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Estimated Per Capita Water Ingestion in the United States

Based on Data Collected by the United States Department of Agriculture's 1994–96 Continuing Survey of Food Intakes by Individuals

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PREFACE

This report presents current estimates of per capita water ingestion. The basis for these estimates is dietary and demographic data collected during a 1994 through 1996 survey conducted by the United States Department of Agriculture (USDA). In this survey, known as the Continuing Survey of Food Intakes by Individuals (CSFII), two non–consecutive days of food ingestion data were collected from a sample of more than 15,000 individuals in the 50 United States and the District of Columbia. Respondent information, in conjunction with food code, recipe, and nutrient data from USDA, forms the means of estimating per capita ingestion of plain drinking water (direct water) and water ingested indirectly. Water used in the final preparation of foods and beverages at home, or by food service establishments such as school cafeterias and restaurants is defined as indirect water. Quantities of ingested water reported in the USDA 1994 through 1996 CSFII are averaged by participant to generate a two–day average. These daily average ingestion amounts comprise the empirical distributions from which mean and upper percentile per capita ingestion estimates are produced.

The CSFII survey, and consequently estimates reported in this document, extend to the population of the United States. We augment population per capita ingestion estimates with estimates of per capita ingestion by various population subsets. These population subsets include (1) gender and age categories and (2) pregnant, lactating, and childbearing–age women. Subpopulation ingestion estimates support assessments of "at risk" populations.

EPA generated the estimates in this report in response to legislative mandates in Safe Drinking Water Act Amendments of 1996. These mandates require up–to–date information on water ingestion to identify subpopulations at elevated risk of health effects from exposure to contaminants in drinking water. These up–to–date estimates also support characterization of health risks to sensitive populations from contaminants in drinking water. The estimates in this document characterize the empirical distributions of two–day average per capita ingestion of water for specific subpopulations. Subpopulation estimates apply to demographic categories but do not distinguish individuals with a history of serious illness or with lifestyles that effect water consumption.

Water ingestion rates for the overall population and for subpopulations have several important applications within the United States Environmental Protection Agency (USEPA). Information on water intake is used in risk assessment and regulations which involve default values for water ingestion and in the estimation of risks to highly exposed and/or sensitive populations.

It is important to emphasize that risk is a function of both exposure and sensitivity. Sensitivity is determined by genetics, developmental stage (old as well as young), lifestyle, and preexisting disease

conditions. With the exception of age, these other determinants of sensitivity are not addressed in this report.

Water ingestion estimates in this document support the evaluation and possible revision of the standard water ingestion quantities of two liters for a 70–kilogram average adult and one liter for a 10–kilogram child. These standard quantities are used by many federal agencies including the EPA and the World Health Organization (WHO). The two liter standard is supported by a 1989 National Cancer Institute report on tap water consumption (Ershow and Cantor, 1989). Estimates of water ingested in this report differ from the estimates reported by Ershow and Cantor for several reasons. Ershow and Cantor's estimates are based on data from the 1977–78 USDA National Food Consumption Survey while the estimates reported here are based on 1994–96 data. Also, the 1989 report presents estimates of tap water ingestion. Ershow and Cantor define tap water as "water from the household tap." In this report, water coming from the tap is distinguished by source. Sources of water coming from the tap may include: community water, household well or cistern, a household or public spring, and other. Thus, estimates in this report are expected to differ from those reported in 1989 because the estimates in this report incorporate more recent ingestion data and thus reflect changes in ingestion behavior. Also, estimates will differ between the 1989 report and this report because the sources of water ingested are more definitive in this report. A third way that the estimates in this report differ from those in the 1989 report is that the 1994–96 data include water ingestion by pregnant and lactating women. These women were excluded from the 1989 report. To further address changes in water ingestion patterns, this report provides separate estimates for community water, bottled water, and water from other sources.

This report consists of the following chapters:

- **Executive Summary,** summarizes the most pertinent information contained in this report, including the main features of the CSFII data collection and results from the analysis.

- **Chapter 1, Definitions,** identifies water–related terms used in the report. Definitions distinguish indirect water from direct water and identify water sources.

- **Chapter 2, Sources of Data,** describes the surveys; summarizes the method of data collection; and identifies the respondent data files and concomitant information files used to establish the estimates. Appendix D provides the details of the sample design.

- **Chapter 3, Methods,** presents the means of determining source and amount of direct water ingested by survey respondents. Conventions for identifying and determining the amount of water ingested indirectly through food preparations are also presented. Data convention descriptions are followed by a summary of the statistical methods used for generating mean and empirical percentile

estimates and the size of the subpopulation to which the estimates are applicable. Appendix D records statistical estimation formulae.

- **Chapter 4, Results,** provides an overview of key results. These results are augmented with graphical presentations and numerous tables of the empirical distribution of estimated average daily per capita ingestion of water.

- **Chapter 5, Discussion,** discusses the advantages and disadvantages of the CSFII for estimating per capita water ingestion in the United States. Sources of error, bias, and uncertainty are defined, and the report's conclusions are presented.

Material included in the appendices augment the data convention descriptions and methods described in Chapters 2 and 3. Appendix E presents tabulated estimates of per capita water ingestion by water source and subpopulation for all respondents and for "consumers only."

- **Appendix A, CSFII Survey Questions Pertaining to Water Ingestion,** lists the household level questions that are used to determine water source, sample person questions that identify the number of fluid ounces and source of directly ingested water, and food item questions for determining foods with water added at home or by a food service facility.

- **Appendix B, Examples of Procedures Used in the Estimation of Indirect Water Ingestion**, provides three sets of examples. For food codes that were prepared at home or by food service establishments, Appendix B1 identifies how the proportion of indirect water in 100 grams of each food was estimated and provides examples. Appendix B2 provides examples, supplied by USDA, of how to estimate preparation water absorbed in foods such as cooked pasta, rice, cereal grains, beans, and legumes. USDA guidance and examples for calculating the percent and amount of moisture in 100 grams of food follow in Appendix B3.

- **Appendix C, 1994–96 CSFII Food Codes,** lists CSFII Food Codes at the three–digit level and the assignments of percentage of indirect water and commercial water in C1 and C2, respectively. Commercially added waters are not included in the ingestion estimates presented in this report. Appendix C3 lists food codes and their corresponding proportions of water in 100 grams of food.

- **Appendix D, Statistical Methods and Sample Design,** provides the statistical formulae for generating point and interval estimates about the mean and upper percentiles of the distribution of two–day average per capita water ingestion. This appendix also provides the details of the sample design.

- **Appendix E, Per Capita Water Ingestion Estimates,** includes tabulated presentations of per capita water ingestion estimates. All estimates are from empirical distributions of two–day average amounts of water ingested. This appendix presents tables for the entire population and for individuals in specific subpopulations in four parts. Parts I and II record estimates of direct, indirect, and both direct and indirect water ingestion for all individuals. Parts III and IV contain water ingestion estimates for "consumers only." These estimates only include individuals who reported ingestion of the water under consideration. Therefore, these estimates do not include individuals who reported zero amounts of water ingested from the water source under consideration. Biological and commercially added waters are not included in the amounts of indirect water ingested.

  Five sets of estimates comprise each part of this appendix. The five sets differ by the source of water ingested. These sources are community water, bottled water, water from other sources, missing source, and all sources. Each part contains three tables of estimates for each water source. These tables report water ingestion estimates by gender and broad age category; fine age category; and pregnant, lactating, and childbearing–age women. For each water source, ingestion estimates contained in Parts I and Parts III are reported in units of milliliters/person/day. Units for Parts II and IV are in milliliters/kilogram of body weight/day.

- **Appendix F, Final SAB Report and EPA Response**, includes the results of a review of the July 1999 version of this report by the Drinking Water Intake Subcommittee (DWIS), a special subcommittee of the EPA SAB. The EPA's response to this report is also included.

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EXECUTIVE SUMMARY

The objective of the report is to provide current estimates of water ingestion for the population of the United States and selected subpopulations. The subpopulations include gender and age categories, pregnant women, lactating women and women of childbearing age. These ingestion estimates may be used in estimating risk to human health from the ingestion of contaminated waters. Knowledge of water ingestion is of fundamental importance to the mission of the Office of Water, and credible national estimates are of great utility to many EPA programs. In particular, the estimates support the development of risk assessments based on the ingestion of water that may be contaminated. The Safe Drinking Water Act Amendments of 1996 require EPA to identify subpopulations at elevated risk of health effects from exposure to contaminants in drinking water and to conduct studies characterizing health risk to sensitive populations from contaminants in drinking water. The process of establishing human risk requires up–to–date information on water ingestion and this report responds to that need.

The reported estimates were calculated using data from the combined 1994, 1995, and 1996 Continuing Survey of Food Intakes by Individuals (CSFII), conducted by the United States Department of Agriculture (USDA). The CSFII is a complex, multistage area probability sample of the entire United States and is conducted to survey the food and beverage intake of the United States. The CSFII collected two non–consecutive days of food ingestion data from a sample of more than 15,000 individuals. The two days of dietary intake, in conjunction with food code, recipe, and nutrient data from the USDA, were used to identify the direct (plain drinking water) and indirect water consumed by each respondent. Indirect water is defined as water used in the final preparation of foods and beverages at home, or by food service establishments such as school cafeterias and restaurants. Quantities of ingested water reported were averaged by participant to generate a two–day average. These daily average ingestion amounts comprise the empirical distributions from which mean and percentile per capita ingestion estimates are produced.

This report provides ingestion estimates of direct water, indirect water and both direct and indirect water combined .[1] Also provided are water ingestion amounts by water source. Sources include community water, bottled water, other sources, and all sources combined (total water)[2]. Other sources include water from private household wells and rain cisterns, and household and public springs.

[1]For the purpose of this report, indirect water does not include water found naturally in foods (biological water) and water added by commercial food and beverage manufacturers (commercial water).

[2]References in this report to the ingestion of community water, bottled water, and other water refer to the ingestion of the combined amount of direct and indirect community, bottled, or other water, respectively.

Additionally, the report provides estimates of water consumption for "all individuals" and for "consumers only". The estimates for all individuals are based on all survey respondents in the population (or subpopulation) under consideration including those who reported no consumption of the water from the source under consideration during the two survey days. The "consumers only" estimates are based on only those respondents in the population (or subpopulation) of interest who reported ingestion of the water from the source under consideration during the two survey days and excludes the "zero" consumers. All estimates are provided in units of milliliters/person/day (ml/person/day) and milliliters/kilogram of body weight/day (ml/kg/day).

The estimated mean two–day average per capita ingestion of community water is 927 ml/person/day. This mean ingestion estimate applies to all individuals in the United States population. A 90% confidence interval about this mean ingestion ranges from 902 to 951 ml/person/day (See Table 4–1–B1). These estimates of community water are based on a sample of 15,303 individuals in the 50 United States and the District of Columbia. The sample was selected to represent the entire population of the United States based on 1990 census data.

The estimated 90th percentile of the empirical distribution of two–day average per capita ingestion of community water is 2.016 liters/person/day. The 90% bootstrap interval about the 90th percentile estimate ranges from 1.991 to 2.047 liters/person/day. Therefore, current ingestion data indicate that 90 percent of the United States population ingests an amount of community water which is approximately less than or equal to the two liters/person/day estimate used as a standard ingestion value by many federal agencies (See Table 4–1–B1).

Women aged 15 to 44 years, the childbearing years, ingest a mean of 922 ml of community water per day (90% confidence interval is 887 to 957 ml). This mean ingestion is similar to the mean daily per capita ingestion of community water for the United States population. Lactating women have the highest community water ingestion of any subpopulation identified in the sample. Lactating women reported a mean two–day average ingestion of 1.379 liters (90% confidence interval is 1.021 to 1.737 ml/person/day). The 90th and 95th percentile estimates of ingestion of community water for lactating women are 2.872 and 3.434 liters/day, respectively (See Table 4–1–E).

The estimates of community water ingestion based on "consumers only" are higher than those based on all individuals because respondents reporting zero community water ingestion during the two survey days are excluded from the analysis. For "consumers only," the estimated mean two–day average per capita ingestion of community water is 1.0 liter/person/day (90% confidence interval is 976 to 1,024 ml/person/day). These estimates are based on the 14,012 respondents to the CSFII who reported consuming community water. The estimated 90th percentile of consumption is 2.069 liters/person/day (See Table 4–2–B1).

The highest consumption estimates (and therefore most conservative with regard to risk) are for total water ingestion by "consumers only." The estimated mean ingestion of total water by "consumers only" is 1,241 ml/person/day (90% confidence interval is 1,208 to 1,274 ml/person/day). The estimated 90th and 95th percentiles are 2,345 ml/person/day and 2,922 ml/person/day, respectively (See Table 4–2–A).

For babies younger than one year old the estimated mean community water ingestion is 342 ml/person/day (90% confidence interval is 295 to 388 ml/person/day); the estimated 90th percentile is 878 ml/person/day (90% bootstrap interval is 849 to 918 ml/person/day); and the 95th percentile is 1,040 ml/person/day (90% bootstrap interval is 936 to 1121 ml/person/day) (See Table 4–1–B1). Thus, the standard one liter ingestion rate used in risk assessments for a 10–kilogram child is approximately less than or equal to the 95th percentile of the empirical distribution of community water ingestion for infants.

For babies younger than one year old who are water consumers, the estimated mean total water ingestion is 563 ml/person/day (90% confidence interval is 508 to 618 ml/person/day). The estimated 90th percentile is 968 ml/person/day (90% bootstrap interval is 940 to 1,121 ml/person/day), and the estimated 95th percentile is 1,236 ml/person/day (90% bootstrap interval is 1,121 to 1,282 ml/person/day). Thus, the one liter standard used in risk assessments for a 10–kilogram child is approximately less than or equal to the 90th percentile of the empirical distribution of total water ingestion for babies less than one year old when considering "consumers only" (See Table 4–2–D1).

The Recommended Dietary Allowances (RDA, 1989) for water intake are 1.5 ml/K cal and 980 K cal/day for a child between six months and one year old. Thus, the RDA for a 10–kilogram child is equivalent to 1,275 ml of water/day. Therefore, the default of 1 liter/10–kg child/day is slightly lower than the RDA value of 1,275 milliliters per child per day.

For children one to ten years old, the estimated mean community water ingestion is 400 ml/person/day (90% confidence interval is 380 to 420 ml/person/day); the 90th percentile is 905 ml/person/day (90% bootstrap interval is 863 to 935 ml/person/day) and the 95th percentile is 1,118 ml/person/day (90% bootstrap interval is 1,079 to 1,143 ml/person/day), respectively (See Table 4–1–B1). Thus, the standard one liter ingestion rate used for risk assessments for a 10–kilogram child lies between the 90th and 95th percentiles of the empirical distribution of community water ingestion for children one to ten years old.

For children one to ten years old who consume water, the estimated mean total water ingestion is 532 ml/person/day (90% confidence interval is 509 to 556 ml/person/day). The estimated 90th percentile of total water ingestion is 1,004 ml/person/day (90% bootstrap interval is 980 to 1,030 ml/person/day), and the estimated 95th percentile is 1,242 ml/person/day (90% bootstrap interval is 1,198 to 1,284 ml/person/day) (See Table 4–2–D1). Thus, the one liter standard ingestion used in risk assessments for a 10–kilogram child is approximately less than or equal to the 90th percentile of the empirical distributions of total water ingestion for children one to ten years old when considering "consumers only."

When considering water ingestion rates based on units of milliliters per kilogram of body weight per day, this analysis shows that the mean ingestion rates for babies younger than one year are estimated to be three to four times higher than the mean rates for the population as a whole. For example, the estimated community water ingestion rate is 46 ml/kg/day (90% confidence interval is 39 to 53 ml/kg/day) for babies in the U.S. population versus 16 ml/kg/day (90% confidence interval is 15 to 16 ml/kg/day) for the general population (See Table 4–1–B2). The estimated community water ingestion rate for babies consuming community water is 69 ml/kg/day (90% confidence interval is 62 to 77 ml/kg/day) versus 17 ml/kg/day (90% confidence interval is 16 to 17 ml/person/day) for the general population (See Table 4–2–B2).

The mean per capita ingestion of community water is 75 percent of the mean total water ingested from all sources. The mean bottled water ingested is 13 percent of the mean of total water ingestion, while water from other sources such as wells and rain cisterns is 10 percent of the mean of total water ingested.

Many federal agencies, including EPA, use the standard water ingestion quantities of two liters for a 70–kilogram adult and one liter for a 10–kilogram child. This 2–liter quantity of ingested water is supported by a National Cancer Institute (NCI) analysis of the USDA 1977–78 USDA National Food Consumption Survey (NFCS) data (1989, Ershow and Cantor). The mean per capita daily intake of tap water, as estimated from the 1977–78 NFCS data is 1.193 liters/person/day. The estimated percentile corresponding to two liters per day ingested is the 88th. There are a number of differences in the methodologies used in the Ershow and Cantor study and this analysis. One difference is that the Ershow and Cantor estimates were based on 1977–78 data while the estimates in this document are based on data collected in 1994 through 1996. A second difference is that the 1977–78 NFCS was based on three consecutive days of food intake while the 1994–96 CSFII was based on two non–consecutive days. A third difference is that the Ershow and Cantor report defined tap water as "water from the household tap." In this report, water coming from the tap is distinguished by source. Sources of water coming from the tap may include: community water, household well or cistern, a household or public spring, and other. Another way that the estimates in this report differ from those in the 1989 report is that the 1994–96 data include water ingestion by pregnant and lactating women. These women were excluded from the 1989 report.

The CSFII surveys have advantages and limitations for estimating per capita water ingestion. The primary advantage of the CSFII surveys is that they were designed and conducted by the USDA to support unbiased estimation of food consumption across the population in the United States and the District of Columbia. One limitation of the CSFII surveys is that individual food consumption data were collected for only two days—a brief period which does not necessarily depict “usual intake.” Usual dietary intake is defined as “the long–run average of daily intakes by an individual.” Upper percentile estimates may differ for short–term and long–term data because short term food consumption data tend to be inherently more variable. It is important to note, however, that variability due to duration of the survey does not result in bias of estimates of overall mean consumption levels. A second limitation is that the multistage survey

design does not support interval estimates for many of the subpopulations reported in this document because of sparse representation in the sample. Therefore, only mean and percentile estimates are reported for all subpopulations considered here. The survey does support interval estimates for the U.S. population and some large subpopulations which are presented in Chapter 4. A third limitation is that the survey design does not support generating water consumption estimates for certain subpopulations of interest. Examples of such subpopulations are Native Americans with traditional lifestyles, people who live in hot climates, people who consume large amounts of water because of physical activity, and people with medical conditions necessitating increased water intake. While these individuals are participants in the survey, they are not present in sufficient numbers to support water ingestion estimates.

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1. DEFINITIONS

Biological Water is water found naturally in foods. This water source is not included in the estimates presented in this document.

Bottled Water is purchased plain water.

Broad Age Categories cover babies (less than one year old), children (one to 10 years old), young adults (11 to 19 years old), adults (20 years and older).

Commercial Water is water added by the manufacturer prior to merchandising. This water is not included in the estimates presented in this document. An example of commercial water is water added to bottled iced tea by the manufacturer.

Community Water is tap water from the community water supply.

Consumers are individuals who reported ingestion of the water source under consideration. Individuals with reported ingestions of zero are not considered consumers.

CSFII is the acronym for the USDA's Continuing Survey of Food Intakes by Individuals.

Direct Water is plain water ingested directly as a beverage.

Fine Age Categories include 11 age groupings. These groupings are less than six months (<0.5 years), between six months and one year (0.5 to 0.9 years), 1 to 3 years, 4 to 6 years, 7 to 10 years, 11 to 14 years, 15 to 19 years, 20 to 24 years, 25 to 54 years, 55 to 64 years, and 65 and older.

Food Code is an 8–digit number assigned to each unique food in the USDA Food Coding Database.

Food Coding Database is a database in the USDA CSFII 1994–96 Technical Support Files which contains information used to code foods and amounts, including descriptions of the food code.

Indirect Water is water added to foods and beverages during final preparation at home, or by food service establishments such as school cafeterias and restaurants. An example of indirect water is water added to dry cake mix.

Missing Water Source indicates that a survey participant responded "don't know" or "not ascertained" to the survey question regarding the source of water.

Nutrient Database is a database in the USDA 1994–96 CSFII Technical Support Files which contains nutrient composition information (including grams of water per 100 grams of food) used to calculate the nutrient value of foods ingested in the CSFII.

Other Water is water obtained from one of the following sources: a well or rain cistern (household's), spring (household's or public), or other source.

Preparation Water is water used to prepare foods. Preparation water includes the water used to prepare foods at home and by local food service establishments (indirect water), as well as, water added by commercial food manufacturers.

Recipe Database is a database in the USDA 1994–96 CSFII Technical Support Files which provides, for each food code, a standard recipe including the gram weight of each ingredient.

Technical Support Files consist of four USDA technical databases used to code food data collected in the 1994–96 CSFII. They are the Food Coding Database, the Nutrient Database, the Recipe Database, and the Pyramid Servings Database.

Total Water is the sum of direct and indirect water from all sources. Water sources include community water, bottled water, other water and missing sources.

2. USDA's CSFII SURVEY DESCRIPTION AND FILES

A brief description of the USDA's 1994, 1995, and 1996 series of the Continuing Survey of Food Intakes by Individuals (CSFII) is presented in this chapter. Section 2.1 provides a description of the surveys, and Section 2.2 describes the process used to collect the dietary recall information. Files from which data were drawn to produce the estimates in this report are listed in Section 2.3. Section 2.4 presents a brief discussion about survey weights and their use. The details of the sample design and resulting survey weights are provided in Appendix D.

2.1 Survey Description

The CSFII, conducted by the United States Department of Agriculture (USDA), collects dietary intake information from nationally representative samples of non–institutionalized persons residing in United States households. Households in these national surveys are sampled from the 50 states and Washington, D.C. Each survey collects daily consumption records for approximately 10,000 food codes across nine food groups. These food groups are (1) milk and milk products; (2) meat, poultry, and fish; (3) eggs; (4) dry beans, peas, legumes, nuts, and seeds; (5) grain products; (6) fruit; (7) vegetables; (8) fats, oils, and salad dressings; and (9) sweets, sugars, and beverages. Data provide "up–to–date information on food intakes by Americans for use in policy formation, regulation, program planning and evaluation, education, and research." The survey is "the cornerstone of the National Nutritional Monitoring and Related Research Program, a set of related federal activities intended to provide regular information on the nutritional status of the United States population" (CSFII survey documentation, p. 2–3).

The 1994–1996 CSFII was conducted according to a stratified, multi–area probability sample organized using estimates of the 1990 United States population. Stratification accounted for geographic location, degree of urbanization, and socioeconomics. Each year of the survey consisted of one sample with oversampling for low–income households. Eligibility for the low–income sample was limited to households with gross incomes at or below 130 percent of the federal poverty guidelines (DHHS 1996). The sample design aimed at specified precision levels for estimates of mean one–day consumption of saturated fat and iron.

Two days of dietary recall data were provided by 15,303 individuals across the three survey years. This constitutes an overall two–day response rate of 75.9 percent. Response rates for each survey year are provided in Table 2–1. Survey weights were corrected by the USDA for nonresponse.

TABLE 2–1 CSFII RESPONSE RATES

YEAR	TOTAL ELIGIBLE INDIVIDUALS SAMPLED	NUMBER WITH TWO–DAY RESPONSE	(TWO–DAY) RESPONSE RATE
1994	6,973	5,311	76.2%
1995	6,664	5,072	76.1%
1996	6,484	4,920	75.9%

2.2 Dietary Records

Survey participants provided two non–consecutive, 24–hour days of dietary data. Both days' dietary recall information was collected by an in–home interviewer. Interviewers provided participants with an instructional booklet and standard measuring cups and spoons to assist them in adequately describing the type and amount of food ingested. If the respondent referred to a cup or bowl in their own home, a 2–cup measuring cup was provided to aid in the calculation of the amount consumed. The sample person could fill their own bowl or cup with water to represent the amount eaten or drunk, and the interviewer could then measure the amount consumed by pouring it into the 2–cup measure. The Day 2 interview occurred 3 to 10 days after the Day 1 interview, but not on the same day of the week. The interviews allowed participants "three passes" through the daily intake record to maximize recall (CSFII survey documentation, p. 3–6). Proxy interviews were conducted for children aged six and younger and sampled individuals unable to report due to mental or physical limitations. The average questionnaire administration time for Day 1 intake was 30 minutes, while Day 2 averaged 27 minutes.

2.3 Data Files

The USDA records 1994–96 CSFII participant information in three record types. Data extracted from these record types provide the information to determine the amount and source of commodities ingested by participants. These data are publicly available on CD–ROM (See Section 5.4 References), and the three CSFII record types used for this report are described here. Record type 15 (RT15) reports household information. Generally the source of water is determined from these records. Record type 25 (RT25) records individual information. This is where the amount of direct water ingested is recorded. Record type 30 (RT30) records food items ingested on each of the two survey days by each individual. The amount of indirect water ingested can be calculated from these records in conjunction with the CSFII 1994–96 Technical Support Files including the food coding, recipe and nutrient databases. Refer to Appendix A for the CSFII questions related to the amount of water ingested and the source of the water. Chapter 3 details how these record types were combined to establish a working database of individual records with the amount, source, and type of ingestion (direct or indirect).

2.4 Survey Weights

USDA files provide a survey weight for each individual with two days of consumption data in the 1994-96 survey. These weights account for the probability that the individual was selected and contain adjustments for non-respondents. The recorded weights also reflect USDA's calibration to ensure that the sample is representative of population characteristics during the three years of the survey. Survey weights are applied during the generation of ingestion estimates recorded in this report. These weights project data from an individual to the population. Appendix D provides a more detailed discussion of the development and application of the three year, two day survey weights.

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3. METHODS

This chapter addresses the methods employed to produce the reported daily average per capita water ingestion estimates by source and type of ingestion. Section 3.1 defines the data conventions applied to the CSFII data to establish water ingestion records for each respondent with two days of consumption data. These conventions include identification of the records from CSFII used to determine the source and amount of directly ingested waters. We also describe CSFII auxiliary files and how they were used to quantify the amount of indirect water ingested by a survey participant. Section 3.2 summarizes the statistical methods used to estimate the mean and percentiles of the empirical distributions of daily average per capita water ingestion. Appendix D provides the statistical formulae used to calculate these estimates. Rounding procedures and units of measurement are recorded in Sections 3.3 and 3.4, respectively. Section 3.5 provides the minimum sample size requirements used to identify potentially unreliable estimates.

3.1 Data Conventions Applied to the 1994–96 CSFII Data

A series of CSFII records is used to define the source and type of water ingested by a survey respondent. We drew from household records and individual records to define the amount and source of plain water ingested as a beverage. The source and amount of indirect water ingestion was determined using the household and individual records in conjunction with the 1994–96 CSFII Technical Support Files including the food coding, recipe and nutrient databases. All CSFII data used are publicly available on CD–ROM (See Section 5.4 References). The following paragraphs describe the protocols followed for assigning the source and quantifying the amount of the daily average water ingested by each respondent with two days of consumption records.

CSFII record type 15 (RT15) reports household information. The source of water ingested is generally assigned from these records. Record type 25 (RT25) records the amount of direct water ingested. Record type 30 (RT30) reports food items ingested on each of the two survey days by each individual. The amount of indirect water ingested by each participant was calculated from food code records in conjunction with the 1994–96 CSFII Technical Support Files. A more detailed description of how information was drawn from these three sets of records to determine the average daily water ingestion for each survey participant is provided in the remainder of this chapter. We first describe the data conventions and then follow the description with a flow chart. As a point of reference, Appendix A contains all CSFII questions related to the amount of water ingested and the source of the water.

Water Ingestion listed as “Direct” is defined as plain water directly ingested by an individual. The amount of water ingested is recorded in CSFII RT25, variables D1_H2O_O and D2_H2O_O. The number following the letter D in these variables indicates the day of the survey to which the consumption corresponds. It is in these two variables that the amount of direct water ingested by participants is recorded

in fluid ounces (fl oz). This amount was converted to milliliters by multiplying the amount in fluid ounces by the conversion factor of 29.574 ml/fl oz.

The companion RT25 variables to which respondents to the question (D1_H2O_O) "How many fluid ounces of plain drinking water did you consume?" are directed are D1_H2O_H and D1_H2O_A. A similar set of variables records information for D2_H2O_O. The variable with the suffix "H" asks the respondent how much of this water was ingested at home. The choice of responses is all, most, some, none, don't know, and not ascertained. The variable D1_H2O_A asks what the source was of plain drinking water that did not come from your home. The choices of responses are tap/fountain, bottled, other, don't know, and not ascertained. If an individual answers with either of the last two responses, the source of that water is considered "missing."

Because the amount of plain, noncarbonated water ingested by an individual as recorded in the RT25 files does not completely designate the source of the water, RT15 household records were consulted. The RT15 variable, H2O_DRNK, records source information for the household. For this variable, the following conventions were applied to assign source.

If H2O_DRNK is valued as

1, then the water source was a **community water supply**
2, then the water source was a **household well or rain cistern**
3, then the water source was a **household or public spring**
4, then the water source was considered **bottled water (purchased)**
96, it is defined explicitly as **"other"** and considered to be **"other" water** sources.

All remaining values of the associated variable, which include 98 for "don't know" and 99 for "not ascertained," are considered missing water sources.

To determine source for direct water ingestion (D1_H2O_O), **if RT25 variable D1_H2O_H is valued as**

"1" designating "**all**," then the source was derived from RT15 variable H2O_DRNK.
"2" designating "**most**," then 75% of the water ingested was allocated according to the RT15 variable H2O_DRNK and 25% according to the response to RT25 variable D1_H2O_A.
"3" designating "**some**," then 25% was allocated according to the RT15 variable H2O_DRNK and 75% according to the response to RT25 variable D1_H2O_A.
"4" designating "**none**," then the source was derived from RT25 variable D1_H2O_A.
"8" or "9" designating "**don't know**" or "**not ascertained**," respectively, then 50% was allocated according to the RT15 variable H2O_DRNK and 50% according to the response to RT25 variable D1_H2O_A.

Indirect water is defined as water added to foods and beverages during final preparation at home or by local food service establishments (e.g., school cafeterias and restaurants). Excluded from indirect water are biological water and water added by the manufacturer during processing. For example, an apple contains biological water, and canned ready–to–serve soup contains water added by the manufacturer. The 1994–96 CSFII Food Coding Database contains 10,620 food codes. The food code descriptions contained in USDA's Food Coding Database generally do not indicate where the food was prepared. Therefore, in order to identify indirect water ingestion, each food code description, corresponding recipe and in some instances nutrient composition information associated with the reported food codes for the 1994–96 CSFII was reviewed. A subset of these food codes which contained preparation water was created. A food code was considered to contain preparation water if the food code recipe contained one of the following ingredients: (1) water; (2) an ingredient which had its own recipe which contained water; (3) brewed coffee or tea; and (4) pre–cooked pasta, rice, cereals, beans or legumes. The subset consisted of 7,560 food codes which contained preparation water. The food codes in this subset were then reviewed to identify and exclude those which appeared to be commercial products (e.g., yogurt, frozen milk desserts, frozen entrees, ready–to–serve soups, ready–to–serve fruitades and drinks, all soft drinks, and other food codes with descriptions identifying brand names). This resulted in a smaller subset of 2,478 food codes which were assumed to contain indirect water. Next the foods which could reasonably be assumed to have been prepared in final form in the home or by a food service establishment were identified (e.g., foods described as "made from home recipe," orange juice made from concentrate, infant formula made from concentrate, canned soup with water added). It was assumed that the recipe water in such foods was 100% indirect. For some foods, both homemade and commercially prepared varieties were identified under one food code. For these food codes, a "best guess" estimate was made as to the proportion which would have been home–prepared versus commercially processed. For example, it was estimated that 50% of pre–cooked beans to be home–prepared and 50% to be commercially canned. These allocations are documented in Appendix C1.

When a respondent supplied specific information about ingredients that differed from the standard recipe maintained in the Food Coding Database, this modification was recorded. This flexibility allowed the database to capture the specific type of fat, type of milk, and dilution of foods. For example, if the standard recipe in the Food Coding Database for an infant formula prepared from liquid concentrate calls for a specified amount of water to be added and a respondent reported making the formula with 3 times that amount of water, a recipe modification would be created to allow for this deviation from the standard recipe.

Appendix B1 contains examples for estimating the proportion of indirect water in 100 grams of a food. The ingredient amount as a percent of the prepared product (P%) was calculated for each ingredient of each recipe that contains indirect water using the method provided in USDA guidance examples. Appendix B3 contains these guidance documents. The grams absorbed moisture per 100 grams cooked ingredient

(G_am) was calculated for pre–cooked pasta, rice, cereals, beans, and legumes using the total solids method provided by the USDA (refer to Appendix B2).

Next, the proportion of moisture in 100 grams of food as ingested (P_m) was found. These values were taken from a file (WTR_FC.TXT) provided by the USDA when available. The WTR_FC.TXT file contains the amounts of water in 100 grams of the CSFII 1994–96 foods. These amounts represent both water from survey recipes as well as from ingredients (referred to as PDS ingredients) used in the survey recipes. Adjustments were made by USDA for any moisture and fat losses/gains associated with the recipe in which the PDS codes with water appear. For those recipe ingredients not available in WTR_FC.TXT, the values were calculated as follows:

P_m = (P%)(G_am/100), for pre–cooked pasta, rice, cereals, beans, and legumes
P_m = P%, for water, brewed coffee and tea, and pds–coded ingredients

Then the proportion of indirect preparation water per 100 grams of food (G_i) was calculated for each ingredient. This was done by multiplying the proportion of moisture in 100 grams of a food as ingested (P_m) by the percentage of that ingredient assumed to be home or food service establishment prepared and dividing by 100. (Appendix B1 provides examples of these calculations.)

For recipes with indirect water, the ratio of the amount of water to the total grams in the recipe was derived by summing the values of G_i across all ingredients in the recipe. This water ratio was then multiplied by the amount of the given food ingested by the respondent to determine the number of grams of indirect water. Under the assumption that the density of this water is 1, the number of grams of indirect water ingested from foods or beverages was converted to milliliters.

To assign the source of indirect water, several variables were consulted. First, if the respondent indicated in RT30 variable FOODSRCE that the source was >1, then the source was assumed to be tap water. If FOODSRCE=1 to indicate that the food items were obtained from the store, then it was assumed the recipe was prepared at home. In this case, RT15 variables H2O_COOK or H2O_BEVR were consulted. If the first three digits of the food code indicated that the ingested food was a beverage, then the water source was assigned to the record based on the response to H2O_BEVR. This question indicated, "What is the main source of the water used in your home for preparing beverages such as coffee, tea, juices, and baby formula?" The same source allocations in RT15 variable H2O_DRNK were applied to these records. Likewise, if the first three digits of the food code indicated that the food code was not a beverage, then the source was assigned according to the response to H2O_COOK, which asked, "What is the main source of the water used for cooking in your home?"

Figures 3–1 through 3–4 present flow charts of the data conventions for the assignment of water source.

For each of the 15,303 respondents with two days of records in the CSFII databases, a daily average ingestion value was determined for each water source and ingestion type (direct, indirect, and both direct and indirect). For subpopulation estimates, if a respondent was a member of the subpopulation but did not report ingestion of the specified water source and ingestion type, then that individual's average daily amount of water ingested entered the estimation algorithms as zero. These estimates are provided in the tables of this report identified as "All Individuals."

Ingestion (direct, indirect, and both direct and indirect) was also estimated for consumers with two days of records in the CSFII databases. Hence, these estimates do not include individuals who reported zero amounts of water ingested from the water source under consideration. These estimates are provided in the tables of this report identified as "Consumer Only."

The convention described in the preceding paragraphs produces individual daily averages in milliliters/person/day. If estimates are required on the milliliters/kilogram body weight/day basis, then the individual's daily average is divided by the individual's body weight in kilograms. The milliliters/kilogram body weight daily average for each individual then enters the estimating algorithm described in Section 3.2 and Appendix D, as do the milliliter daily averages.

Internal quality assurance and quality control procedures were utilized during the calculation of estimates for this report. Algorithm testing was conducted for data procedures. Data subsetting procedures were quality assessed by intermediate estimates verification. Final tabulated estimates were reviewed for consistency and validity. USDA experts were consulted on data assumptions.

3.2 Statistical Methods

This section summarizes the statistical methods used to generate point and interval estimates of daily average per capita water ingestion. Point estimates include the mean, 1st, 5th, 10th, 25th, 50th, 75th, 90th, 95th, and 99th percentiles. Mean estimates were generated using ratio estimation techniques. The mean, daily average per capita ingestion for a given commodity type, was estimated as the ratio of total ingestion by the United States population or subpopulation, divided by the estimate of the total number of individuals in the population or subpopulation. Empirical percentiles were estimated using nonparametric techniques. All estimates incorporated CSFII survey weights to project a sampled individual's ingestion to the population.

The majority of the per capita water ingestion estimates in this report are presented for specific subpopulations and water source. The design of the CSFII survey did not always support estimation of the variance when subpopulations were evaluated. Without a variance estimate, confidence intervals about the mean or bootstrap intervals about percentile estimates cannot be produced. Therefore, the tabulated presentations in Appendix E include only point estimates. However, the survey did support variance, and

thus interval estimation, for some subpopulations. These estimates are presented in the key figures of Chapter 4 augmenting tabulated estimates for the all individuals.

When a variance was estimated for the mean per capita ingestion, we estimated the variance of the mean using a Taylor series approximation of the deviation of estimates from their expected values. The Taylor series approximations were applied to ultimate clusters, which resulted in an overall estimate of the variance instead of estimating variance components due to sample–design stages. In Appendix D, we include the statistical formulae for generating both the mean estimate and the estimate of the confidence interval about the mean. We also provide the method for generating percentile estimates and estimates of 90% bootstrap intervals about the percentile estimates.

All three CSFII surveys are multistage, stratified–cluster samples. Sample weights, which project the data from a sampled individual to the population, are based on the probability of an individual being sampled at each stage of the sampling design. As mentioned in Chapter 2 of this report, the sample weights associated with each individual reporting two days of consumption data were adjusted to correct for nonresponse bias. These adjusted sample weights, which are recorded in the CSFII data in the variable SAM_WT, record the number of individuals the sampled person represents in the population. For example, a sample weight valued as 22 projects the data from the individual with that sample weight to 22 individuals in the population of the 50 United States and the District of Columbia.

Because the sample design contains multiple levels, specific information is necessary to partition the variance–of–the–mean estimate into components. That is, specification of the sample size and population size within each level of sampling is required. However, this information is not inherent in the CSFII data. Rather, the CSFII reports an adjusted sample weight for each individual who reported two non–consecutive days of consumption data during the survey. Given that only the adjusted weight was available, and not the specific sample and population size in each phase, it was necessary to estimate the mean using ratio estimation techniques and the variance of the mean using the ultimate cluster methodology, which does not partition the variance into sample design components (refer to Appendix D).

Interval estimates for percentiles are bootstrap intervals. The reported bootstrap intervals do not result from direct estimates of the standard deviation of the point estimate. Rather, the bootstrap estimates result from the percentile method, which estimates the lower and upper bounds for the interval estimate by the 100α percentile and $100(1-\alpha)$ percentile estimates from the nonparametric distribution of the given point estimate. This distribution of the observed values of the given point estimate is determined from repeated resampling of the empirical data.

3.3 Rounding Procedures

Tabulated estimates of per capita ingestion in milliliters are rounded to the nearest whole number. Conventional rounding procedures were applied such that the whole number remained the same if decimal estimates were less than 0.5 and increased by one if the decimal estimate was 0.5 or greater. Whole number presentations do not reflect significant digits as the number of significant digits is not available for the CSFII.

3.4 Units of Measure Including Conversion Factors

Per capita water ingestion estimates are presented in this report in units of ml/person/day or ml/kg body wt/day. The person/day component reflects that estimates are based on an average of two days of consumption. When the units are ml/kg body wt/day, the average water ingestion over two days by an individual is divided by the individual's body weight. Body weight is recorded in the CSFII in pounds (lb). These pounds are converted to kilograms by multiplying the reported body weight by a factor of 0.454 kg/lb.

Survey participants reported the amount of plain water ingested directly as a beverage in fluid ounces. Reported ingestions were multiplied by 29.574 to convert fluid ounces to milliliters. Water ingested indirectly from foods with water added at home or locally during the final stage of preparation was estimated in grams as food consumption and recipe amount are reported in the CSFII in grams. These grams of water were converted into milliliters based on the assumption that the specific gravity of water is one for the temperature range of ingested foods.

3.5 Sample Size Criteria

Estimates based on small sample sizes may be less statistically reliable than estimates based on larger sample sizes. "Third Report on Nutrition Monitoring in the United States" suggest minimal reporting requirements (LSRO 1995). If the sample size is less than 30*(variance inflation factor), the estimate of the mean may be unreliable and is marked with an asterisk. If the (sample size)*(1–percentile) is less than 8*(variance inflation factor), then the percentile estimate may be unreliable and is marked with an asterisk. The variance inflation factor for the two days of CSFII data is 1.60. The variance inflation factor is sample design specific and is a broadly calculated design effect measure. In accordance with the suggested minimum reporting requirements, mean ingestions estimated with sample size < 48 are marked with an asterisk to designate that they may be statistically unreliable. Similarly, percentiles estimated with sample size < 12.8/(1–percentile) are marked and may be statistically unreliable.

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4. RESULTS

This chapter presents point and interval estimates of the mean, 90th percentile and 95th percentile for select subpopulations. We augment tabulated estimates in this chapter with graphical presentations of the empirical distributions of per capita water ingestion estimates for select subpopulations. Because EPA anticipates that per capita ingestion of community water will be of primary interest to the readers of this report, we emphasize these results in this chapter. Since children less than one year of age and pregnant, lactating, and childbearing–age women are considered to be high risk subpopulations, we also discuss their estimates in this chapter. Finally, to reflect changes in consumer behavior since the 1977–78 survey, which was the basis for the Ershow and Cantor report, we report per capita ingestion of bottled water from 1994–96 CSFII.

This report provides tables and figures of per capita estimates of daily average water ingestion. Tables and figures of estimates are provided for all individuals and for "consumers only" by source, and type of ingestion. Sources of ingestion include community water, bottled water, other sources, and total water (all sources combined). Other sources include a household well, household rain cistern, household or public spring and other sources. Types of ingestion are direct for plain water ingested as a beverage, indirect for ingestion of the water added to foods and beverages during final preparation at home or by food service establishments (e.g., school cafeterias and restaurants), and both direct and indirect for combined direct and indirect water ingestion. Biological and commercial water are excluded from these estimates of water ingestion. Estimates are provided in both units of milliliters/person/day (ml/person/day) and milliliters/kilogram of body weight/day (ml/kg/day).

Refer to Appendix E for a more comprehensive set of empirical distributions of estimated per capita water ingestion. In addition to the broad age categories reported in this chapter, Appendix E provides estimates of water ingestion by finer age categories. Appendix E also provides a more extensive percentile distribution which includes point estimates of the mean, and 1st, 5th, 10th, 25th, 50th, 75th, 90th, 95th and 99th percentiles.

It should be noted that the dispersion of individuals for some subpopulations across CSFII estimation strata did not always support generation of variance estimates. Therefore, the following discussions will point out differences in mean per capita ingestion between subpopulations, but these differences are a quantitative statement and do not imply statistical differences. Without variance estimates about the means of the subpopulations, we cannot perform formal statistical tests to ascertain whether means for various subpopulations differ statistically.

4.1.a Ingestion of Community Water (ml/person/day)

The mean daily average of estimated per capita community water is 927 ml/person. This average projects to the population of the United States. The 90% confidence interval about the mean is 902 to 951 ml/person/day. The estimated 90th percentile from the empirical distribution of daily average per capita community water ingestion is 2.016 liters. A 90% bootstrap interval about the 90th percentile intake estimate for all individuals is 1.991 liters to 2.047 liters (See Table 4–1–A).

Figure 4–1–F1 depicts the empirical distribution of daily average per capita community water ingestion for all individuals during 1994–96. Considering that the 5th percentile estimate from this empirical distribution is zero and the 95th percentile estimate is 2.544 liters (See Appendix E, Part I, Table A1), the empirical distribution is obviously skewed. That is, the mean estimate is influenced by people ingesting either zero to a very little amount of water or very large volumes of water. Figure 4–1–G1 displays a histogram of daily average per capita community water estimates. This histogram illustrates that most of the daily average ingestion reported by CSFII respondents are less than two liters. The bar with the midpoint of 1.575 liters has an upper value of 2.2 liters. This is between the estimated 90th and 95th percentiles of the empirical distribution.

The mean daily average of estimated per capita ingestion of community water for "consumers only" is 1.0 liter/person (90% confidence interval is 976 ml to 1.024 liter/person). The estimated 90th percentile from the empirical distribution of daily average per capita community water ingestion for consumers is 2.069 liters (90% bootstrap interval is 2.041 to 2.106 liters/person/day) (See Table 4–2–A). Figure 4–2–F1 portrays the empirical distribution of daily average per capita community water ingestion for consumers.

One point of clarification regarding the histograms (See Figures 4–1–G1, 4–1–G2, 4–2–G1, and 4–2–G2) is necessary. Amounts printed along the x–axis are midpoint values for all the bars except the first two. That is, the width of the third bar and beyond is 630 ml. The first bar for Figures 4–1–G1 and 4–1–G2 represents nonconsumers (respondents with zero reported water ingestion or with missing ingestion) and respondents with minimal ingestion. In this case, minimal ingestion is more than zero but less than 157.5 ml/day. The second bar represents ingestion of greater than 157.5 ml/day but less than 630 ml/day. Therefore, the first two bars together represent ingestion of 630 ml/day or less. All other bars are each intervals of 630 ml/day. Bars are defined similarly for Figures 4–2–G1 and 4–2–G2 for consumers except that the first bar only represents respondents with minimal ingestion defined as more than zero but less than 157.5 ml/day.

4.1.b Ingestion of Community Water (ml/kg of body weight/day)

The mean ingestion of community water for the United States population, reported in units of per kilogram of body weight, is 16 ml/kg/day (90% confidence interval is 15 to 16 ml/kg/day) (See Table

4–1–B2). For "consumers only," the mean ingestion of community water is 17 ml/kg/day (90% confidence interval is 16 to 17 ml/kg/day) (See Table 4–2–B2). The 90th percentile from the empirical distribution of daily average per capita ingestion of community water for all individuals and "consumers only" is 33 ml/kg (See Table 4–1–B2 and Table 4–2–B2).

4.2.a Ingestion of Community Water by Age and Gender (ml/person/day)

In the United States population, individuals 20 years and older ingest an average of 1.098 liters (90% confidence interval is 1.068 to 1.127 liters) of community water per day. This is followed by individuals 11 to 19 years old who ingest an average of 683 ml daily (90% confidence interval is 634 to 732 ml), children one to ten years old who ingest an average of 400 ml daily (90% confidence interval is 380 to 420 ml), and children less than one year old who ingest an average of 342 ml daily (90% confidence interval is 295 to 388 ml) (See Table 4–1–B1).

Results for "consumers only" by age category are similar. Individuals 20 years or older ingest an average of 1.176 liters of community water per day (90% confidence interval is 1.148 to 1.204 liters/day). Young adults 11 to 19 years old ingest an average of 735 ml/day (90% confidence interval is 684 to 786 ml/day), children one to ten years old ingest an average of 435 ml/day (90% confidence interval is 414 to 457 ml/day), and children less than one year old ingest an average of 513 ml/day (90% confidence interval is 460 to 567 ml/day) (See Table 4–2–B1).

The mean community water ingested by males is higher than that ingested by females in all age categories except for children younger than one year old and children one to ten years of age. The highest mean per capita ingestion by males is found in the 20 years and older age group. The mean for this group is 1.162 liters/person/day and the 90th percentile is 2.337 liters/person/day. For females 20 years and older, the mean daily average of estimated per capita community water ingestion is 1.039 liters, while the 90th percentile estimate is 2.126 liters. Ninetieth percentile estimates are less than two liters/person/day for males and females less than one year old, between the ages of one and ten, and between the ages of 11 and 19 (See Table 4–1–C1).

Similarly, male consumers ingest more community water on average than female consumers. Male consumers 20 years and older have the highest mean per capita ingestion (1.242 liters). The 90th percentile estimate of daily average per capita community water ingestion for male consumers 20 years and older is 2.387 liters. The daily average per capita community water ingestion for female consumers 20 years and older is 1.116 liters, and the 90th percentile estimate is 2.165 liters. The mean difference between the two genders for individuals 20 years and older is 126 ml or 4.2 fluid ounces. Ninetieth percentile estimates are less than two liters/person/day for male and female consumers for all age categories younger than 20 years old (See Table 4–2–C1).

4.2.b Ingestion of Community Water By Age and Gender (ml/kg of body weight/day)

For all individuals, the lowest mean daily average per capita ingestion from community water, reported per kilogram of body weight, is 12 ml/kg for individuals aged 11 to 19 years old. The highest mean daily average per capita ingestion is 46 ml/kg for children less than one year old. Adults 20 years and older have a mean daily average per capita ingestion of 15 ml/kg, and children one to ten years old have a mean daily average per capita ingestion of 19 ml/kg (See Table 4–1–B2). This pattern is similar for consumers (See Table 4–2–B2). Thus, based on per kilogram body weight, the infants less than one year of age consume approximately three times the estimated amount of community water as the adult 20 years or older.

Males and females in the U.S. population have similar mean daily average per capita ingestion, reported per kilogram of body weight, from community water. Females have higher mean ingestion for all age groups except for individuals 11 to 19 years old (11 ml/kg/day vs. 13 ml/kg/day) (See Table 4–1–C2). The comparison between mean ingestion estimates for male and female consumers is similar (See Table 4–2–C2).

4.3.a Ingestion of Community Water for Children Younger Than One Year of Age (ml/person/day)

The age group with the lowest mean ingestion of direct and indirect community water for both genders is children less than one year old. This is also the only age group where the mean per capita ingestion by females (384 ml) is higher than that for males (298 ml) (See Table 4–1–C1). Similarly, female consumers less than one year old have a higher mean per capita ingestion of community water than male consumers (560 ml/day vs. 462 ml/day) (See Table 4–2–C1).

4.3.b Ingestion of Community Water for Children Younger Than One Year of Age (ml/kg of body weight/day)

Children younger than one year old have a mean intake of community water of 46 ml/kg/day, the highest of the age categories. The average for all individuals (all ages) is 16 ml/kg/day (See Table 4–1–B2) Likewise, consumers less than one year old have the highest mean ingestion, 69 ml/kg/day. The mean for all individuals (all ages) is 17 ml/kg/day. Therefore, infants younger than one year of age ingest approximately three to four times the estimated amount of community water than do individuals in all age groups (See Table 4–2–B2).

4.4.a Ingestion of Community Water for Women in Childbearing Years (ml/person/day)

Lactating women have the highest mean water ingestion. The mean daily average ingestion by lactating women is 1.379 liters, while the means for pregnant women and women in childbearing years are 819 and 922 ml, respectively. The 75th percentile estimate for lactating women exceeds two liters (2.263

liters), compared to 1.272 liters for women of childbearing age. The 90th percentile daily average per capita ingestion by lactating women is 2.872 liters as compared to 2.008 liters for women in childbearing years. The 90th percentile estimate from the empirical distribution of daily average per capita ingestion of community water by pregnant women is 1.816 liters. The 95th percentile estimates from the empirical distributions of daily average per capita ingestion of community water for pregnant women, lactating women, and women aged 15 to 44 are 2.501, 3.434, and 2.604 liters, respectively (See Table 4–1–E and Appendix E, Part I, Table A3).

Similarly, for "consumers only," lactating women ingest more water than do pregnant women or women in the childbearing ages. The mean daily average ingestion, for "consumers only," of community water for lactating women is 1.665 liters, for pregnant women is 872 ml, and for women in childbearing years is 984 ml. As noted above, the 75th percentile estimate of ingestion, for "consumers only," for lactating women exceeds two liters/day (2.417 liters/day), compared to 1.314 liters/day for women of childbearing age and 1.424 liters/day for pregnant women. The 90th percentile estimate of ingestion for "consumers only" exceeds two liters/day for both lactating women and women of childbearing age (2.959 liters and 2.044 liters, respectively). The 95th percentile estimates of daily average per capita ingestion of community water for pregnant consumers, lactating consumers, and female consumers aged 15 to 44 are 2.588, 3.588, and 2.722 liters, respectively (See Table 4–2–E and Appendix E, Part III, Table A3).

4.4.b Ingestion of Community Water for Women in Childbearing Years (ml/kg of body weight/day)

When estimates are reported for all women of childbearing age in units of milliliter/kilogram of body weight/day, the mean ingestion by lactating women is the highest at 21 ml/kg. Pregnant women have the lowest mean ingestion of community water with a mean of 13 ml/kg. Women in childbearing years have an estimated mean ingestion of 14 ml/kg. The 90th and 95th percentiles from the empirical distribution of daily average per capita ingestion per kilogram of body weight for lactating women both exceed 50 ml/kg. Ninetieth percentile estimates for pregnant women and women in childbearing years are 32 ml/kg, while the 95th percentile estimates from these two distributions are 43 and 39 ml/kg, respectively (See Appendix E, Part II, Table A3).

The mean ingestion of community water is 26 ml/kg/day for lactating consumers, 14 ml/kg/day for pregnant consumers, and 15 ml/kg/day for female consumers aged 15 to 44. The 90th and 95th percentiles of daily average per capita ingestion per kilogram of body weight for lactating consumers both exceed 50 ml/kg. Ninetieth percentile estimates for pregnant consumers and female consumers aged 15 to 44 are 33 and 32 ml/kg/day, while the 95th percentile estimates from these two groups are 43 and 39 ml/kg/day (See Appendix E, Part IV, Table A3).

4.5 Ingestion of Bottled Water and Water from Other Sources

Mean per capita ingestion of bottled water for the United States population is 161 ml. The 90th and 95th percentile estimates from the empirical distribution of daily average per capita ingestion of bottled water for the United States population are 591 ml and 1.036 liters, respectively (See Table 4–1–A). Mean ingestion of water from other sources by the United States population is 128 ml. Ninetieth and 95th percentile estimates of per capita ingestion of water from other sources are 343 ml and 1.007 liters, respectively (See Table 4–1–A). Other sources include water from wells, rain cisterns, springs, and sources identified by respondents as "other." Comparing the mean daily average per capita ingestion of bottled water and water from other sources to total water ingestion regardless of sources (1.232 liters) suggests that 13 percent of total water ingestion is attributable to bottled water while 10 percent is attributable to water from other sources. Community water comprises 75 percent of the total water ingestion by individuals in the United States population.

Daily average per capita ingestion for consumers of bottled water is 737 ml/person. The 90th and 95th percentile estimates of ingestion for consumers of bottled water are 1.568 liters/person/day and 1.967 liters/person/day (See Table 4–2–A). The daily average per capita ingestion for consumers of water from other sources is 965 ml. The 90th and 95th percentile estimates of daily per capita ingestion are 1.971 and 2.475 liters (See Table 4–2–A).

4.6.a Ingestion of Total Water for All Individuals

The mean estimate of total water ingestion (ingestion of water from all sources) for the general population is 1,232 ml/person/day (90% confidence interval is 1,199 to 1,265 ml/person/day). The 90th and 95th percentiles of the distribution are 2,341 ml/person/day and 2,908 ml/person/day, respectively (See Table 4–1–D1). Approximately 84 percent of the U.S. population ingests two liters or less per day of total water (See Figure 4–1–F2).

For babies younger than one year old, the estimated mean consumption of total water is 484 ml/person/day (90% confidence interval is 438 to 530 ml/person/day). The 90th and 95th percentiles of consumption are 949 ml/person/day (90% bootstrap interval is 893 to 1,046 ml/person/day) and 1,182 ml/person/day, (90% bootstrap interval is 1,046 to 1,282 ml/person/day), respectively. The mean value of the daily total water ingestion for a child one to ten years old is 528 ml/person/day (90% confidence interval is 505 to 552 ml/person/day). The 90th and 95th percentiles of total water ingestion are 1,001 ml/person/day (90% bootstrap interval is 980 to 1,027 ml/person/day) and 1,242 ml/person/day (90% bootstrap interval is 1,189 to 1,264 ml/person/day), respectively (See Table 4–1–D1). Thus, approximately 90 percent of the children ten years of age or younger consume less than or equal to the standard default value of one liter per day.

4.6.b Ingestion of Total Water for "Consumers Only"

The most conservative water ingestion distributions for the two–day average per capita ingestion of water from all sources are by "consumers only". The estimated mean for the general population is 1,241 ml/person/day (90% confidence interval is 1,208 to 1,274 ml/person/day). The 90th and 95th percentiles are 2,345 ml/person/day (90% bootstrap interval is 2,315 to 2,378 ml/person/day) and 2,922 ml/person/day (90% bootstrap interval is 2,848 to 2,959 ml/person/day), respectively (See Table 4–2–D1). Approximately 83 percent of "consumers only" ingest less than or equal to the standard two liters/day when considering total water (See Fig. 4–2–F2). For "consumer only" infants younger than one year old, the estimated mean ingestion of total water is 563 ml/person/day (90% confidence interval is 508 to 618 ml/person/day). The 90th and 95th percentiles are 968 ml/person/day (90% bootstrap interval is 940 to 1,121 ml/person/day) and 1,236 ml/person/day (90% bootstrap interval is 1,121 to 1,282 ml/person/day), respectively. For "consumer only" children one to ten years of age, the estimated mean consumption of total water is 532 ml/person/day (90% confidence interval is 509 to 556 ml/person/day). The 90th and 95th percentiles are 1,004 ml/person/day (90% bootstrap interval is 980 to 1,030 ml/person/day) and 1,242 ml/person/day (90% bootstrap interval is 1,198 to 1,284 ml/person/day), respectively (See Table 4–2–D2). Therefore, even by the most conservative estimate (i.e., water from all sources and excluding the zero consumers), 90% of all children ten years or younger drink less than or equal to the default value of one liter of water per day.

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5. DISCUSSION

All surveys have strengths and limitations when assessed against the specific objective being addressed. There are also biases introduced in the survey process. Section 5.1 presents the strengths and limitations of the USDA's 1994–96 CSFII data for supporting the estimates reported in this document. Section 5.2 identifies and discusses sources of bias and error in the 1994–96 CSFII with respect to water ingestion estimates. Section 5.3 presents the report conclusions, and Section 5.4 provides a listing of references used in this report.

5.1 Survey Strengths and Limitations

The strengths of the USDA's 1994–96 CSFII survey for supporting estimates of per capita water ingestion are twofold. First, the survey design is structured to obtain a statistically representative sample of the United States population. Second, the survey is designed to record daily intakes of foods and nutrients and support estimation of food consumption. These features are in direct alignment with the objective of producing current, per capita water ingestion estimates for the United States population and for population subsets sensitive to potential contaminants in drinking water.

The 1994–96 CSFII survey design allows the combination of three years of data through a weighting scheme. This combination of three years provides a sample of over 15,000 respondents. With increased sample sizes, the precision and accuracy of estimates are improved and the support for subpopulation estimates is enhanced. This design structure, in conjunction with the implementation of a sampling protocol, increases the sample's representation of the United States population and minimizes seasonal and/or regional bias from respondents. Low–income individuals are oversampled to ensure their representation in the survey. Finally, the survey weight associated with each respondent's information to project the response to the population has been adjusted for nonresponse bias. These adjustments were based on sociodemographic factors. Nonresponse adjustments were also significantly reduced for the current CSFII. The response rate for participants with multiple days of food intake information is 75.9 percent for the 1994–96 CSFII, as opposed to approximately 45 percent for the 1989–91 CSFII.

The method employed to collect dietary intake data also strengthened the CSFII design for supporting per capita ingestion estimates. For example, the USDA's 1994–96 CSFII survey was administered by an interviewer on both days of data collection. This administration provided multiple passes through the day's intake to facilitate more complete responses. Previous surveys have relied on interviewer administration for the first day and self–administration on subsequent days. This change in administration method insures consistency with respect to the way responses are recorded across interview days.

Previous CSFII surveys have collected dietary intake information on consecutive days. This collection method raises issues about the contribution of within–individual variance to overall estimates. Because the 1994–96 CSFII collects data on two non–consecutive days, the within–individual variance component is diminished. The third change in data collection methods that facilitates completion of the objective of this report is that previous surveys included all members of a household in the survey. The 1994–96 survey includes a subsample of household members with sampling rates varying to achieve more responses from children and the elderly.

Another important feature of the 1994–96 CSFII that supports per capita estimation of water ingestion is the questionnaire design. The questionnaire collects data on a household's source of drinking water and water used for the preparation of foods and beverages. It also allows a respondent to indicate if water was ingested at home or away from home. This information directly supports the assignment of water source for both direct and indirect water intake. The 1994–96 CSFII Technical Support Files supported the estimation of the amount of water ingested through food. This enhances the estimation of indirect water ingestion and partitions it from water directly ingested as a beverage.

The limitations of the CSFII survey for supporting per capita ingestion estimates involve the length of time data were collected, the influence of extreme values on estimates, and the availability of information to support variance estimation. The CSFII survey collects only two non–consecutive days of data. Because daily averages are estimated from each respondent from only two days, the precision of an individual's daily average consumption is diminished. Also, the limited time period of dietary intake collection does not produce usual intake estimates. Usual intakes are defined as "the long run average of daily intakes of a dietary component by an individual." Rather, the estimates presented in this report characterize the empirical distribution of daily average per capita ingestion. Because the data from the CSFII are not usual intakes and some consumers report no direct and minimal amounts of indirect water ingestion, while other consumers report over two liters of ingestion, the empirical distribution of daily average per capita ingestion can be skewed.

Another limitation of the 1994–96 CSFII is a function of the way that survey data are reported. Data from two variance estimation units are required to generate an estimate of the variance within a variance estimation stratum. These variances are then summed across strata to generate a variance estimate for the subpopulation. For many of the subpopulations evaluated in this report, numerous strata did not have information for two variance estimation units. Because there is insufficient information in the naming convention, combining data across like strata was not possible. Therefore, the survey did not support variance estimation for many of the reported subpopulations. Because of this, means differences cannot be formally tested and interval estimates about the mean and upper percentiles cannot be supplied, except for the larger subpopulation. All reported differences are empirical as opposed to statistical. Also, certain variables, such as region, are at a summary level. USDA has named the States within a region. Estimates by State, however, are not trackable because USDA data do not contain a variable identifying States. For this reason, water ingestion estimates by State are not possible.

Statistically significant differences can be found by comparing the confidence intervals between two independent groups. If the confidence intervals for the two groups do not overlap, then the estimates for these groups are statistically significant at the 0.10 alpha level since 90% confidence intervals are reported. For example, children one to ten years old (90% confidence interval about the mean is 380 to 420 ml/person/day) ingest significantly less community water than children 11 to 19 years old (90% confidence interval about the mean is 634 to 732 ml/person/day) (See Table 4–1–B1).

A final limitation is that the survey does not support water ingestion estimates for subpopulations with different lifestyles, occupations, or activities. Examples include:

- People with traditional life styles (e.g., Native Americans and recent immigrants).
- People who live in hot climate areas.
- People who consume large amounts of water because of physical activity.
- People with health conditions that affect water ingestion, such as diabetes, kidney disease, conditions requiring rapid rehydration needs (GI upsets, food poisoning), and disorders of water and sodium metabolism.

While individuals from these specific subpopulations are included in the survey and U.S. population estimates, they were not targeted during survey design and thus do not occur in high enough frequencies to support estimate generation.

5.2 Sources of Error, Bias, and Uncertainty

All surveys contain errors despite the diligence of the design statistician and the respondents. These errors ultimately lead to bias and uncertainty in the estimates resulting from the survey's data. Some errors are quantifiable, while others are not. Random error occurs in all stochastic processes. To quantify error and bias, we must know the true population value. In reality, these are not known. In general, the estimation process assumes that the true population value is known and the error is random or partitioned to assess components of the variance. In complex surveys, these assumptions may be violated.

In general, there are three sources of error in a survey. Two of these sources involve the survey design and data collection. The third source of error is introduced during the use of the data. The following paragraphs discuss these sources of error specific to the 1994–96 USDA's CSFII survey and its use to generate the estimates presented in this report.

The first source of error is attributed to the survey design. All designs are constructed to minimize the coefficient of variation with respect to a given parameter. For the 1994–96 CSFII, the goal was to

minimize the variance of the mean Day 1 saturated fat and iron intakes. In this report, we address water ingestion. Thus, the design has not been specifically structured to minimize the coefficient of variation with respect to water ingestion. Another design error is attributed to nonresponse and the representative nature of the sample frame. The CSFII adjusts for these through its sample weights. The method USDA used to derive survey sample weights is discussed in Chapter 2 of this report. For the combined three–year sample, the USDA estimates the variance inflation factor (VIF) for two–day respondents to be 1.60. The 1994–96 CSFII documentation describes the VIF as "the proportional increase in the variance of survey estimates resulting from the variation in weights" and indicates that the VIF measures "the broadly calculated average design effect" (CSFII survey documentation, p. 5–4 and 5–5).

The second source of error is measurement error. For the CSFII, this error presents itself in the records of foods and beverages ingested by the participant. Measurement error in this case is comprised of the amount of a food or beverage consumption reported and the completeness of the reported consumption record. It is generally anticipated that food and beverage intakes are under–reported (Swan, 1983).

The third source of error is introduced when data are used. The first incidence of this occurring is in the data coding and database building by the USDA. Other sources occur during applications of data conventions. As indicated in Chapter 3 of this report, assumptions were made about sources of water and about which foods were prepared at home or by a food service establishment.

5.3 Conclusion

The purpose of this study is to provide current estimates of per capita water ingestion in the United States. Results are presented for the general U.S. population and for certain sub–populations (i.e. gender and age categories, pregnant and lactating women). The data on water ingestion were obtained from the U.S. Department of Agriculture's 1994-96 Continuing Survey of Food Intake by Individuals. The estimates report mean and percentiles from empirical distributions for both direct (plain water ingested as a beverage) and indirect water (water added to food and beverages during preparation). Commercial and natural water in the food and beverages are not included in the analysis.

Two liters/person/day has been used as the default value for water ingestion by EPA, other Federal agencies, and the WHO. This value is supported by the National Cancer Institute's report (Ershow and Cantor, 1989) based on 1977–78 survey data. The two liters included the sum of direct and indirect tap water ingestion and was the 88th percentile for the United States population when excluding pregnant and lactating women and breast–fed children.

This analysis, based on 1994–96 CSFII data, found that 90 percent of the population of the United States ingests two liters/day or less of community water. This analysis also found that approximately 83 percent of the population ingests two liters/day or less of total water (i.e., water from all sources) (See Figure 4–1–F2).

For babies younger than one year of age who ingested community water during the two survey days (i.e., "consumers only"), this analysis showed that 90 percent ingested less than or equal to one liter/day of community water. For babies who ingested water from any source during the two survey days, this analysis showed that over 90 (but less than 95) percent ingested less than or equal to one liter/day of total water.

When considering water ingestion in units of milliliters per kilogram of body weight per day, this analysis shows that the mean per capita ingestion rates for babies younger than one year are estimated to be three to four times higher than the mean rates for the population as a whole.

Our results show that pregnant women do not differ significantly in their water intake compared with women of childbearing age (age 15–44). However, lactating women ingest significantly more water than the other two groups. These conclusions are a result of comparing the confidence intervals among the three groups of women. Note, however, that the pregnant women and lactating women are included in the larger group of childbearing–age women.

The mean community water ingested by males is significantly higher than that ingested by females in all age categories except for babies younger than one year old and children one to ten years of age. The highest mean per ingestion by males is found in males in the 20 years and older age group.

A comparison of ingestion by various sources, indicates that community water comprises 75 percent of the total water ingested by individuals in the United States population, followed by bottled water which constitutes 13 percent of total water ingested while 10 percent is attributable to water from other sources.

The results presented may be used in risk assessment analyses where exposures that occur through ingestion of water are of concern. The ingestion estimates presented provide the basis for evaluation of the proportion of the population that may be affected under various exposure scenarios.

5.4 References

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