3. DRINKING WATER INTAKE

3.1. BACKGROUND

Drinking water is a potential source of human exposure to toxic substances. Contamination of drinking water may occur by, for example, percolation of toxics through the soil to ground water that is used as a source of drinking water; runoff or discharge to surface water that is used as a source of drinking water; intentional or unintentional addition of substances to treat water (e.g., chlorination); and leaching of materials from plumbing systems (e.g., lead). Estimating the magnitude of the potential dose of toxics from drinking water requires information on the quantity of water consumed. The purpose of this section is to describe key published studies that provide information on drinking water consumption (Section 3.2) and to provide recommendations of consumption rate values that should be used in exposure assessments (Section 3.6).

Currently, the U.S. EPA uses the quantity of 2 L per day for adults and 1 L per day for infants (individuals of 10 kg body mass or less) as default drinking water intake rates (U.S. EPA, 1980; 1991). These rates include drinking water consumed in the form of juices and other beverages containing tapwater (e.g., coffee). The National Academy of Sciences (NAS, 1977) estimated that daily consumption of water may vary with levels of physical activity and fluctuations in temperature and humidity. It is reasonable to assume that some individuals in physically-demanding occupations or living in warmer regions may have high levels of water intake.

Numerous studies cited in this chapter have generated data on drinking water intake rates. In general, these sources support EPA's use of 2 L/day for adults and 1 L/day for children as upper-percentile tapwater intake rates. Many of the studies have reported fluid intake rates for both total fluids and tapwater. *Total fluid intake* is defined as consumption of all types of fluids including tapwater, milk, soft drinks, alcoholic beverages, and water intrinsic to purchased foods. *Total tapwater* is defined as water consumed directly from the tap as a beverage or used in the preparation of foods and beverages (i.e., coffee, tea, frozen juices, soups, etc.). Data for both consumption categories are presented in the sections that follow. However, for the purposes of exposure assessments involving source-specific contaminated drinking water, intake rates based on total tapwater are more representative of source-specific tapwater intake. Given the assumption that purchased foods and beverages are widely distributed and less likely to contain source-specific water, the use of total fluid intake rates may overestimate the potential exposure to toxic substances present only in local water supplies; therefore tapwater intake, rather than total fluid intake, is emphasized in this section.

All studies on drinking water intake that are currently available are based on short-term survey data. Although short-term data may be suitable for obtaining mean intake values that are representative of both short- and long-term consumption patterns, upper-percentile values may be different for short-term and long-term data because more variability generally occurs in short-term surveys. It should also be noted that most drinking water surveys currently available are based on recall. This may be a source of uncertainty in the estimated intake rates because of the subjective nature of this type of survey technique.

The distribution of water intakes is usually, but not always, lognormal. Instead of presenting only the lognormal parameters, the actual percentile distributions are presented in this handbook, usually with a comment on whether or not it is lognormal. To facilitate comparisons between studies, the mean and the 90th percentiles are given for all studies where the distribution data are available. With these two parameters, along with information about which distribution is being followed, one can calculate, using standard formulas, the geometric mean and geometric standard deviation and hence any desired percentile of the distribution. Before doing such a calculation one must be sure that one of these distributions adequately fits the data.

The available studies on drinking water consumption are summarized in the following sections. They have been classified as either key studies or relevant studies based on the applicability of their survey designs to exposure assessment of the entire United States population. Recommended intake rates are based on the results of key studies, but relevant studies are also presented to provide the reader with added perspective on the current state-of-knowledge pertaining to drinking water intake.

3.2. KEY GENERAL POPULATION STUDIES ON DRINKING WATER INTAKE

Canada Department of Health and Welfare (1981) - Tapwater Consumption in Canada - In a study conducted by the Canadian Department of Health and Welfare, 970 individuals from 295 households were surveyed to

determine the per capita total tapwater intake rates for various age/sex groups during winter and summer seasons (Canadian Ministry of National Health and Welfare, 1981). Intake rate was also evaluated as a function of physical activity. The population that was surveyed matched the Canadian 1976 census with respect to the proportion in different age, regional, community size and dwelling type at home and tapwater consumed away from home. The survey also did not attempt to estimate intake rates for fluids other than tapwater. Consequently, no intake rates for total fluids were reported.

Daily consumption distribution patterns for various age groups are presented in Table 3-1. For adults (over 18 years of age) only, the average total tapwater intake rate was

Table 3-1. Daily Total Tapwater Intake Distribution for Canadians, by Age Group
(approx. 0.20 L increments, both sexes, combined seasons)

Amount Consumed[a]	Age Group (years)					
	5 and under		6-17		18 and over	
L/day	%	Number	%	Number	%	Number
0.00 - 0.21	11.1	9	2.8	7	0.5	3
0.22 - 0.43	17.3	14	10.0	25	1.9	12
0.44 - 0.65	24.8	20	13.2	33	5.9	38
0.66 - 0.86	9.9	8	13.6	34	8.5	54
0.87 - 1.07	11.1	9	14.4	36	13.1	84
1.08 - 1.29	11.1	9	14.8	37	14.8	94
1.30 - 1.50	4.9	4	9.6	24	15.3	98
1.51 - 1.71	6.2	5	6.8	17	12.1	77
1.72 - 1.93	1.2	1	2.4	6	6.9	44
1.94 - 2.14	1.2	1	1.2	3	5.6	36
2.15 - 2.36	1.2	1	4.0	10	3.4	22
2.37 - 2.57	-	0	0.4	1	3.1	20
2.58 - 2.79	-	0	2.4	6	2.7	17
2.80 - 3.00	-	0	2.4	6	1.4	9
3.01 - 3.21	-	0	0.4	1	1.1	7
3.22 - 3.43	-	0	-	0	0.9	6
3.44 - 3.64	-	0	-	0	0.8	5
3.65 - 3.86	-	0	-	0	-	0
>3.86	-	0	1.6	4	2.0	13
TOTAL	100.0	81	100.0	250	100.0	639

[a] Includes tapwater and foods and beverages derived from tapwater.
Source: Canadian Ministry of National Health and Welfare, 1981.

groups. Participants monitored water intake for a 2-day period (1 weekday, and 1 weekend day) in both late summer of 1977 and winter of 1978. All 970 individuals participated in both the summer and winter surveys. The amount of tapwater consumed was estimated based on the respondents' identification of the type and size of beverage container used, compared to standard sized vessels. The survey questionnaires included a pictorial guide to help participants in classifying the sizes of the vessels. For example, a small glass of water was assumed to be equivalent to 4.0 ounces of water, and a large glass was assumed to contain 9.0 ounces of water. The study also accounted for water derived from ice cubes and popsicles, and water in soups, infant formula, and juices. The survey did not attempt to differentiate between tapwater consumed 1.38 L/day, and the 90th percentile rate was 2.41 L/day as determined by graphical interpolation. These data follow a lognormal distribution. The intake data for males, females, and both sexes combined as a function of age and expressed in the units of milliliters (grams) per kilogram body weight are presented in Table 3-2. The tapwater survey did not include body weights of the participants, but the body weight information was taken from a Canadian health survey dated 1981; it averaged 65.1 kg for males and 55.6 kg for females. Intake rates for specific age groups and seasons are presented in Table 3-3. The average daily total tapwater intake rates for all ages and seasons combined was 1.34 L/day, and the 90th percentile rate was 2.36 L/day. The summer intake rates are nearly the same as the winter intake rates. The authors speculate that the reason for the

small seasonal variation here is that in Canada, even in the summer, the ambient temperature seldom exceeded 20 degrees C and marked increase in water consumption with high activity levels has been observed in other studies only when the ambient temperature has been higher than 20 degrees. Average daily total tapwater intake rates as a function of the level of physical activity, as estimated subjectively, are presented in Table 3-4. The amounts of tapwater consumed that are derived from various foods and beverages are presented in Table 3-5. Note that the consumption of direct "raw" tapwater is almost constant across all age groups from school-age children through the oldest ages. The increase in total tapwater consumption beyond school age is due to coffee and tea consumption.

Table 3-2. Average Daily Tapwater Intake of Canadians (expressed as milliliters per kilogram body weight)

	Average Daily Intake (mL/kg)		
Age Group (years)	Females	Males	Both Sexes
<3	53	35	45
3-5	49	48	48
6-17	24	27	26
18-34	23	19	21
35-54	25	19	22
55+	24	21	22
Total Population	24	21	22

Source: Canadian Ministry of National Health and Welfare, 1981.

Table 3-3. Average Daily Total Tapwater Intake of Canadians, by Age and Season (L/day)[a]

	Age (years)						
	<3	3-5	6-17	18-34	35-54	≤55	All Ages
Average							
Summer	0.57	0.86	1.14	1.33	1.52	1.53	1.31
Winter	0.66	0.88	1.13	1.42	1.59	1.62	1.37
Summer/Winter	0.61	0.87	1.14	1.38	1.55	1.57	1.34
90th Percentile							
Summer/Winter	1.50	1.50	2.21	2.57	2.57	2.29	2.36

[a] Includes tapwater and foods and beverages derived from tapwater.

Source: Canadian Ministry of National Health and Welfare, 1981.

Table 3-4. Average Daily Total Tapwater Intake of Canadians as a Function of Level of Physical Activity at Work and in Spare Time (16 years and older, combined seasons, L/day)

	Work		Spare Time	
Activity Level[a]	Consumption[b] L/day	Number of Respondents	Consumption[b] L/day	Number of Respondents
Extremely Active	1.72	99	1.57	52
Very Active	1.47	244	1.51	151
Somewhat Active	1.47	217	1.44	302
Not Very Active	1.27	67	1.52	131
Not At All Active	1.30	16	1.35	26
Did Not State	1.30	45	1.31	26
TOTAL		688		688

[a] The levels of physical activity listed here were not defined any further by the survey report, and categorization of activity level by survey participants is assumed to be subjective.

[b] Includes tapwater and foods and beverages derived from tapwater.

Source: Canadian Ministry of National Health and Welfare, 1981.

Table 3-5. Average Daily Tapwater Intake by Canadians, Apportioned Among Various Beverages (both sexes, by age, combined seasons, L/day)[a]

	Age Group (years)					
	Under 3	3-5	6-17	18-34	35-54	55 and Over
Total Number in Group 34	47	250	232	254	153	
Water	0.14	0.31	0.42	0.39	0.38	0.38
Ice/Mix	0.01	0.01	0.02	0.04	0.03	0.02
Tea	*	0.01	0.05	0.21	0.31	0.42
Coffee	0.01	*	0.06	0.37	0.50	0.42
"Other Type of Drink"	0.21	0.34	0.34	0.20	0.14	0.11
Reconstituted Milk	0.10	0.08	0.12	0.05	0.04	0.08
Soup	0.04	0.08	0.07	0.06	0.08	0.11
Homemade Beer/Wine	*	*	0.02	0.04	0.07	0.03
Homemade Popsicles	0.01	0.03	0.03	0.01	*	*
Baby Formula, etc.	0.09	*	*	*	*	*
TOTAL	0.61	0.86	1.14	1.38	1.55	1.57

[a] Includes tapwater and foods and beverages derived from tapwater.
* Less than 0.01 L/day

Source: Canadian Ministry of National Health and Welfare, 1981.

Data concerning the source of tapwater (municipal, well, or lake) was presented in one table of the study. This categorization is not appropriate for making conclusions about consumption of ground versus surface water.

This survey may be more representative of total tapwater consumption than some other less comprehensive surveys because it included data for some tapwater-containing items not covered by other studies (i.e., ice cubes, popsicles, and infant formula). One potential source of error in the study is that estimated intake rates were based on identification of standard vessel sizes; the accuracy of this type of survey data is not known. The cooler climate of Canada may have reduced the importance of large tapwater intakes resulting from high activity levels, therefore making the study less applicable to the United States. The authors were not able to explain the surprisingly large variations between regional tapwater intakes; the largest regional difference was between Ontario (1.18 liters/day) and Quebec (1.55 liters/day).

Ershow and Cantor (1989) - Total Water and Tapwater Intake in the United States: Population-Based Estimates of Quantities and Sources - Ershow and Cantor (1989) estimated water intake rates based on data collected by the USDA 1977-1978 Nationwide Food Consumption Survey (NFCS). Daily intake rates for tapwater and total water were calculated for various age groups for males, females, and both sexes combined. Tapwater was defined as "all water from the household tap consumed directly as a beverage or used to prepare foods and beverages." Total water was defined as tapwater plus "water intrinsic to foods and beverages" (i.e., water contained in purchased food and beverages). The authors showed that the age, sex, and racial distribution of the surveyed population closely matched the estimated 1977 U. S. population.

Daily total tapwater intake rates, expressed as mL (grams) per day by age group are presented in Table 3-6. These data follow a lognormal distribution. The same data, expressed as mL (grams) per kg body weight per day are presented in Table 3-7. A summary of these tables, showing the mean, the 10th and 90th percentile intakes, expressed as both mL/day and mL/kg-day as a function of age, is presented in Table 3-8. This shows that the mean and 90th percentile intake rates for adults (ages 20 to 65+) are approximately 1,410 mL/day and 2,280 mL/day and for all ages the mean and 90th percentile intake rates are 1,190 mL/day and 2,090 mL/day. Note that older adults have greater intakes than do adults between age 20 and

Table 3-6. Total Tapwater Intake (mL/day) for Both Sexes Combined[a]

Age (years)	Number of Observations	Mean	SD	S.E. of Mean	Percentile Distribution								
					1	5	10	25	50	75	90	95	99
<0.5	182	272	247	18	*	0	0	80	240	332	640	800	*
0.5 - 0.9	221	328	265	18	*	0	0	117	268	480	688	764	*
1 - 3	1498	646	390	10	33	169	240	374	567	820	1162	1419	1899
4 - 6	1702	742	406	10	68	204	303	459	660	972	1302	1520	1932
7 - 10	2405	787	417	9	68	241	318	484	731	1016	1338	1556	1998
11 - 14	2803	925	521	10	76	244	360	561	838	1196	1621	1924	2503
15 - 19	2998	999	593	11	55	239	348	587	897	1294	1763	2134	2871
20 - 44	7171	1255	709	8	105	337	483	766	1144	1610	2121	2559	3634
45 - 64	4560	1546	723	11	335	591	745	1057	1439	1898	2451	2870	3994
65 - 74	1663	1500	660	16	301	611	766	1044	1394	1873	2333	2693	3479
75+	878	1381	600	20	279	568	728	961	1302	1706	2170	2476	3087
Infants (ages <1)	403	302	258	13	0	0	0	113	240	424	649	775	1102
Children (ages 1-10)	5605	736	410	5	56	192	286	442	665	960	1294	1516	1954
Teens (ages 11-19)	5801	965	562	7	67	240	353	574	867	1246	1701	2026	2748
Adults (ages 20-64)	11731	1366	728	7	148	416	559	870	1252	1737	2268	2707	3780
Adults (ages 65+)	2541	1459	643	13	299	598	751	1019	1367	1806	2287	2636	3338
All	26081	1193	702	4	80	286	423	690	1081	1561	2092	2477	3415

[a] Total tapwater is defined as "all water from the household tap consumed directly as a beverage or used to prepare foods and beverages."
* Value not reported due to insufficient number of observations.

Source: Ershow and Cantor, 1989.

Table 3-7. Total Tapwater Intake (mL/kg-day) for Both Sexes Combined[a]

Age (years)	Number of Observations: Actual Count	Number of Observations: Weighted Count	Mean	SD	S.E. of Mean	1	5	10	25	50	75	90	95	99
<0.5	182	201.2	52.4	53.2	3.9	*	0.0	0.0	14.8	37.8	66.1	128.3	155.6	*
0.5 - 0.9	221	243.2	36.2	29.2	2.0	*	0.0	0.0	15.3	32.2	48.1	69.4	102.9	*
1 - 3	1498	1687.7	46.8	28.1	0.7	2.7	11.8	17.8	27.2	41.4	60.4	82.1	101.6	140.6
4 - 6	1702	1923.9	37.9	21.8	0.5	3.4	10.3	14.9	21.9	33.3	48.7	69.3	81.1	103.4
7 - 10	2405	2742.4	26.9	15.3	0.3	2.2	7.4	10.3	16.0	24.0	35.5	47.3	55.2	70.5
11 - 14	2803	3146.9	20.2	11.6	0.2	1.5	4.9	7.5	11.9	18.1	26.2	35.7	41.9	55.0
15 - 19	2998	3677.9	16.4	9.6	0.2	1.0	3.9	5.7	9.6	14.8	21.5	29.0	35.0	46.3
20 - 44	7171	13444.5	18.6	10.7	0.1	1.6	4.9	7.1	11.2	16.8	23.7	32.2	38.4	53.4
45 - 64	4560	8300.4	22.0	10.8	0.2	4.4	8.0	10.3	14.7	20.2	27.2	35.5	42.1	57.8
65 - 74	1663	2740.2	21.9	9.9	0.2	4.6	8.7	10.9	15.1	20.2	27.2	35.2	40.6	51.6
75+	878	1401.8	21.6	9.5	0.3	3.8	8.8	10.7	15.0	20.5	27.1	33.9	38.6	47.2
Infants (ages <1)	403	444.3	43.5	42.5	2.1	0.0	0.0	0.0	15.3	35.3	54.7	101.8	126.5	220.5
Children (ages 1-10)	5605	6354.1	35.5	22.9	0.3	2.7	8.3	12.5	19.6	30.5	46.0	64.4	79.4	113.9
Teens (ages 11-19)	5801	6824.9	18.2	10.8	0.1	1.2	4.3	6.5	10.6	16.3	23.6	32.3	38.9	52.6
Adults (ages 20-64)	11731	21744.9	19.9	10.8	0.1	2.2	5.9	8.0	12.4	18.2	25.3	33.7	40.0	54.8
Adults (ages 65+)	2541	4142.0	21.8	9.8	0.2	4.5	8.7	10.9	15.0	20.3	27.1	34.7	40.0	51.3
All	26081	39510.2	22.6	15.4	0.1	1.7	5.8	8.2	13.0	19.4	28.0	39.8	50.0	79.8

[a] Total tapwater is defined as "all water from the household tap consumed directly as a beverage or used to prepare foods and beverages."
* Value not reported due to insufficient number of observations.

Source: Ershow and Cantor, 1989.

Table 3-8. Summary of Tapwater Intake by Age				
Age Group	Intake (mL/day)		Intake (mL/kg-day)	
	Mean	10th-90th Percentiles	Mean	10th-90th Percentiles
Infants (<1 year)	302	0-649	43.5	0 - 100
Children (1-10 years)	736	286-1,294	35.5	12.5 - 64.4
Teens (11-19 years)	965	353-1,701	18.2	6.5 - 32.3
Adults (20 -64 years)	1,366	559-2,268	19.9	8.0 - 33.7
Adults (65+ years)	1,459	751-2,287	21.8	10.9 - 34.7
All ages	1,193	423-2,092	22.6	8.2 - 39.8
Source: Ershow and Cantor (1989)				

65, an observation bearing on the interpretation of the Cantor, et al. (1987) study which surveyed a population that was older than the national average (see Section 3.3).

Ershow and Cantor (1989) also measured total water intake for the same age groups and concluded that it averaged 2,070 mL/day for all groups combined and that tapwater intake (1,190 mL/day) is 55 percent of the total water intake. (The detailed intake data for various age groups are presented in Table 3-9). Ershow and Cantor (1989) also concluded that, for all age groups combined, the proportion of tapwater consumed as drinking water, foods, and beverages is 54 percent, 10 percent and 36 percent, respectively. (The detailed data on proportion of tapwater consumed for various age groups are presented in Table 3-10). Ershow and Cantor (1989) also observed that males of all age groups had higher total water and tapwater consumption rates than females; the variation of each from the combined-sexes mean was about 8 percent.

Ershow and Cantor (1989) also presented data on total water intake and tapwater intake for children of various ages. They found, for infants and children between the ages of 6 months and 15 years, that the total water intake per unit body weight increased smoothly and sharply from 30 mL/kg-day above age 15 years to 190 mL/kg-day for ages less than 6 months. This probably represents metabolic requirements for water as a dietary constituent. However, they found that the intake of tapwater alone went up only slightly with decreasing age (from 20 to 45 mL/kg-day as age decreases from 11 years to less than 6 months). Ershow and Cantor (1989) attributed this small effect of age on tapwater intake to the large number of alternative water sources (besides tapwater) used for the younger age groups.

Table 3-9. Total Tapwater Intake (as percent of total water intake) by Broad Age Category[a,b]										
Age (years)	Mean	Percentile Distribution								
		1	5	10	25	50	75	90	95	99
<1	26	0	0	0	12	22	37	55	62	82
1-10	45	6	19	24	34	45	57	67	72	81
11-19	47	6	18	24	35	47	59	69	74	83
20-64	59	12	27	35	49	61	72	79	83	90
65+	65	25	41	47	58	67	74	81	84	90

[a] Does not include pregnant women, lactating women, or breast-fed children.
[b] Total tapwater is defined as "all water from the household tap consumed directly as a beverage or used to prepare foods and beverages."
0 = Less than 0.5 percent.

Source: Ershow and Cantor, 1989.

Table 3-10. General Dietary Sources of Tapwater for Both Sexes[a,b]

Age (years)	Source	% of Tapwater							
		Mean	Standard Deviation	5	25	50	75	95	99
<1	Food[c]	11	24	0	0	0	10	70	100
	Drinking Water	69	37	0	39	87	100	100	100
	Other Beverages	20	33	0	0	0	22	100	100
	All Sources	100							
1-10	Food[c]	15	16	0	5	10	19	44	100
	Drinking Water	65	25	0	52	70	84	96	100
	Other Beverages	20	21	0	0	15	32	63	93
	All Sources	100							
11-19	Food[c]	13	15	0	3	8	17	38	100
	Drinking Water	65	25	0	52	70	85	98	100
	Other Beverages	22	23	0	0	16	34	68	96
	All Sources	100							
20-64	Food[c]	8	10	0	2	5	11	25	49
	Drinking Water	47	26	0	29	48	67	91	100
	Other Beverages	45	26	0	25	44	63	91	100
	All Sources	100							
65+	Food[c]	8	9	0	2	5	11	23	38
	Drinking Water	50	23	0	36	52	66	87	99
	Other Beverages	42	23	3	27	40	57	85	100
	All Sources	100							
All	Food[c]	10	13	0	2	6	13	31	64
	Drinking Water	54	27	0	36	56	75	95	100
	Other Beverages	36	27	0	14	34	55	87	100
	All Sources	100							

[a] Does not include pregnant women, lactating women, or breast-fed children.
[b] Individual values may not add to totals due to rounding.
[c] Food category includes soups.
0 = Less than 0.5 percent.
Source: Ershow and Cantor, 1989.

With respect to region of the country, the northeast states had slightly lower average tapwater intake (1,200 mL/day) than the three other regions (which were approximately equal at 1,400 mL/day).

This survey has an adequately large size (26,446 individuals) and it is a representative sample of the United States population with respect to age distribution, sex, racial composition, and residential location. It is therefore suitable as a description of national tapwater consumption. The chief limitation of the study is that the data were collected in 1978 and do not reflect the expected increase in the consumption of soft drinks and bottled water or changes in the diet within the last two decades. Since the data were collected for only a three-day period, the extrapolation to chronic intake is uncertain.

Roseberry and Burmaster (1992) - Lognormal Distributions for Water Intake - Roseberry and Burmaster (1992) fit lognormal distributions to the water intake data reported by Ershow and Cantor (1989) and estimated population-wide distributions for total fluid and total tapwater intake based on proportions of the population in each age group. Their publication shows the data and the fitted log-normal distributions graphically. The mean was estimated as the zero intercept, and the standard deviation was estimated as the slope of the best fit line for the natural logarithm of the intake rates plotted against their

corresponding z-scores (Roseberry and Burmaster, 1992). Least squares techniques were used to estimate the best fit straight lines for the transformed data. Summary statistics for the best-fit lognormal distribution are presented in Table 3-11. In this table, the simulated balanced population represents an adjustment to account for the different age distribution of the United States population in 1988 from the age distribution in 1978 when Ershow and Cantor (1989) collected their data. Table 3-12 summarizes the quantiles and means of tapwater intake as estimated from the best-fit distributions. The mean total tapwater intake rates for the two adult populations (age 20 to 65 years, and 65+ years) were estimated to be 1.27 and 1.34 L/day.

Table 3-11. Summary Statistics for Best-Fit Lognormal Distributions for Water Intake Rates[a]

Group (age in years)	ln Total Fluid Intake Rate μ	σ	R^2
0 < age <1 6.979	0.291	0.996	
1 ≤ age <11	7.182	0.340	0.953
11 ≤ age <20	7.490	0.347	0.966
20 ≤ age <65	7.563	0.400	0.977
65 ≤ age	7.583	0.360	0.988
All ages	7.487	0.405	0.984
Simulated balanced population	7.492	0.407	1.000

Group (age in years)	ln Total Tapwater Intake μ	σ	R^2
0 < age <1 5.587	0.615	0.970	
1 ≤ age <11	6.429	0.498	0.984
11 ≤ age <20	6.667	0.535	0.986
20 ≤ age <65	7.023	0.489	0.956
65 ≤ age	7.088	0.476	0.978
All ages	6.870	0.530	0.978
Simulated balanced population	6.864	0.575	0.995

[a] These values (mL/day) were used in the following equations to estimate the quantiles and averages for total tapwater intake shown in Tables 3-12.

97.5 percentile intake rate = exp [μ + (1.96 · σ)]
75 percentile intake rate = exp [μ + (0.6745 · σ)]
50 percentile intake rate = exp [μ]
25 percentile intake rate = exp [μ - (0.6745 · σ)]
2.5 percentile intake rate = exp [μ - (1.96 · σ)]
Mean intake rate - exp [μ + 0.5 · σ^2)]
Source: Roseberry and Burmaster, 1992.

These intake rates were based on the data originally presented by Ershow and Cantor (1989). Consequently, the same advantages and disadvantages associated with the Ershow and Cantor (1989) study apply to this data set.

3.3. RELEVANT GENERAL POPULATION STUDIES ON DRINKING WATER INTAKE

National Academy of Sciences (1977) - Drinking Water and Health - NAS (1977) calculated the average per capita water (liquid) consumption per day to be 1.63 L. This figure was based on a survey of the following literature sources: Evans (1941); Bourne and Kidder (1953); Walker et al. (1957); Wolf (1958); Guyton (1968); McNall and Schlegel (1968); Randall (1973); NAS (1974); and Pike and Brown (1975). Although the calculated average intake rate was 1.63 L per day, NAS (1977) adopted a larger rate (2 L per day) to represent the intake of the majority of water consumers. This value is relatively consistent with the total tapwater intakes rate estimated from the key studies presented previously. However, the use of the term "liquid" was not clearly defined in this study, and it is not known whether the populations surveyed are representative of the adult U.S. population. Consequently, the results of this study are of limited use in recommending total tapwater intake rates and this study is not considered a key study.

Hopkins and Ellis (1980) - Drinking Water Consumption in Great Britain - A study conducted in Great Britain over a 6-week period during September and October 1978, estimated the drinking water consumption rates of 3,564 individuals from 1,320 households in England, Scotland, and Wales (Hopkins and Ellis, 1980). The participants were selected randomly and were asked to complete a questionnaire and a diary indicating the type and quantity of beverages consumed over a 1-week period. Total liquid intake included total tapwater taken at home and away from home; purchased alcoholic beverages; and non-tapwater-based drinks. Total tapwater included water content of tea, coffee, and other hot water drinks; homemade alcoholic beverages; and tapwater consumed directly as a beverage. The assumed tapwater contents for these beverages are presented in Table 3-13. Based on responses from 3,564 participants, the mean intake rates and frequency distribution data for various beverage categories were estimated by Hopkins and Ellis (1980). These data are listed in Table 3-14. The mean per capita total liquid intake rate for all individuals surveyed was 1.59 L/day, and the mean per capita total tapwater intake rate was 0.95 L/day, with a 90th percentile

Table 3-12. Estimated Quantiles and Means for Total Tapwater Intake Rates (mL/day)[a]

Age Group (years)	Percentile					Arithmetic Average
	2.5	25	50	75	97.5	
0 <age < 1	80	176	267	404	891	323
1 ≤ age < 11	233	443	620	867	1,644	701
11 ≤ age < 20	275	548	786	1,128	2,243	907
20 ≤ age < 65	430	807	1,122	1,561	2,926	1,265
65 ≤ age	471	869	1,198	1,651	3,044	1,341
All ages	341	674	963	1,377	2,721	1,108
Simulated Balanced Population	310	649	957	1,411	2,954	1,129

[a] Total tapwater is defined as "all water from the household tap consumed directly as a beverage or used to prepare foods and beverages."
Source: Roseberry and Burmaster, 1992

Table 3-13. Assumed Tapwater Content of Beverages

Beverage	% Tapwater
Cold Water	100
Home-made Beer/Cider/Lager	100
Home-made Wine	100
Other Hot Water Drinks	100
Ground/Instant Coffee:[a]	
Black	100
White	80
Half Milk	50
All Milk	0
Tea	80
Hot Milk	0
Cocoa/Other Hot Milk Drinks	0
Water-based Fruit Drink	75
Fizzy Drinks	0
Fruit Juice 1[b]	0
Fruit Juice 2[b]	75
Milk	0
Mineral Water[c]	0
Bought cider/beer/lager	0
Bought Wine	0

[a] Black - coffee with all water, milk not added; White - coffee with 80% water, 20% milk;
Half Milk - coffee with 50% water, 50% milk; All Milk - coffee with all milk, water not added;
[b] Fruit juice: individuals were asked in the questionnaire if they consumed ready-made fruit juice (type 1 above), or the variety that is diluted (type 2);
[c] Information on volume of mineral water consumed was obtained only as "number of bottles per week." A bottle was estimated at 500 mL, and the volume was split so that 2/7 was assumed to be consumed on weekends, and 5/7 during the week.
Source: Hopkins and Ellis, 1980.

value of about 1.3 L/day (which is the value of the percentile for the home tapwater alone in Table 3-14). Liquid intake rates were also estimated for males and females in various age groups. Table 3-15 summarizes the total liquid and total tapwater intake rates for 1,758 males and 1,800 females grouped into six age categories (Hopkins and Ellis, 1980). The mean and 90th percentile total tapwater intake values for adults over age 18 years are, respectively, 1.07 L/day and 1.87 L/day, as determined by pooling data for males and females for the three adult age ranges in Table 3-15. This calculation assumes, as does Table 3-14 and 3-15, that the underlying distribution is normal and not lognormal.

The advantage of using these data is that the responses were not generated on a recall basis, but by recording daily intake in diaries. The latter approach may result in more accurate responses being generated. Also, the use of total liquid and total tapwater was well defined in this study. However, the relatively short-term nature of the survey make extrapolation to long-term consumption patterns difficult. Also, these data were based on the population of Great Britain and not the United States. Drinking patterns may differ among these populations as a result of varying weather conditions and socio-economic factors. For these reasons this study is not considered a key study in this document.

International Commission on Radiological Protection (ICRP) (1981) - Report to the Task Group on Reference Man - Data on fluid intake levels have also been summarized by the International Commission on Radiological Protection (ICRP) in the Report of the Task Group on Reference Man (ICRP, 1981). These intake levels for adults and children are summarized in Table 3-16. The amount of drinking water (tapwater and water-based drinks) consumed by adults ranged from about 0.37 L/day to about 2.18 L/day under "normal" conditions. The levels for children ranged from 0.54 to 0.79 L/day. Because the populations, survey design, and intake categories are not clearly defined, this study has limited usefulness in developing recommended intake rates for use in exposure assessment. It is reported here as a relevant study because the findings, although poorly defined, are consistent with the results of other studies.

Table 3-14. Intake of Total Liquid, Total Tapwater, and Various Beverages (L/day)

Beverage	All Individuals					Consumers Only			
	Mean Intake	Approx. Std. Error of Mean	Approx. 95% Confidence Interval for Mean	10 and 90 Percentiles	1 and 99 Percentiles	Percentage of Total Number of Individuals	Mean Intake	Approx. Std. Error of Mean	Approx. 95% Confidence Interval for Mean
Total Liquid	1.589	0.0203	1.547-1.629	0.77-2.57	0.34-4.50	100.0	1.589	0.0203	1.547-1.629
Total Liquid Home	1.104	0.0143	1.075-1.133	0.49-1.79	0.23-3.10	100.0	1.104	0.0143	1.075-1.133
Total Liquid Away	0.484	0.0152	0.454-0.514	0.00-1.15	0.00-2.89	89.9	0.539	0.0163	0.506-0.572
Total Tapwater	0.955	0.0129	0.929-0.981	0.39-1.57	0.10-2.60	99.8	0.958	0.0129	0.932-0.984
Total Tapwater Home	0.754	0.0116	0.731-0.777	0.26-1.31	0.02-2.30	99.4	0.759	0.0116	0.736-0.782
Total Tapwater Away	0.201	0.0056	0.190-0.212	0.00-0.49	0.00-0.96	79.6	0.253	0.0063	0.240-0.266
Tea	0.584	0.0122	0.560-0.608	0.01-1.19	0.00-2.03	90.9	0.643	0.0125	0.618-0.668
Coffee	0.190	0.0059	0.178-0.202	0.00-0.56	0.00-1.27	63.0	0.302	0.0105	0.281-0.323
Other Hot Water Drinks	0.011	0.0015	0.008-0.014	0.00-0.00	0.00-0.25	9.2	0.120	0.0133	0.093-0.147
Cold Water	0.103	0.0049	0.093-0.113	0.00-0.31	0.00-0.85	51.0	0.203	0.0083	0.186-0.220
Fruit Drinks	0.057	0.0027	0.052-0.062	0.00-0.19	0.00-0.49	46.2	0.123	0.0049	0.113-0.133
Non Tapwater	0.427	0.0058	0.415-0.439	0.20-0.70	0.06-1.27	99.8	0.428	0.0058	0.416-0.440
Home-brew	0.010	0.0017	0.007-0.013	0.00-0.00	0.00-0.20	7.0	0.138	0.0209	0.096-0.180
Bought Alcoholic Beverages	0.206	0.0123	0.181-0.231	0.00-0.68	0.00-2.33	43.5	0.474	0.0250	0.424-0.524

[a] Consumers only is defined as only those individuals who reported consuming the beverage during the survey period.
Source: Hopkin and Ellis, 1980.

Table 3-15. Summary of Total Liquid and Total Tapwater Intake for Males and Females (L/day)

Beverage	Age Group (years)	Number		Mean Intake		Approx. Std. Error of Mean		Approx 95% Confidence Interval for Mean		10 and 90 Percentiles	
		Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Total Liquid Intake	1-4	88	75	0.853	0.888	0.0557	0.0660	0.742-0.964	0.756-1.020	0.38-1.51	0.39-1.48
	5-11	249	201	0.986	0.902	0.0296	0.0306	0.917-1.045	0.841-0.963	0.54-1.48	0.51-1.39
	12-17	180	169	1.401	1.198	0.0619	0.0429	1.277-1.525	1.112-1.284	0.75-2.27	0.65-1.74
	18-30	333	350	2.184	1.547	0.0691	0.0392	2.046-2.322	1.469-1.625	1.12-3.49	0.93-2.30
	31-54	512	551	2.112	1.601	0.0526	0.0215	2.007-2.217	1.558-1.694	1.15-3.27	0.95-2.36
	55+	396	454	1.830	1.482	0.0498	0.0356	1.730-1.930	1.411-1.553	1.03-2.77	0.84-2.17
Total Tapwater Intake	1-4	88	75	0.477	0.464	0.0403	0.0453	0.396-0.558	0.373-0.555	0.17-0.85	0.15-0.89
	5-11	249	201	0.550	0.533	0.0223	0.0239	0.505-0.595	0.485-0.581	0.22-0.90	0.22-0.93
	12-17	180	169	0.805	0.725	0.0372	0.0328	0.731-0.8790	0.659-0.791	0.29-1.35	0.31-1.16
	18-30	333	350	1.006	0.991	0.0363	0.0304	0.933-1.079	0.930-1.052	0.45-1.62	0.50-1.55
	31-54	512	551	1.201	1.091	0.0309	0.0240	1.139-1.263	1.043-1.139	0.64-1.88	0.62-1.68
	55+	396	454	1.133	1.027	0.0347	0.0273	1.064-1.202	0.972-1.082	0.62-1.72	0.54-1.57

Source: Hopkin and Ellis, 1980.

Table 3-16. Measured Fluid Intakes (mL/day)

Subject	Total Fluids	Milk	Tapwater	Water-Based Drinks[a]
Adults ("normal" conditions)[b]	1000-2400	120-450	45-730	320-1450
Adults (high environmental temperature to 32°C)	2840-3410 3256 ± SD = 900			
Adults (moderately active)	3700			
Children (5-14 yr)	1000-1200 1310-1670	330-500 540-650	ca. 200 540-790	ca. 380

[a] Includes tea, coffee, soft drinks, beer, cider, wine, etc.
[b] "Normal" conditions refer to typical environmental temperature and activity levels.
Source: ICRP, 1981.

Gillies and Paulin (1983) - Variability of Mineral Intakes from Drinking Water - Gillies and Paulin (1983) conducted a study to evaluate variability of mineral intake from drinking water. A study population of 109 adults (75 females; 34 males) ranging in age from 16 to 80 years (mean age = 44 years) in New Zealand was asked to collect duplicate samples of water consumed directly from the tap or used in beverage preparation during a 24-hour period. Participants were asked to collect the samples on a day when all of the water consumed would be from their own home. Individuals were selected based on their willingness to participate and their ability to comprehend the collection procedures. The mean total tapwater intake rate for this population was 1.25 (±0.39) L/day, and the 90th percentile rate was 1.90 L/day. The median total tapwater intake rate (1.26 L/day) was very similar to the mean intake rate (Gillies and Paulin, 1983). The reported range was 0.26 to 2.80 L/day.

The advantage of these data are that they were generated using duplicate sampling techniques. Because this approach is more objective than recall methods, it may result in more accurate response. However, these data are based on a short-term survey that may not be representative of long-term behavior, the population surveyed is small and the procedures for selecting the survey population were not designed to be representative of the New Zealand population, and the results may not be applicable to the United States. For these reasons the study is not regarded as a key study in this document.

Pennington (1983) - Revision of the Total Diet Study Food List and Diets - Based on data from the U.S. Food and Drug Administration's (FDA's) Total Diet Study, Pennington (1983) reported average intake rates for various foods and beverages for five age groups of the population. The Total Diet Study is conducted annually to monitor the nutrient and contaminant content of the U.S. food supply and to evaluate trends in consumption. Representative diets were developed based on 24-hour recall and 2-day diary data from the 1977-1978 U.S. Department of Agriculture (USDA) Nationwide Food Consumption Survey (NFCS) and 24-hour recall data from the Second National Health and Nutrition Examination Survey (NHANES II). The number of participants in NFCS and NHANES II was approximately 30,000 and 20,000, respectively. The diets were developed to "approximate 90 percent or more of the weight of the foods usually consumed" (Pennington, 1983). The source of water (bottled water as distinguished from tapwater) was not stated in the Pennington study. For the purposes of this report, the consumption rates for the food categories defined by Pennington (1983) were used to calculate total fluid and total water intake rates for five age groups. Total water includes water, tea, coffee, soft drinks, and soups and frozen juices that are reconstituted with water. Reconstituted soups were assumed to be composed of 50 percent water, and juices were assumed to contain 75 percent water. Total fluids include total water in addition to milk, ready-to-use infant formula, milk-based soups, carbonated soft drinks, alcoholic beverages, and canned fruit juices. These intake rates are presented in Table 3-17. Based on the average intake rates for total water for the two adult age groups, 1.04 and 1.26 L/day, the average adult intake rate is about 1.15 L/day. These rates should be more representative of the amount of source-specific water consumed than are total fluid intake rates. Because this study was designed to measure food intake, and it used both USDA 1978 data and NHANES II data, there was not necessarily a systematic attempt to define tapwater intake per se, as distinguished from bottled

water. For this reason, it is not considered a key tapwater study in this document.

Table 3-17. Intake Rates of Total Fluids and Total Tapwater by Age Group

Age Group	Average Daily Consumption Rate (L/day) Total Fluids[a]	Total Tapwater[b]
6-11 months	0.80	0.20
2 years	0.99	0.50
14-16 years	1.47	0.72
25-30 years	1.76	1.04
60-65 years	1.63	1.26

[a] Includes milk, "ready-to-use" formula, milk-based soup, carbonated soda, alcoholic beverages, canned juices, water, coffee, tea, reconstituted juices, and reconstituted soups. Does not include reconstituted infant formula.

[b] Includes water, coffee, tea, reconstituted juices, and reconstituted soups.

Source: Derived from Pennington, 1983.

U.S. EPA (1984) - An Estimation of the Daily Average Food Intake by Age and Sex for Use in Assessing the Radionuclide Intake of the General Population - Using data collected by USDA in the 1977-78 NFCS, U.S. EPA (1984) determined daily food and beverage intake levels by age to be used in assessing radionuclide intake through food consumption. Tapwater, water-based drinks, and soups were identified subcategories of the total beverage category. Daily intake rates for tapwater, water-based drinks, soup, and total beverage are presented in Table 3-18. As seen in Table 3-18, mean tapwater intake for different adult age groups (age 20 years and older) ranged from 0.62 to 0.76 L/day, water-based drinks intake ranged from 0.34 to 0.69 L/day, soup intake ranged from 0.03 to 0.06 L/day, and mean total beverage intake levels ranged from 1.48 to 1.73 L/day. Total tapwater intake rates were estimated by combining the average daily intakes of tapwater, water-based drinks, and soups for each age group. For adults (ages 20 years and older), mean total tapwater intake rates range from 1.04 to 1.47 L/day, and for children (ages <1 to 19 years), mean intake rates range from 0.19 to 0.90 L/day. These intake rates do not include reconstituted infant formula. The total tapwater intake rates, derived by combining data on tapwater, water-based drinks, and soup should be more representative of source-specific drinking water intake than the total beverage intake rates reported in this study. These intake rates are based on the same USDA NFCS data used in Ershow and Cantor (1989). Therefore, the data limitations discussed previously also apply to this study.

Cantor et al. (1987) - Bladder Cancer, Drinknig Water Source, and Tapwater Consumption - The National Cancer Institute (NCI), in a population-based, case control study investigating the possible relationship between bladder cancer and drinking water, interviewed approximately 8,000 adult white individuals, 21 to 84 years of age (2,805 cases and 5,258 controls) in their homes, using a standardized questionnaire (Cantor et al., 1987). The cases and controls resided in one of five metropolitan areas (Atlanta, Detroit, New Orleans, San

Table 3-18. Mean and Standard Error for the Daily Intake of Beverages and Tapwater by Age

Age (years)	Tapwater Intake (mL)	Water-Based Drinks (mL)[a]	Soups (mL)	Total Beverage Intake[b] (mL)
All ages	662.5 ± 9.9	457.1 ± 6.7	45.9 ± 1.2	1434.0 ± 13.7
Under 1	170.7 ± 64.5	8.3 ± 43.7	10.1 ± 7.9	307.0 ± 89.2
1 to 4	434.6 ± 31.4	97.9 ± 21.5	43.8 ± 3.9	743.0 ± 43.5
5 to 9	521.0 ± 26.4	116.5 ± 18.0	36.6 ± 3.2	861.0 ± 36.5
10 to 14	620.2 ± 24.7	140.0 ± 16.9	35.4 ± 3.0	1025.0 ± 34.2
15 to 19	664.7 ± 26.0	201.5 ± 17.7	34.8 ± 3.2	1241.0 ± 35.9
20 to 24	656.4 ± 33.9	343.1 ± 23.1	38.9 ± 4.2	1484.0 ± 46.9
25 to 29	619.8 ± 34.6	441.6 ± 23.6	41.3 ± 4.2	1531.0 ± 48.0
30 to 39	636.5 ± 27.2	601.0 ± 18.6	40.6 ± 3.3	1642.0 ± 37.7
40 to 59	735.3 ± 21.1	686.5 ± 14.4	51.6 ± 2.6	1732.0 ± 29.3
60 and over	762.5 ± 23.7	561.1 ± 16.2	59.4 ± 2.9	1547.0 ± 32.8

[a] Includes water-based drinks such as coffee, etc. Reconstituted infant formula does not appear to be included in this group.

[b] Includes tapwater and water-based drinks such as coffee, tea, soups, and other drinks such as soft drinks, fruitades, and alcoholic drinks.

Source: U.S. EPA, 1984.

Francisco, and Seattle) and five States (Connecticut, Iowa, New Jersey, New Mexico, and Utah). The individuals interviewed were asked to recall the level of intake of tapwater and other beverages in a typical week during the winter prior to the interview. Total beverage intake was divided into the following two components: 1) beverages derived from tapwater; and 2) beverages from other sources. Tapwater used in cooking foods and in ice cubes was apparently not considered. Participants also supplied information on the primary source of the water consumed (i.e., private well, community supply, bottled water, etc.). The control population was randomly selected from the general population and frequency matched to the bladder cancer case population in terms of age, sex, and geographic location of residence. The case population consisted of Whites only, had no people under the age of 21 years and 57 percent were over the age of 65 years. The fluid intake rates for the bladder cancer cases were not used because their participation in the study was based on selection factors that could bias the intake estimates for the general population. Based on responses from 5,258 White controls (3,892 males; 1,366 females), average tapwater intake rates for a "typical" week were compiled by sex, age group, and geographic region. These rates are listed in Table 3-19. The average total fluid intake rate was 2.01 L/day for men of which 70 percent (1.4 L/day) was derived from tapwater, and 1.72 L/day for women of which 79 percent (1.35 L/day) was derived from tapwater. Frequency distribution data for the 5,081 controls, for which the authors had information on both tapwater consumption and cigarette smoking habits, are presented in Table 3-20. These data follow a lognormal distribution having an average value of 1.30 L/day and an upper 90th percentile value of approximately 2.40 L/day. These values were determined by graphically interpolating the data of Table 3-20 after plotting it on log probability graph paper. These values represent the usual level of intake for this population of adults in the winter.

A limitation associated with this data set is that the population surveyed was older than the general population and consisted exclusively of Whites. Also, the intake data are based on recall of behavior from the winter previous to the interview. Extrapolation to other seasons and intake durations is difficult.

The authors presented data on person-years of residence with various types of water supply sources (municipal versus private, chlorinated versus nonchlorinated, and surface versus well water). Unfortunately, these data can not be used to draw conclusions about the National average apportionment of surface versus groundwater since a large fraction (24 percent) of municipal water intake in this survey could not be specifically attributed to either ground or surface water.

Table 3-19. Average Total Tapwater Intake Rate by Sex Age, and Geographic Area

Group/Subgroup	Number of Respondents	Average Total Tapwater Intake,[a,b] L/day
Total group	5,258	1.39
Sex		
Males	3,892	1.40
Females	1,366	1.35
Age, years		
21-44	291	1.30
45-64	1,991	1.48
65-84	2,976	1.33
Geographic area		
Atlanta	207	1.39
Connecticut	844	1.37
Detroit	429	1.33
Iowa	743	1.61
New Jersey	1,542	1.27
New Mexico	165	1.49
New Orleans	112	1.61
San Francisco	621	1.36
Seattle	316	1.44
Utah	279	1.35

[a] Standard deviations not reported in Cantor et al. (1987).
[b] Total tapwater defined as all water and beverages derived from tapwater.
Source: Cantor et al., 1987.

Table 3-20. Frequency Distribution of Total Tapwater Intake Rates[a]

Consumption Rate (L/day)	Frequency[b] (%)	Cumulative Frequency[b] (%)
≤0.80	20.6	20.6
0.81-1.12	21.3	41.9
1.13-1.44	20.5	62.4
1.45-1.95	19.5	81.9
≥1.96	18.1	100.0

[a] Represents consumption of tapwater and beverages derived from tapwater in a "typical" winter week.
[b] Extracted from Table 3 in Cantor et al. (1987).

Source: Cantor, et al., 1987.

AIHC (1994) - Exposure Factors Handbook - The Exposure Factors Sourcebook (AIHC, 1994) presented

drinking water intake rate recommendations for adults. Although AIHC (1994) provided little information on the studies used to derive mean and upper percentile recommendations, the references indicate that several of the studies used were the same as ones categorized as relevant studies in this handbook. The mean adult drinking water recommendations in AIHC (1994) and this handbook are in agreement. However, the upper percentile value recommended by AIHC (1994) (2.0 L/day) is slightly lower than that recommended by this handbook (2.4 L/day). Based on data provided by Ershow and Cantor (1989), 2.0 L/day corresponds to only approximately the 84th percentile of the drinking water intake rate distribution. Thus, a slightly higher value is appropriate for representing the upper percentile (i.e., 90 to 95th percentile) of the distribution. AIHC (1994) also presents simulated distributions of drinking water intake based on Roseberry and Burmaster (1992). These distributions are also described in detail in Section 3.2 of this handbook. AIHC (1994) has been classified as a relevant rather than a key study because it is not the primary source for the data used to make recommendations for this document.

USDA (1995) - Food and Nutrient Intakes by Individuals in the United States, 1 Day, 1989-91. - USDA (1995) collected data on the quantity of "plain drinking water" and various other beverages consumed by individuals in 1 day during 1989 through 1991. The data were collected as part of USDA's Continuing Survey of Food Intakes by Individuals (CSFII). The data used to estimate mean per capita intake rates combined one-day dietary recall data from 3 survey years: 1989, 1990, and 1991 during which 15,128 individuals supplied one-day intake data. Individuals from all income levels in the 48 conterminous states and Washington D.C. were included in the sample. A complex three-stage sampling design was employed and the overall response rate for the study was 58 percent. To minimize the biasing effects of the low response rate and adjust for the seasonality, a series of weighting factors was incorporated into the data analysis. The intake rates based on this study are presented in Table 3-21. Table 3-21 includes data for: a) "plain drinking water", which might be assumed to mean tapwater directly

Table 3-21 Mean Per Capita Drinking Water Intake Based on USDA, CSFII Data From 1989-91 (mL/day)

Sex and Age (years)	Plain Drinking Water	Coffee	Tea	Fruit Drinks and Ades[a]	Total
Males and Females:					
Under 1	194	0	<0.5	17	211.5
1-2	333	<0.5	9	85	427.5
3-5	409	2	26	100	537
5 & Under	359	1	17	86	463
Males:					
6-11	537	2	44	114	697
12-19	725	12	95	104	936
20-29	842	168	136	101	1,247
30-39	793	407	136	50	1,386
40-49	745	534	149	53	1,481
50-59	755	551	168	51	1,525
60-69	946	506	115	34	1,601
70-79	824	430	115	45	1,414
80 and over	747	326	165	57	1,295
20 and over	809	408	139	60	1,416
Females:					
6-11	476	1	40	86	603
12-19	604	21	87	87	799
20-29	739	154	120	61	1,074
30-39	732	317	136	59	1,244
40-49	781	412	174	36	1,403
50-59	819	438	137	37	1,431
60-69	829	429	124	36	1,418
70-79	772	324	161	34	1,291
80 and over	856	275	149	28	1,308
20 and over	774	327	141	46	1,288
All individuals	711	260	114	65	1,150

[a] Includes regular and low calorie fruit drinks, punches, and ades, including those made from powdered mix and frozen concentrate. Excludes fruit juices and carbonated drinks.

Source: USDA, 1995.

consumed rather than bottled water; b) coffee and tea, which might be assumed to be constituted from tapwater; and 3) fruit drinks and ades, which might be assumed to be reconstituted from tapwater rather than canned products; and 4) the total of the three sources. With these assumptions, the mean per capita total intake of water is estimated to be 1,416 mL/day for adult males (i.e., 20 years of age and older), 1,288 mL/day for adult females (i.e., 20 years of age and older) and 1,150 mL/day for all ages and both sexes combined. Although these assumptions appear reasonable, a close reading of the definitions used by USDA (1995) reveals that the word "tapwater" does not occur, and this uncertainty prevents the use of this study as a key study of tapwater intake.

The advantages of using these data are that; 1) the survey had a large sample size; 2) the authors attempted to represent the general United States population by oversampling low-income groups and by weighting the data to compensate for low response rates; and 3) it reflects more recent intake data than the key studies. The disadvantages are that: 1) the response rate was low; 2) the word "tapwater" was not defined and the assumptions that must be used in order to compare the data with the other tapwater studies might not be valid; 3) the data collection period reflects only a one-day intake period, and may not reflect long-term drinking water intake patterns; and 4) data on the percentiles of the distribution of intakes were not given.

Tsang and Klepeis (1996) - National Human Activity Pattern Survey (NHAPS) - The U.S. EPA collected information on the number of glasses of drinking water and juice reconstituted with tapwater consumed by the general population as part of the National Human Activity Pattern Survey (Tsang and Klepeis, 1996). NHAPS was conducted between October 1992 and September 1994. Over 9,000 individuals in the 48 contiguous United States provided data on the duration and frequency of selected activities and the time spent in selected microenvironments via 24-hour diaries. Over 4,000 NHAPS respondents also provided information of the number of 8-ounce glasses of water and the number of 8-ounce glasses of juice reconstituted with water than they drank during the 24-hour survey period (Tables 3-22 and 3-23). The median number of glasses of tapwater consumed was 1-2 and the median number of glasses of juice with tapwater consumed was 1-2.

For both individuals who drank tapwater and individuals who drank juices reconstituted with tapwater, the number of glasses ranged from 1 to 20. The highest percentage of the population (37.1 percent) who drank tapwater consumed 3-5 glasses and the highest percentage of the population (51.5 percent) who consumed juice reconstituted with tapwater drank 1-2 glasses. Based on the assumption that each glass contained 8 ounces of water (226.4 mL), the total volume of tapwater and juice with tapwater consumed would range from 0.23 L/day (1 glass) to 4.5 L/day (20 glasses) for respondents who drank tapwater. Using the same assumption, the volume of tapwater consumed for the population who consumed 3-5 glasses would be 0.68 L/day to 1.13 L/day and the volume of juice with tapwater consumed for the population who consumed 1-2 glasses would be 0.23 L/day to 0.46 L/day. Assuming that the average individual consumes 3-5 glasses of tapwater plus 1-2 glasses of juice with tapwater, the range of total tapwater intake for this individual would range from 0.9 L/day to 1.64 L/day. These values are consistent with the average intake rates observed in other studies.

The advantages of NHAPS is that the data were collected for a large number of individuals and that the data are representative of the U.S. population. However, evaluation of drinking water intake rates was not the primary purpose of the study and the data do not reflect the total volume of tapwater consumed. However, using the assumptions described above, the estimated drinking water intake rates from this study are within the same ranges observed for other drinking water studies.

3.4. PREGNANT AND LACTATING WOMEN

Ershow et al. (1991) - Intake of Tapwater and Total Water by Pregnant and Lactating Women - Ershow et al. (1991) used data from the 1977-78 USDA NFCS to estimate total fluid and total tapwater intake among pregnant and lactating women (ages 15-49 years). Data for 188 pregnant women, 77 lactating women, and 6,201 non-pregnant, non-lactating control women were evaluated. The participants were interviewed based on 24 hour recall, and then asked to record a food diary for the next 2 days. "Tapwater" included tapwater consumed directly as a beverage and tapwater used to prepare food and tapwater-based beverages. "Total water" was defined as all water from tapwater and non-tapwater sources, including water contained in food. Estimated total fluid and total tapwater intake rates for the three groups are

Table 3-22. Number of Respondents that Consumed Tapwater at a Specified Daily Frequency

Population Group	Total N	Number of Glasses in a Day						
		None	1-2	3-5	6-9	10-19	20+	DK
Overall	4,663	1,334	1,225	1,253	500	151	31	138
Gender								
Male	2,163	604	582	569	216	87	25	65
Female	2,498	728	643	684	284	64	6	73
Refused	2	2	•	•	•	•	•	•
Age (years)								
1-4	263	114	96	40	7	1	0	5
5-11	348	90	127	86	15	7	2	20
12-17	326	86	109	88	22	7	•	11
18-64	2,972	908	751	769	334	115	26	54
> 64	670	117	127	243	112	20	2	42
Race								
White	3,774	1,048	1,024	1,026	416	123	25	92
Black	463	147	113	129	38	9	1	21
Asian	77	25	18	23	6	1	•	4
Some Others	96	36	18	22	6	7	2	5
Hispanic	193	63	42	40	28	10	2	7
Refused	60	15	10	13	6	1	1	9
Hispanic								
No	4,244	1,202	1,134	1,162	451	129	26	116
Yes	347	116	80	73	41	18	4	13
DK	26	5	6	7	4	3	•	1
Refused	46	11	5	11	4	1	1	8
Employment								
Full-time	2,017	637	525	497	218	72	18	40
Part-time	379	90	94	120	50	13	7	5
Not Employed	1,309	313	275	413	188	49	3	54
Refused	32	6	4	11	1	2	1	4
Education								
< High School	399	89	95	118	51	14	2	28
High School Graduate	1,253	364	315	330	132	52	13	37
< College	895	258	197	275	118	31	5	9
College Graduate	650	195	157	181	82	19	4	6
Post Graduate	445	127	109	113	62	16	3	12
Census Region								
Northeast	1,048	351	262	266	95	32	7	28
Midwest	1,036	243	285	308	127	26	9	33
South	1,601	450	437	408	165	62	11	57
West	978	290	241	271	113	31	4	20
Day of Week								
Weekday	3,156	864	840	862	334	96	27	106
Weekend	1,507	470	385	391	166	55	4	32
Season								
Winter	1,264	398	321	336	128	45	5	26
Spring	1,181	337	282	339	127	33	10	40
Summer	1,275	352	323	344	155	41	9	40
Fall	943	247	299	234	90	32	7	32
Asthma								
No	4,287	1,232	1,137	1,155	459	134	29	115
Yes	341	96	83	91	40	16	1	13
DK	35	6	5	7	1	1	1	10
Angina								
No	4,500	1,308	1,195	1,206	470	143	29	123
Yes	125	18	25	40	27	6	1	6
DK	38	8	5	7	3	2	1	9
Bronchitis/Emphysema								
No	4,424	1,280	1,161	1,189	474	142	29	124
Yes	203	48	55	58	24	9	1	5
DK	36	6	9	6	2	•	1	9

NOTE: "•" = Missing Data
"DK" = Don't know
N = sample size
Refused = respondent refused to answer
Source: Tsang and Kleipeis, 1996

Table 3-23. Number of Respondents that Consumed Juice Reconstituted with Tapwater at a Specified Daily Frequency

Population Group	Total N	Number of Glasses in a Day						
		None	1-2	3-5	6-9	10-19	20+	DK
Overall	4,663	1,877	1,418	933	241	73	21	66
Gender								
Male	2,163	897	590	451	124	35	17	33
Female	2,498	980	826	482	117	38	4	33
Refused	2	•	2	•	•	•	•	•
Age (years)								
1-4	263	126	71	48	11	4	1	2
5-11	348	123	140	58	12	2	1	11
12-17	326	112	118	63	18	7	1	4
18-64	2,972	1,277	817	614	155	46	16	30
> 64	670	206	252	133	43	12	2	14
Race								
White	3,774	1,479	1,168	774	216	57	16	44
Black	463	200	142	83	15	9	1	7
Asian	77	33	27	15	1	•	•	0
Some Others	96	46	19	24	2	1	3	1
Hispanic	193	95	51	30	5	5	1	5
Refused	60	24	11	7	2	1	•	9
Hispanic								
No	4,244	1,681	1,318	863	226	64	17	49
Yes	347	165	87	61	14	7	4	7
DK	26	11	6	5	•	1	•	3
Refused	46	20	7	4	1	1	•	7
Employment								
Full-time	2,017	871	559	412	103	32	9	20
Part-time	379	156	102	88	19	7	2	5
Not Employed	1,309	479	426	265	75	20	7	21
Refused	32	15	4	4	2	1	•	3
Education								
< High School	399	146	131	82	25	7	2	4
High School Graduate	1,253	520	355	254	68	21	7	17
< College	895	367	253	192	47	18	5	11
College Graduate	650	274	201	125	31	7	1	5
Post Graduate	445	182	130	92	26	5	3	4
Census Region								
Northeast	1,048	440	297	220	51	13	4	15
Midwest	1,036	396	337	200	63	17	4	14
South	1,601	593	516	332	84	26	10	28
West	978	448	268	181	43	17	3	9
Day of Week								
Weekday	3,156	1,261	969	616	162	51	11	46
Weekend	1,507	616	449	307	79	22	10	20
Season								
Winter	1,264	529	382	245	66	23	4	10
Spring	1,181	473	382	215	54	19	8	17
Summer	1,275	490	389	263	68	18	6	28
Fall	943	385	265	210	53	13	3	11
Asthma								
No	4,287	1,734	1,313	853	216	69	20	55
Yes	341	130	102	74	25	3	1	5
DK	35	13	3	6	•	1	•	6
Angina								
No	4,500	1,834	1,362	900	231	67	20	59
Yes	125	31	53	25	7	5	1	1
DK	38	12	3	8	3	1	•	6
Bronchitis/Emphysema								
No	4,424	1,782	1,361	882	230	65	21	57
Yes	203	84	53	44	10	6	•	3
DK	36	11	4	7	1	2	•	6

NOTE: "•" = Missing Data
"DK" = Don't know
N = sample size
Refused = Respondent refused to answer
Source: Tsang and Klepeis, 1996

presented in Tables 3-24 and 3-25, respectively. Lactating women had the highest mean total fluid intake rate (2.24 L/day) compared with both pregnant women (2.08 L/day) and control women (1.94 L/day). Lactating women also had a higher mean total tapwater intake rate (1.31 L/day) than pregnant women (1.19 L/day) and control women (1.16 L/day). The tapwater distributions are neither normal nor lognormal, but lactating women had a higher mean tapwater intake than controls and pregnant women. Ershow et al. (1991) also reported that rural women (n=1,885) consumed more total water (1.99 L/day) and tapwater (1.24 L/day) than urban/suburban women (n=4,581, 1.93 and 1.13 L/day, respectively). Total water and tapwater intake rates were lowest in the northeastern region of the United States (1.82 and 1.03 L/day) and highest in the western region of the United States (2.06 L/day and 1.21 L/day). Mean intake per unit body weight was highest among lactating women for both total fluid and total tapwater intake. Total tapwater intake accounted for over 50 percent of mean total fluid in all three groups of women (Table 3-25). Drinking water accounted for the largest single proportion of the total fluid intake for control (30 percent), pregnant (34 percent), and lactating women (30 percent) (Table 3-26). All other beverages combined accounted for approximately 46 percent, 43 percent, and 45 percent of the total water intake for control, pregnant, and lactating women, respectively. Food accounted for the remaining portion of total water intake.

The same advantages and limitations associated with the Ershow and Cantor (1989) data also apply to these data sets (Section 3.2). A further advantage of this study is that it provides information on estimates of total waterand tapwater intake rates for pregnant and lactating women. This topic has rarely been addressed in the literature.

Table 3-24. Total Fluid Intake of Women 15-49 Years Old

Reproductive Status[a]	Mean	Standard Deviation	Percentile Distribution 5	10	25	50	75	90	95
mL/day									
Control	1940	686	995	1172	1467	1835	2305	2831	3186
Pregnant	2076	743	1085	1236	1553	1928	2444	3028	3475
Lactating	2242	658	1185	1434	1833	2164	2658	3169	3353
mL/kg/day									
Control	32.3	12.3	15.8	18.5	23.8	30.5	38.7	48.4	55.4
Pregnant	32.1	11.8	16.4	17.8	17.8	30.5	40.4	48.9	53.5
Lactating	37.0	11.6	19.6	21.8	21.8	35.1	45.0	53.7	59.2

[a] Number of observations: nonpregnant, nonlactating controls (n = 6,201); pregnant (n = 188); lactating (n = 77).
Source: Ershow et al., 1991.

3.5. HIGH ACTIVITY LEVELS/HOT CLIMATES

McNall and Schlegel (1968) - Practical Thermal Environmental Limits for Young Adult Males Working in Hot, Humid Environments - McNall and Schlegel (1968) conducted a study that evaluated the physiological tolerance of adult males working under varying degrees of physical activity. Subjects were required to pedal pedal-driven propeller fans for 8-hour work cycles under varying environmental conditions. The activity pattern for each individual was: cycled at 15 minute pedalling and 15 miute rest for each 8-hour period. Two groups of eight subjects each were used. Work rates were divided into three categories as follows: high activity level [0.15 horsepower (hp) per person], medium activity level (0.1 hp per person), and low activity level (0.05 hp per person). Evidence of physical stress (i.e., increased body temperature, blood pressure, etc.) was recorded, and individuals were eliminated from further testing if certain stress criteria were met. The amount of water consumed by the test subjects during the work cycles was also recorded. Water was provided to the individuals on request. The water intake rates obtained at the three different activity levels and the various environmental temperatures are presented in Table 3-27. The data

Table 3-25. Total Tapwater Intake of Women 15-49 Years Old

Reproductive Status[a]	Mean	Standard Deviation	Percentile Distribution						
			5	10	25	50	75	90	95
mL/day									
Control	1157	635	310	453	709	1065	1503	1983	2310
Pregnant	1189	699	274	419	713	1063	1501	2191	2424
Lactating	1310	591	430	612	855	1330	1693	1945	2191
mL/kg/day									
Control	19.1	10.8	5.2	7.5	11.7	17.3	24.4	33.1	39.1
Pregnant	18.3	10.4	4.9	5.9	10.7	16.4	23.8	34.5	39.6
Lactating	21.4	9.8	7.4	9.8	14.8	20.5	26.8	35.1	37.4
Fraction of daily fluid intake that is tapwater (%)									
Control	57.2	18.0	24.6	32.2	45.9	59.0	70.7	79.0	83.2
Pregnant	54.1	18.2	21.2	27.9	42.9	54.8	67.6	76.6	83.2
Lactating	57.0	15.8	27.4	38.0	49.5	58.1	65.9	76.4	80.5

[a] Number of observations: nonpregnant, nonlactating controls (n = 6,201); pregnant (n = 188); lactating (n = 77).
Source: Ershow et al., 1991.

Table 3-26. Total Fluid (mL/Day) Derived from Various Dietary Sources by Women Aged 15-49 Years[a]

Sources	Control Women			Pregnant Women			Lactating Women		
	Mean[b]	Percentile		Mean[b]	Percentile		Mean[b]	Percentile	
		50	95		50	95		50	95
Drinking Water	583	480	1440	695	640	1760	677	560	1600
Milk and Milk Drinks	162	107	523	308	273	749	306	285	820
Other Dairy Products	23	8	93	24	9	93	36	27	113
Meats, Poultry, Fish, Eggs	126	114	263	121	104	252	133	117	256
Legumes, Nuts, and Seeds	13	0	77	18	0	88	15	0	72
Grains and Grain Products	90	65	257	98	69	246	119	82	387
Citrus and Noncitrus Fruit Juices	57	0	234	69	0	280	64	0	219
Fruits, Potatoes, Vegetables, Tomatoes	198	171	459	212	185	486	245	197	582
Fats, Oils, Dressings, Sugars, Sweets	9	3	41	9	3	40	10	6	50
Tea	148	0	630	132	0	617	253	77	848
Coffee and Coffee Substitutes	291	159	1045	197	0	955	205	80	955
Carbonated Soft Drinks[c]	174	110	590	130	73	464	117	57	440
Noncarbonated Soft Drinks[c]	38	0	222	48	0	257	38	0	222
Beer	17	0	110	7	0	0	17	0	147
Wine Spirits, Liqueurs, Mixed Drinks	10	0	66	5	0	25	6	0	59
All Sources	1940	NA	NA	2076	NA	NA	2242	NA	NA

[a] Number of observations: nonpregnant, nonlactating controls (n = 6,201); pregnant (n = 188); lactating (n = 77).
[b] Individual means may not add to all-sources total due to rounding.
[c] Includes regular, low-calorie, and noncalorie soft drinks.
NA: Not appropriate to sum the columns for the 50th and 95th percentiles of intake.
Source: Ershow et al., 1991.

Table 3-27. Water Intake at Various Activity Levels (L/hr)[a]

Room Temperature[b] (°F)	Activity Level					
	High (0.15 hp/man)[c]		Medium (0.10 hp/man)[c]		Low (0.05 hp/man)[c]	
	No.[d]	Intake	No.	Intake	No.	Intake
100	--	--	--	--	15	0.653 (0.75)
95	18	0.540 (0.31)	12	0.345 (0.59)	6	0.50 (0.31)
90	7	0.286 (0.26)	7	0.385 (0.26)	16	0.23 (0.20)
85	7	0.218 (0.36)	16	0.213 (0.20)	--	--
80	16	0.222 (0.14)	--	--	--	--

[a] Data expressed as mean intake with standard deviation in parentheses.
[b] Humidity = 80 percent; air velocity = 60 ft/min.
[c] The symbol "hp" refers to horsepower.
[d] Number of subjects with continuous data.
Source: McNall and Schlegel, 1968.

presented are for test subjects with continuous data only (i.e., those test subjects who were not eliminated at any stage of the study as a result of stress conditions). Water intake was the highest at all activity levels when environmental temperatures were increased. The highest intake rate was observed at the low activity level at 100°F (0.65 L/hour) however, there were no data for higher activity levels at 100°F. It should be noted that this study estimated intake on an hourly basis during various levels of physical activity. These hourly intake rates cannot be converted to daily intake rates by multiplying by 24 hours/day because they are only representative of intake during the specified activity levels and the intake rates for the rest of the day are not known. Therefore, comparison of intake rate values from this study cannot be made with values from the previously described studies on drinking water intake.

United States Army (1983) - Water Consumption Planning Factors Study - 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). Both climate and activity levels were used to determine the appropriate water consumption needs. Consumption factors have been established for the following uses: 1) drinking, 2) heat treatment, 3) personal hygiene, 4) centralized hygiene, 5) food preparation, 6) laundry, 7) medical treatment, 8) vehicle and aircraft maintenance, 9) graves registration, and 10) construction. Only personal drinking water consumption factors are described here.

Drinking water consumption planning factors are based on the estimated amount of water needed to replace fluids lost by urination, perspiration, and respiration. It assumes that water lost to urinary output averages one quart/day (0.9 L/day) and perspiration losses range from almost nothing in a controlled environment to 1.5 quarts/day (1.4 L/day) in a very hot climate where individuals are performing strenuous work. Water losses to respiration are typically very low except in extreme cold where water losses can range from 1 to 3 quarts/day (0.9 to 2.8 L/day). This occurs when the humidity of inhaled air is near zero, but expired air is 98 percent saturated at body temperature (U.S. Army, 1983). Drinking water is defined by the U.S. Army (1983)

as "all fluids consumed by individuals to satisfy body needs for internal water." This includes soups, hot and cold drinks, and tapwater. Planning factors have been established for hot, temperate, and cold climates based on the following mixture of activities among the work force: 15 percent of the force performing light work, 65 percent of the force performing medium work, and 20 percent of the force performing heavy work. Hot climates are defined as tropical and arid areas where the temperature is greater than 80°F. Temperate climates are defined as areas where the mean daily temperature ranges from 32°F to 80°F. Cold regions are areas where the mean daily temperature is less than 32°F. Drinking water consumption factors for these three climates are presented in Table 3-28. These factors are based on research on individuals and small unit training exercises. The estimates are assumed to be conservative because they are rounded up to account for the subjective nature of the activity mix and minor water losses that are not considered (U.S. Army, 1983). The advantage of using these data is that they provide a conservative estimate of drinking water intake among individuals performing at various levels of physical activity in hot, temperate, and cold climates. However, the planning factors described here are based on assumptions about water loss from urination, perspiration, and respiration, and are not based on survey data or actual measurements.

3.6. RECOMMENDATIONS

The key studies described in this section were used in selecting recommended drinking water (tapwater) consumption rates for adults and children. The studies on other subpopulations were not classified as key versus relevant. Although different survey designs and populations were utilized by key and relevant studies described in this report, the mean and upper-percentile estimates reported in these studies are reasonably similar. The general design of both key and relevant studies and their limitations are summarized in Table 3-29. It should be noted that studies that surveyed large representative samples of the population provide more reliable estimates of intake rates for the general population. Most of the surveys described here are based on short-term recall which may be biased toward excess intake rates. However, Cantor et al. (1987) noted that retrospective dietary assessments generally produce moderate correlations with "reference data from the past." A summary of the recommended values for drinking water intake rates is presented in Table 3-30.

Adults - The total tapwater consumption rates for adults (older than 18 or 20 years) that have been reported in the key surveys can be summarized in Table 3-31. For comparison, values for daily tapwater intake for the relevant studies are shown in Table 3-32.

Note that both Ershow and Cantor (1989) and Pennington (1983) found that adults above 60 years of age had larger intakes than younger adults. This is difficult to reconcile with the Cantor et al. (1987) study because the latter, older population had a smaller average intake. Because of these results, combined with the fact that the Cantor et al. (1987) study was not intended to be representative of the U. S. population, it is not included here in the determination of the recommended value. The

Table 3-28. Planning Factors for Individual Tapwater Consumption

Environmental Condition	Recommended Planning Factor (gal/day)[a]	Recommended Planning Factor (L/day)[a,b]
Hot	3.0[c]	11.4
Temperate	1.5[d]	5.7
Cold	2.0[e]	7.6

[a] Based on a mix of activities among the work force as follows: 15% light work; 65% medium work; 20% heavy work. These factors apply to the conventional battlefield where no nuclear, biological, or chemical weapons are used.

[b] Converted from gal/day to L/day.

[c] This assumes 1 quart/12-hour rest period/man for perspiration losses and 1 quart/day/man for urination plus 6 quarts/12-hours light work/man, 9 quarts/12-hours moderate work/man, and 12 quarts/12-hours heavy work/man.

[d] This assumes 1 quart/12-hour rest period/man for perspiration losses and 1 quart/day/man for urination plus 1 quart/12-hours light work/man, 3 quarts/12-hours moderate work/man, and 6 quarts/12-hours heavy work/man.

[e] This assumes 1 quart/12-hour rest period/man for perspiration losses, 1 quart/day/man for urination, and 2 quarts/day/man for respiration losses plus 1 quart/12-hours light work/man, 3 quarts/12-hours moderate work/man, and 6 quarts/6-hours heavy work/man.

Source: U.S. Army, 1983.

Table 3-29. Drinking Water Intake Surveys

Study	Number of Individuals	Type of Water Consumed	Time Period/ Survey Type	Population Surveyed	Comments
<u>KEY</u>					
Canadian Ministry of National Health and Welfare, 1981	970	Total tapwater consumption	Weekday and weekend day in both summer and winter; estimation based on sizes and types of containers used	All ages; Canada	Seasonal data; includes many tapwater-containing items not commonly surveyed; possible bias because identification of vessel size used as survey techniques; short-term study
Ershow and Cantor, 1989	Based on data from NFCS; approximately 30,000 individuals	Total tapwater; total fluid consumption	3-day recall, diaries	All ages; large sample representative of U.S. population	Short-term recall data; seasonally balanced data
Rosenberry and Burmaster, 1992	Based on data from Ershow and Cantor, 1989	Total tapwater; total fluid consumption	3-day recall, diaries	All ages; large sample representative of US population	Short-term recall data; seasonally balanced; suitable for Monte Carlo simulations
<u>RELEVANT</u>					
Cantor et al., 1987	5,258	Total tapwater; total fluid consumption	1 week/usual intake in winter based on recall	Adults only; weighted toward older adults; U.S. population	Based on recall of behavior from previous winter; short-term data; population not representative of general U.S. population
Gillies and Paulin, 1983	109	Total tapwater consumption	24 hours; duplicate water samples collected	Adults only; New Zealand	Based on short-term data
Hopkin and Ellis, 1980	3,564	Total tapwater, total liquid consumption	1 week period, diaries	All ages; Great Britain	Short-term diary data
ICRP, 1981	Based on data from several sources	Water and water-based drinks; milk; total fluids	NA[a]	NA[a]	Survey design and intake categories not clearly defined
NAS, 1977	Calculated average based on several sources	Average per capita "liquid" consumption	NA[a]	NA[a]	Total tapwater not reported; population and survey design not reported

Table 3-29. Drinking Water Intake Surveys (continued)

Study	Number of Individuals	Type of Water Consumed	Time Period/ Survey Type	Population Surveyed	Comments
Pennington, 1983	Based on NFCS and NHANES II; approximately 30,000 and 20,000 participants, respectively	Total tapwater; total fluid consumption	NFCS:24-hour recall on 2-day dairy; NHANES II:24-hour recall	NFCS:1 month to 97 years; NHANES II:6 months to 74 years; representative samples of U.S. population	Based on short-term recall data
USDA, 1995	Based on 89-91 CSF11; approximately 15,000 individuals	Plain drinking water, coffee, tea, fruit drinks and ades	1-day recall	All ages, large sample representative of U.S. population	Short-term recall data; seasonally adjusted
U.S. EPA, 1984	Based on NFCS; approximately 30,000 individuals	Tapwater; water based foods and beverages; soups; beverage consumption	3-day recall, diaries	All ages; large sample representative of U.S. population	Short-term recall data; seasonally balanced
U.S. EPA, 1995	Over 4,000 participants of NHAPS	Number of glasses of drinking water and juice with tapwater	24-hour diaries	All ages, large representative sample of U.S. population	Does not provide data on the volume of tapwater consumed
McNall and Schlegel, 1968	Based on 2 groups of 8 subjects each	Tapwater	8-hour work cycle	Males between 17-25 years of age; small sample; high activity levels/hot climates	Based on short-term data
U.S. Army, 1983	NA	All fluids consumed to satisfy body needs for internal water; includes soups, hot and cold drinks and tapwater	NA	High activity levels/hot climates	Study designed to provide water consumption planning factors for various activities and field conditions; based on estimated amount of water required to account for losses from urination, perspiration, and respiration

[a] Not applicable.

Table 3-30. Summary of Recommended Drinking Water Intake Rates

Age Group/ Population	Mean	Percentiles 50th	Percentiles 90th	Percentiles 95th	Multiple	Fitted Distributions
<1 year[a]	0.30 L/day 44 mL/kg-day	0.24 L/day 35 mL/kg-day	0.65 L/day 102 mL/kg-day	0.76 L/day 127 mL/kg-day	Tables 3-6, 3-7, and 3-8	Table 3-11[b]
<3 years[c]	0.61 L/day	--	1.5 L/day	--	Table3-3	
3-5 years[c]	0.87 L/day	--	1.5 L/day	--	Table3-3	
1-10 years[a]	0.74 L/day 35 mL/kg-day	0.66 L/day 31 mL/kg-day	1.3 L/day 64 mL/kg-day	1.5 L/day 79.4 mL/kg-day	Tables 3-6, 3-7, and 3-8	Table 3-11[b]
11-19 years[a]	0.97 L/day 18 mL/kg-day	0.87 L/day 16 mL/kg-day	1.7 L/day 32 mL/kg-day	2.0 L/day 40 mL/kg-day	Tables 3-6, 3-7, and 3-8	Table 3-11[b]
Adults[a]	1.4 L/day 21 mL/kg-day	1.3 L/day 19 mL/kg-day	2.3 L/day 34 mL/kg-day		Tables 3-6, 3-7, and 3-8	Table 3-11[b]
Pregnant Women[d]	1.2 L/day 18.3 mL/kg-day	1.1 L/day 16 mL/kg-day	2.2 L/day 35 mL/kg-day	2.4 L/day 40 mL/kg-day	Table 3-25	
Lactating Women[d]	1.3 L/day 21.4 mL/kg-day	1.3 L/day 21 mL/kg-day	1.9 L/day 35 mL/kg-day	2.2 L/day 37 mL/kg-day	Table 3-25	
Adults in High Activity/Hot Climate Conditions[e]	0.21 to 0.65 L/hour, depending on ambient temperature and activity level; see Table 3-27.					
Active Adults[f]	6 L/day (temperate climate) to 11 L/day (hot climate); see Table 3-28.					

a Source: Ershow and Cantor, 1989
b Source: Roseberry and Burmaster, 1992
c Source: Canadian Ministry of Health and Welfare, 1981
d Ershow et al. (1991) presented data for pregnant women, lactating women, and control women.
e Source: McNall and Schlegal, 1968
f Source: U.S. Army, 1983

Table 3-31. Total Tapwater Consumption Rates From Key Studies

Mean (L/day)	90th Percentile (L/day)	Number in Survey	Reference
1.38	2.41	639	Canadian Ministry of Health and Welfare, 1981
1.41	2.28	11,731	Ershow and Cantor, 1989

Table 3-32. Daily Tapwater Intake Rates From Relevant Studies

Mean (L/day)	90th Percentile	Reference
1.30[a]	2.40	Cantor et al., 1987
1.63 (calculated)	--	NAS, 1977
1.25	1.90	Gillies and Paulin, 1983
1.04 (25 to 30 yrs)	--	Pennington, 1983
1.26 (60 to 65 yrs)	--	Pennington, 1983
1.04-1.47 (ages 20+)	--	U.S. EPA, 1984
1.37 (20 to 64 yrs)	2.27	Ershow and Cantor, 1989
1.46 (65+ yrs)	2.29	Ershow and Cantor, 1989
1.15	--	USDA, 1995
1.07	1.87	Hopkins and Ellis, 1980

[a] Age of the Cantor et al. (1987) population was higher than the U.S. average.

USDA (1995) data are not included because tapwater was not defined in the survey and because the response rate was low, although the results (showing lower intakes than the studies based on older data) may be accurately reflecting an expected lower use of tapwater (compared to 1978) because of increasing use of bottled water and soft drinks in recent years.

A value of 1.41 L/day, which is the population-weighted mean of the two national studies (Ershow and Cantor, 1989 and Canadian Ministry of Health and Welfare, 1981) is the recommended average tapwater intake rate.

The average of the 90th percentile values from the same two studies (2.35 L/day) is recommended as the appropriate upper limit. (The commonly-used 2.0 L/day intake rate corresponds to the 84th percentile of the intake rate distribution among the adults in the Ershow and Cantor (1989) study). In keeping with the desire to incorporate body weight into exposure assessments without introducing extraneous errors, the values from the

Ershow and Cantor (1989) study (Tables 3-7 and 3-8) expressed as mL/kg-day are recommended in preference to the liters/day units. For adults, the mean and 90th percentile values are 21 mL/kg-day and 34.2 mL/kg/day, respectively.

In the absence of actual data on chronic intake, the values in the previous paragraph are recommended as chronic values, although the chronic 90th upper percentile may very well be larger than 2.35 L/day. If a mathematical description of the intake distribution is needed, the parameters of lognormal fit to the Ershow and Cantor (1989) data (Tables 3-11 and 3-12) generated by Roseberry and Burmaster (1992) may be used. The simulated balanced population distribution of intakes generated by Roseberry and Burmaster is not recommended for use in the post-1997 time frame, since it corrects the 1978 data only for the differences in the age structure of the U. S. population between 1978 and 1988. These recommended values are different than the 2 liters/day commonly assumed in EPA risk assessments. Assessors are encouraged to use values which most accurately reflect the exposed population. When using values other than 2 liters/day, however, the assessors should consider if the dose estimate will be used to estimate risk by combining with a dose-response relationship which was derived assuming a tap water intake of 2 liters/day. If such an inconsistency exists, the assessor should adjust the dose-response relationship as described in Appendix 1 of Chapter 1. IRIS does not use a tap water intake assumption in the derivation of RfCs and RfDs, but does make the 2 liter/day assumption in the derivation of cancer slope factors and unit risks.

Children - The tapwater intake rates for children reported in the key studies are summarized in Table 3-33.

The intake rates, as expressed as liters per day, generally increase with age, and the data are consistent across ages for the two key studies except for the Canadian Ministry of Health and Welfare (1981) data for ages 6 to 17 years; it is recommended that any of the liters/day values that match the age range of interest except the Canada data for ages 6 to 17 years be used. The mL/kg-day intake values show a consistent downward trend with increasing ages; using the Ershow and Cantor (1989) data in preference to the Canadian Ministry of National Health and Welfare (1981) data is recommended where the age ranges overlap.

The intakes for children as reported in the relevant studies are shown in Table 3-34.

Table 3-33. Key Study Tapwater Intake Rates for Children

Age (years)	Mean (L/day)	90th Percentile (L/day)	Reference
<1	0.30	0.65	Ershow and Cantor, 1989
<3	0.61	1.50	Canadian Ministry of National Health and Welfare, 1981
3-5	0.87	1.50	Canadian Ministry of National Health and Welfare, 1981
1-10	0.74	1.29	Ershow and Cantor, 1989
6-17	1.14	2.21	Canadian Ministry of National Health and Welfare, 1981
11-19	0.97	1.70	Ershow and Cantor, 1989

Table 3-34. Summary of Intake Rates for Children in Relevant Studies

Age	Mean (L/day)	Reference
6-11 months	0.20	Pennington, 1983
<1 yr	0.19	U.S. EPA, 1984
<1 yr	0.32	Roseberry and Burmaster, 1992
2 yrs	0.50	Pennington, 1983
1-4 yrs	0.58	U.S. EPA, 1984
5-9 yrs	0.67	U.S. EPA, 1984
1-10 yrs	0.70	Roseberry and Burmaster, 1992
10-14 yrs	0.80	U.S. EPA, 1984
14-16 yrs	0.72	Pennington, 1983
15-19 yrs	0.90	U.S. EPA, 1984
11-19 yrs	0.91	Roseberry and Burmaster, 1992

Disregarding the Roseberry and Burmaster study, which is a recalculation of the Ershow and Cantor (1989) study, the non-key studies generally have lower mean intake values than the Ershow and Cantor (1899) study. The reason is not known, but the results are not persuasive enough to discount the recommendations based on the latter study. Intake rates for specific percentiles of the distribution may be selected using the lognormal distribution data generated by Roseberry and Burmaster (1992) (Tables 3-11 and 3-12).

Pregnant and Lactating Women -The data on tapwater intakes for control, pregnant, and lactating

women are presented in Table 3-25. The recommended intake values are presented in Table 3-30.

High Activity/Hot Climates - Data on intake rates for individuals performing strenuous activities under various environmental conditions are limited. None of these is classed as a key study because the populations in these studies are not representative of the general U.S. population. However, the data presented by McNall and Schlegel (1968) and U.S. Army (1983) provide bounding intake values for these individuals. According to McNall and Schlegel (1968), hourly intake can range from 0.21 to 0.65 L/hour depending on the temperature and activity level. Intake among physically active individuals can range from 6 L/day in temperate climates to 11 L/day in hot climates (U.S. Army, 1983).

A characterization of the overall confidence in the accuracy and appropriateness of the recommendations for drinking water is presented in Table 3-35. Although the study of Ershow and Cantor (1989) is of high quality and consistent with the other surveys, the low currency of the information (1978 data collection), in the presence of anecdotal information (not presented here) that the consumption of bottled water and beverages has increased since 1980 was the main reason for lowering the confidence score of the overall recommendations from high to medium.

Table 3-35. Confidence in Tapwater Intake Recommendations

Considerations	Rationale	Rating
Study Elements		
• Level of peer review	The study of Ershow and Cantor (1989) had a thorough expert panel review. Review procedures were not reported in the Canadian study; it was a government report. Other reports presented are published in scientific journals.	High
• Accessibility	The two monographs are available from the sponsoring agencies; the others are library-accessible.	High
• Reproducibility	Methods are well-described.	High
• Focus on factor of interest	The studies are directly relevant to tapwater.	High
• Data pertinent to U.S.	See "representativeness" below.	NA
• Primary data	The two monographs used recent primary data (less than one week) on recall of intake.	High
• Currency	Data were all collected in the 1978 era. Tapwater use may have changed since that time period.	Low
• Adequacy of data collection period	These are one- to three-day intake data. However, long term variability may be small. Their use as a chronic intake measure can be assumed.	Medium
• Validity of approach	The approach was competently executed.	High
• Study size	This study was the largest monograph that had data for 11,000 individuals.	High
• Representativeness of the population	The Ershow and Cantor (1989) and Canadian surveys were validated as demographically representative.	High
• Characterization of variability	The full distributions were given in the main studies.	High
• Lack of bias in study design (high rating is desirable)	Bias was not apparent.	High
• Measurement error	No physical measurements were taken. The method relied on recent recall of standardized volumes of drinking water containers, and was not validated.	Medium
Other Elements		
• Number of studies	There were two key studies for the adult and child recommendations. There were six other studies for adults, one study for pregnant and lactating women, and two studies for high activity/hot climates.	High for adult and children. Low for the other recommended subpopulation values.
• Agreement between researchers	This agreement was good.	High
Overall Rating	The data are excellent, but are not current.	Medium

3.7. REFERENCES FOR CHAPTER 3

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