendency plus high-end rates of potentially more susceptible and exposed infants can be identified. U.S. EPA (2008) CEFH Table 3.19 provides these estimates. The U.S. EPA (2008) CEFH Table 3.19 infant estimates are presented in Table 8.16, below. However, the data used to derive these estimates included infants who were breast-fed. Therefore, these values do not represent the high-end exposure subpopulation of formula-fed infants.

Table 8.16 Infants Only -- U.S. EPA (2008), Child-Specific Exposure Factors Handbook Table 3-19. Estimates of Direct + Indirect, Consumer-only, Community Water Intake By Age Group (ml/kg-day)

Age (years)	Mean	Min	Percentiles (ml/kg-day)								
			5	10	25	50	75	90	95	99	Max
0<1 month	137	5	11	11	67	155	198	236	269	269	269
1<3 months	119	3	9	12	72	107	153	247	289	375	375
3<6 months	80	1	3	7	28	77	118	149	174	224	288
6<12 months	53	0	3	5	12	48	81	112	130	186	254

8.5.2 Pregnant and Lactating Women

Pregnant and lactating women have greater water requirements than non-pregnant or non-lactating women. A pregnant woman requires increased water intake in order to support fetal circulation, amniotic fluid, and a higher maternal blood volume, while a lactating woman requires increased water to replace the water excreted in breast milk. Values from the literature support this hypothesis. OEHHA (2000) Exposure Assessment and Stochastic Analysis Guidelines presented a table based on Ershow and Cantor (1989) that compared water intake rates of pregnant and lactating women with ‘control’ (not lactating, not pregnant) women of the same ages (see Table 8.17, below). These estimates demonstrate that lactating women consume significantly more water than non-lactating and pregnant women. More recent data are available than the values in Table 8.17. Therefore the values from Table 8.17 will not be used for Hot Spots guidance values.

Table 8.17 Water Intake Estimates For Pregnant and Lactating Women from Ershow and Cantor (1989) (ml/kg-day) – Tap Water

Group	Sample size	mean	Percentiles			
			50th	75th	90th	95th
Control	6201	19	17	24	33	39
Pregnant	188	18	16	24	35	40
Lactating	77	21	21	27	35	37

* Data from Ershow et al. 1991 based on data from the USDA Nationwide Food Consumption Survey (NFCS 1977-78)

The Office of Water, U.S. EPA (2004) report presented estimates of water intake rates for pregnant and lactating women. These rates are derived from CSFII 1994-1996, 1998 data. The consumer-only intake rates of direct plus indirect community water intakes are presented in Table 8.18 below.

Table 8.18 Water Intake Rates of Direct + Indirect Community Water for Consumers-only (ml/kg-day) for Pregnant, Lactating, and Non-pregnant / Non-lactating Women 15-40 Years of Age

Group	Sample size	mean	Percentiles				
			50th	75th	90th	95th	99th
Pregnant	65	14	9	22	33	43	47
Lactating	33	26	20	41	54	55	57
Non-pregnant, non-lactating, aged 15-44 yrs	2028	15	12	21	32	38	68

- From Part IV Table A3 of U.S. EPA (2004)
- Data used were from CSFII 1994-1996, 1998

8.5.3 High Activity Levels / Hot Climates

In the Exposure Factors handbook (1997), the U.S. EPA also addresses the issue of water consumption for those individuals performing strenuous activities under various environmental conditions, including desert climates (U.S. EPA, 1997). Data on these intake rates are very limited, and since the populations in the available studies are not considered representative of the general U.S. population, U.S. EPA did not use these data as the basis of their recommendations. Instead, they used the data from two studies to provide bounding intake values for those individuals engaged in strenuous activities in hot climates (McNall and Schlegel, 1968; U.S. Army, 1983).

McNall and Schlegel (1968) measured water intake of adult males working under varying degrees of physical activity, and varying temperatures. The results of this study indicate that hourly intake can range from 0.21 to 0.65 L/hour depending on the temperature and activity level.

U.S. EPA notes that these intake rates cannot be multiplied by 24 hours/day to convert to daily intake rates because they are only representative of water intakes during the 8-hour study periods of the test protocol. Intakes of the subjects for the rest of the day are not known.

The U.S. Army has developed water consumption planning factors to enable them to transport an adequate amount of water to soldiers in the field under various conditions (U.S. Army, 1983 and 1999). According to their estimates, intake among physically active individuals can range from 6 L/day in temperate climates to 11 L/day in hot climates. The Army's water consumption planning factors are based on military operations and may over-estimate civilian water consumption.

8.6 References

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