Triclosan (2,4,4’-trichloro-2’-hydroxydiphenyl ether) is a synthetic, broad-spectrum antimicrobial agent that has been used extensively for more than 20 years in a variety of consumer products, including toothpaste, mouthwash, deodorants, soap, textiles, and plastic kitchenware.

Triclosan is a synthetic chemical with broad antimicrobial activity that has been used extensively in consumer products, including personal care products, textiles, and plastic kitchenware.

Background: Triclosan is a synthetic chemical with broad antimicrobial activity that has been used extensively in consumer products, including personal care products, textiles, and plastic kitchenware.

Objectives: This study was designed to assess exposure to triclosan in a representative sample of the U.S. population from the 2003–2004 National Health and Nutrition Examination Survey (NHANES). We analyzed 2,517 urine samples using automated solid-phase extraction coupled to isotope dilution–high-performance liquid chromatography–tandem mass spectrometry.

Results: We detected concentrations of total (free plus conjugated) triclosan in 74.6% of samples at concentrations of 2.4–3,790 µg/L. The geometric mean and 95th percentile concentrations were 13.0 µg/L (12.7 µg/g creatinine) and 459.0 µg/L (363.8 µg/g creatinine), respectively. We observed a curvilinear relation between age and adjusted least square geometric mean (LSGM) concentrations of triclosan: LSGM concentrations of triclosan were higher in people in the high household income than in people in low (p < 0.01) and medium (p = 0.04) income categories.

Conclusions: In about three-quarters of urine samples analyzed as part of NHANES 2003–2004, we detected concentrations of triclosan. Concentrations differed by age and socioeconomic status but not by race/ethnicity and sex. Specifically, the concentrations of triclosan appeared to be highest during the third decade of life and among people with the highest household incomes.

Key Words: 2,4,4’-trichloro-2’-hydroxydiphenyl ether, 5-chloro-2-(2,4-dichlorophenoxy)-phenol, biomonitoring, exposure, human, Irgasan, NHANES 2003–2004, urine. Environ Health Perspect 116:303–307 (2008). doi:10.1289/ehp.10768 available via http://dx.doi.org/ [Online 7 December 2007]

Urinary Concentrations of Triclosan in the U.S. Population: 2003–2004

Antonia M. Calafat, Xiaoyun Ye, Lee-Yang Wong, John A. Reidy, and Larry L. Needham

Division of Laboratory Sciences, National Center for Environmental Health, Centers for Disease Control and Prevention, Atlanta, Georgia, USA

Address correspondence to A.M. Calafat, Division of Laboratory Sciences, National Center for Environmental Health, Centers for Disease Control and Prevention, 4770 Buford Hwy., NE, Mailstop F53, Atlanta, GA 30341 USA. Telephone: (770) 488-7891; Fax: (770) 488-4609. E-mail: Acalafat@cdc.gov

We thank J. Ekong for technical assistance, and J. Osterloh and J. Pickle for useful comments.

The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the Centers for Disease Control and Prevention.

The authors declare they have no competing financial interests.

Received 15 August 2007; accepted 6 December 2007.
Table 1. Geometric mean and selected percentiles of triclosan concentrations (µg/L [95% CI]) in urine for the U.S. population ≥ 6 years of age: data from NHANES 2003–2004.

| Variablea | Geometric mean | 10th percentile | 25th percentile | 50th percentile | 75th percentile | 90th percentile | 95th percentile | No. |
|-----------|----------------|-----------------|-----------------|----------------|----------------|----------------|----------------|-----|
| All       | 13.0 (11.6–14.6) | < LOD          | < LOD           | 9.2 (7.9–10.9) | 47.0 (37.9–58.4) | 249.0 (188.0–304.0) | 459.0 (386.0–522.0) | 2,517 |
| 6–11 years | 12.7 (11.5–14.1) | < LOD          | < LOD           | 9.5 (8.2–10.4) | 43.8 (33.8–60.2) | 212.1 (174.0–251.0) | 363.8 (294.4–462.8) | 2,514 |
| 12–19 years | 14.5 (11.0–19.1) | < LOD          | < LOD           | 7.4 (6.1–9.1) | 33.2 (27.1–39.4) | 144.0 (96.5–250.0) | 363.0 (258.0–430.0) | 1,288 |
| 20–59 years | 10.9 (9.3–14.2) | < LOD          | < LOD           | 7.4 (5.5–10.7) | 31.8 (21.9–61.1) | 193.1 (90.7–317.9) | 363.0 (258.0–430.0) | 1,286 |
| ≥ 60 years | 13.0 (8.0–13.1) | < LOD          | < LOD           | 6.5 (3.9–11.2) | 41.1 (20.9–60.9) | 197.0 (142.2–270.0) | 363.0 (249.4–500.0) | 950  |
| Female    | 12.4 (9.7–15.9) | < LOD          | < LOD           | 8.5 (6.9–10.6) | 39.8 (21.4–93.9) | 216.7 (157.5–307.8) | 382.8 (278.9–703.0) | 537  |
| Male      | 10.6 (9.3–12.1) | < LOD          | < LOD           | 7.4 (6.1–9.1) | 33.2 (27.1–39.4) | 144.0 (96.5–250.0) | 363.0 (258.0–430.0) | 1,286 |
| Male      | 12.3 (10.6–14.2) | < LOD          | < LOD           | 9.5 (8.4–10.4) | 32.3 (26.2–46.6) | 181.8 (138.3–216.7) | 331.5 (225.0–478.6) | 1,286 |
| Male      | 16.2 (13.4–19.6) | < LOD          | < LOD           | 11.7 (9.3–14.8) | 83.3 (50.6–111.0) | 310.0 (231.0–433.0) | 560.0 (418.0–595.0) | 951  |
| Male      | 13.3 (11.3–15.6) | < LOD          | < LOD           | 9.2 (6.9–12.1) | 72.5 (45.8–85.9) | 237.2 (175.3–294.4) | 384.5 (294.4–500.0) | 950  |
| Mexican American | 14.6 (10.6–20.1) | < LOD          | < LOD           | 8.7 (5.3–17.5) | 65.4 (32.8–127.0) | 354.0 (225.0–456.0) | 597.0 (372.0–992.0) | 613  |
| Non-Hispanic black | 13.3 (9.4–18.8) | < LOD          | < LOD           | 9.2 (5.5–13.9) | 66.6 (28.8–112.3) | 291.6 (150.6–432.3) | 446.0 (208.0–532.0) | 314  |
| Non-Hispanic white | 12.9 (11.2–14.9) | < LOD          | < LOD           | 9.1 (7.4–11.0) | 49.2 (37.8–63.4) | 245.0 (163.5–334.0) | 461.0 (383.0–527.0) | 1,032 |
| Non-Hispanic white | 13.3 (11.6–15.1) | < LOD          | < LOD           | 9.8 (6.1–11.5) | 47.0 (34.5–67.6) | 212.9 (159.8–272.2) | 356.0 (249.4–478.6) | 1,031 |

CI, confidence interval. Blue lines denote measure in µg/urine.
*Participants not defined by the three racial/ethnic groups shown were included only in the total population estimate. LOD = 2.3 µg/L.
children and teens model, we included BMIPCT. When both age and age-squared were in the model, to avoid multicollinearity we centered age by subtracting the mean age from each participant’s age (Bradley and Srivastava 1979). To evaluate the relation between the log-transformed concentration of triclosan and age, we estimated the weighted geometric mean and LSGM concentrations after adjusting by the other covariates in the model, and we generated a bar chart of triclosan concentrations by age group.

To reach the final model, we used backward elimination, with a threshold of $p < 0.05$ for retaining the variable in the model, using Satterwaite-adjusted $F$ statistics. We evaluated for potential confounding by adding each of the excluded variables back into the final model one by one and examining changes in the $\beta$ coefficients of the statistically significant main effects. If addition of one of these excluded variables caused a change in a $\beta$ coefficient by $\pm 10\%$, the variable was re-added to the model.

### Results

Free plus conjugated species of triclosan (total triclosan) were detected in 74.6% of the 2,517 urine samples from NHANES 2003–2004 at concentrations ranging from above 2.3 pg/L to 3,790 pg/L (2.644 pg/g creatinine). The geometric mean and 95th percentile concentrations were 13.0 pg/L (12.7 pg/g creatinine) and 459.0 pg/L (363.8 pg/g creatinine), respectively (Table 1).

The children and adolescents model included age ($p = 0.4$), age-squared ($p = 0.04$), income, log-transformed creatinine, race/ethnicity, and interaction terms between race/ethnicity and income ($p = 0.04$) and log-transformed creatinine and income ($p = 0.02$). However, the relatively low frequency of detection of triclosan (55%) in one of the combination groups (non-Hispanic whites with $\geq 20,000–45,000$ household income), although with sufficient sample size, resulted in a biased low LSGM and hence in the significant interaction term between race/ethnicity and income. Therefore, we repeated the multiple regression analyses without these interaction terms. The final model included income ($p = 0.0014$), log-transformed creatinine ($p < 0.001$), age ($p = 0.12$), and age-squared ($p = 0.014$) (Table 2). We observed both an accelerated increasing relationship between the log-transformed triclosan concentration and age ($\beta$ coefficient for age-squared = 0.006), and a linear increasing relationship between the log-transformed triclosan and creatinine concentrations ($\beta$ coefficient = 0.0002). People in the < $20,000 income group had lower LSGM (95% confidence interval (CI)) triclosan concentrations [9.3 pg/L (6.8–12.7 pg/L)] than those in the > $45,000 income group [15.7 pg/L (11.8–20.8 pg/L)]. People in the $20,000–45,000$ income group had the lowest LSGM concentrations [7.7 pg/L (5.6–10.8 pg/L)]. The frequency of detection of triclosan varied by income group [63.7% ($\leq 20,000–45,000$); 78.7% ($< 20,000$); and 76.8% ($> 45,000$)].

In the adult model, log-transformed creatinine, income, and age were significant (Table 2). Triclosan LSGM concentrations (95% CI) increased with household income and were significantly lower for people in the low household income category [10.2 pg/L (8.5–12.2 pg/L)] than for people in the medium [13.8 pg/L (10.9–17.4 pg/L); $p = 0.02$] and high [15.5 pg/L (13.7–17.5 pg/L); $p = 0.01$] income categories; the differences in LSGM concentrations between people in the medium and high household income categories were not statistically significant ($p = 0.38$). Triclosan concentrations decreased as age increased ($\beta$ coefficient = –0.004) and increased as creatinine (log-transformed) increased ($\beta$ coefficient = 0.58).

Because BMI or BMIPCT and smoking status were not significantly associated with the triclosan concentration in the models above, we combined the two models for all ages without including these variables. In the final all-ages model, log-transformed creatinine, household income, age, and age-squared were significant (Table 2). The LSGM urinary triclosan concentration (in micrograms per liter) increased as income increased: Participants in the high household income category had significantly higher LSGM (95% CI) triclosan concentrations [15.3 (13.7–17.3)] than participants in the low- [10.3 (9.1–11.6); $p < 0.01$] and medium-[12.2 (10–14.9); $p = 0.04$] income categories. However, differences in LSGM concentrations between people in the medium and lowest household income categories were not statistically significant ($p = 0.13$). The triclosan concentrations increased as creatinine (log-transformed) increased ($\beta$ coefficient = 0.63). Figure 1 shows the relationship of triclosan concentrations with age.

The univariate analyses showed that regardless of the examination session time, the geometric mean triclosan concentrations were not significantly different (all $p$-values > 0.25). Furthermore, the final multiple regression model did not include examination session time ($p = 0.22$). These results suggest that the time of collection of the sample was not associated with the urinary concentration of triclosan.

### Discussion

We detected concentrations of free plus conjugated species of triclosan in urine in 74.6% of the samples examined. This high frequency of detection is most likely associated with daily

### Table 2. $\beta$-coefficients ($p$-values) for the significant variables from the multiple regression models of the triclosan urinary concentration (log-transformed).

| Variable                      | Children and adolescents (6–19 years of age) | Adult ($\geq 20$ years of age) | All ages |
|-------------------------------|---------------------------------------------|--------------------------------|----------|
| Intercept                     | –0.51 (0.038)                               | 0.21 (0.18)                    | –0.04 (0.73) |
| Creatinine concentration      |                                             |                                |          |
| (log-transformed)             | 0.7903 (0.001)                              | 0.58 (0.001)                   | 0.63 (0.001) |
| Household income              |                                             |                                |          |
| < $20,000                     | –0.23 (0.29)                               | –0.18 (0.005)                  | –0.18 (< 0.001) |
| $20,000–$45,000               | –0.31 (0.82)                               | –0.05 (0.38)                   | –0.1 (0.04) |
| $> 45,000                     | Reference                                  | Reference                      | Reference |
| Age                           | 0.0157 (0.12)                              | –0.004 (0.003)                 | 0.002 (0.86) |
| Age-squared                   | 0.006 (0.01)                               | –0.0001 (< 0.001)              |          |

| Triclosan concentration (µg/L) | Least square geometric mean |
|-------------------------------|----------------------------|
| 10–14                         | 15                          |
| 15–19                         | 20                          |
| 20–24                         | 25                          |
| 25–29                         | 30                          |
| 30–34                         | 35                          |
| 35–39                         | 40                          |
| 40–44                         | 45                          |
| 45–49                         | 50                          |
| 50–54                         | 55                          |
| 55–59                         | 60                          |
| 60–64                         | 65                          |
| 65–69                         | 70                          |
| 70–74                         | 75                          |
| 75–79                         | 80                          |
| 80–84                         | 85                          |
| 85–89                         | 90                          |
| 90–94                         | 95                          |
| 95–99                         | 100                         |

**Figure 1.** Geometric mean and least square geometric mean concentrations of triclosan (adjusted by income, age, and log of creatinine concentrations) by age. Error bars indicate 95% CIs.
use by the U.S. general population of consumer products that contain triclosan, including at least one toothpaste brand (Food and Drug Administration 1997), skin-care products (e.g., soap, deodorant, skin cleanser), and other household products (e.g., pet care, cleaners) (National Library of Medicine 2007). In humans, triclosan can be absorbed through skin (Moss et al. 2000) and through the mucosa in the mouth and intestinal tract (Lin 2000; Sandborgh-Englund et al. 2006). The detection of triclosan in blood (Hovander et al. 2002; Sandborgh-Englund et al. 2006), urine (Sandborgh-Englund et al. 2006; Wolff et al. 2007; Ye et al. 2005), and milk (Allmyr et al. 2006) collected from small groups of persons in the United States and Sweden suggests that the general population is exposed to triclosan.

The range of urinary concentrations of triclosan in the NHANES 2003–2004 sample was wide, with 25% of persons examined having concentrations < 2.3 µg/L, and 5% of the participants having concentrations > 363.8 µg/g creatinine (Table 1). A wide distribution of concentrations of triclosan has also been reported for 10 healthy Swedish volunteers, five of whom related using personal-hygiene products that contained triclosan (Sandborgh-Englund et al. 2006). In the Swedish study, the baseline urinary excretion of triclosan (determined from 24-hr urine samples) was 0.7–43 µg/g day among people not using triclosan-containing products, and 21–218 µg/g day among users of triclosan-containing products. In another Swedish study involving a group of 36 nursing women, triclosan concentrations were higher in both plasma and milk among the women who used personal care products containing triclosan than in the women who did not (Allmyr et al. 2006). These data suggest that personal care products may be a principal source of exposure to triclosan in humans. The wide range of concentrations of triclosan may be attributable to differences in exposure, as well as to individual variations in distribution kinetics and metabolism (Sandborgh-Englund et al. 2006).

Data are limited on the urinary concentrations of triclosan in human populations. In a pilot study, triclosan was detected in 67.8% of 90 prepubertal girls, with mean age of 7.77 years, from New York City, New York; Cincinnati, Ohio; and Northern California (Wolff et al. 2007). The median concentration (5.9 µg/L) was comparable to the median concentration of triclosan for the 341 children 6–11 years of age in this NHANES 2003–2004 population (7.2 µg/L).

As is true for other nonpersistent chemicals (Fenske et al. 2005; Hauser et al. 2004; Hoppin et al. 2002; Meeker et al. 2005), within-person variability in urinary concentrations of triclosan exists. Despite this variability, results from one recent study suggest that triclosan concentrations in a single urine sample can be used to categorize the 6-month average exposure to triclosan among a group of 35 children (Teitelbaum et al. 2007). More important, concentrations based on one spot sample per person can be useful in calculating mean population concentration estimates in cross-sectional studies such as NHANES.

We observed a curvilinear-increased relation between age and triclosan LSGM concentration for people ≥ 6 years of age. For people ≥ 20 years of age, concentrations appeared to decline as age increases (Figure 1 and Table 2). This relation between age and triclosan concentration is not clearly understood, and these differences might reflect differences in lifestyle choices affecting exposure and/or pharmacokinetic factors based on age. We did not observe differences in the adjusted LSGM concentrations of triclosan based on race/ethnicity or sex. LSGM triclosan concentrations were significantly higher among people in the high household income category than among people in the medium (p = 0.04) and low (p < 0.01) income categories. These differences might reflect differences in lifestyle choices (e.g., use of personal care products) that affect exposure to triclosan.

In summary, these NHANES 2003–2004 triclosan data can be used to establish a nationally representative baseline assessment of exposure, a baseline to which the triclosan concentrations in future populations can be compared to identify exposure trends. The reported high frequency of detection of triclosan and the differences in urinary concentrations based on age and socioeconomic status highlight the importance of additional research to identify the sources and potential routes of human exposure to triclosan. In addition, these data provide exposure information that can be useful for risk assessment if toxicologic or epidemiologic studies so indicate.

REFERENCES

Adolfsson-Erici M, Pettersson M, Parkkonen J, Sturve J. 2002. Triclosan, a commonly used bactericide found in human milk and in the aquatic environment in Sweden. Chemosphere 46:1485–1489.

Aiello AE, Larson EL, Levy SB. 2007. Consumer antibacterial soaps effective or just risky? Clin Infect Dis 45:5137–5147.

Allmyr M, Adolfsson-Erici M, McLachlan MS, Sandborgh-Englund G. 2006. Triclosan in plasma and milk from Swedish nursing mothers and their exposure via personal care products. Sci Total Environ 372:87–93.

Barr DB, Wilder LC, Caudill SP, Gonzalez AJ, Needham LJ, Pirkle JL. 2005. Urinary creatinine concentrations in the U.S. population: implications for urinary biologic monitoring measurements. Environ Health Perspect 113:192–200.

Bhargava HN, Leonard PA. 1996. Triclosan: applications and safety. Am J Infect Control 24:209–218.

Bradley RA, Srivastava SS. 1979. Correlation in polynomial regression. Am Stat 33(1):14–19.
Reference range of triclosan urinary concentrations in the United States

2002. Measurement of triclosan in wastewater treatment systems. Environ Toxicol Chem 21:1323–1329.
Meeker JD, Barr DB, Ryan L, Herrick RF, Bennett DH, Bravo R, et al. 2005. Temporal variability of urinary levels of nonpersistent insecticides in adult men. J Expo Anal Environ Epidemiol 15:271–281.
Moss T, Howes D, Williams FM. 2000. Percutaneous penetration and dermal metabolism of triclosan (2,4,4'-trichloro-2'-hydroxydiphenyl ether). Food Chem Toxicol 38:361–370.
National Library of Medicine. 2007. Household Products Database. Bethesda, MD:National Library of Medicine, National Institutes of Health. Available: http://hpd.nlm.nih.gov/index.htm [accessed 4 June 2007].
Okumura T, Nishikawa Y. 5-30-1996. Gas chromatography–mass spectrometry determination of triclosans in water, sediment and fish samples via methylation with diazomethane. Anal Chim Acta 325:175–184.
Perencevich EN, Wong MT, Harris AD. 2001. National and regional assessment of the antibacterial soap market: a step toward determining the impact of prevalent antibacterial soaps. Am J Infect Control 29:281–283.
Russell AD. 2003. Biocide use and antibiotic resistance: the relevance of laboratory findings to clinical and environmental situations. Lancet Infect Dis 3:794–803.
Sandborgh-Englund G, Adolfsson-Erici M, Oatham G, Ekstrand J. 2006. Pharmacokinetics of triclosan following oral ingestion in humans. J Toxicol Environ Health Part A 69:1861–1873.
Singer H, Muller S, Tixier C, Pillonel L. 12-1-2002. Triclosan: occurrence and fate of a widely used biocide in the aquatic environment: field measurements in wastewater treatment plants, surface waters, and lake sediments. Environ Sci Technol 36:4998–5004.
Taylor JK. 1987. Quality Assurance of Chemical Measurements. Chelsea, MI:Lewis Publishers.
Teitelbaum SL, Britton JA, Calafat AM, Ye X, Silva MJ, Reidy JA, et al. 2007. Temporal variability in urinary concentrations of phthalate metabolites, phytoestrogens and phenols among minority children in the United States. Environ Res; doi:10.1016/j.envres.2007.09.010 [Online 31 October 2007].
Voldheen N, Skinrow RC, Oaschhoff H, Wigmore H, Clapson DJ, Gunderson MP, et al. 2006. The bactericidal agent triclosan modulates thyroid hormone-associated gene expression and disrupts postembryonic anuran development. Aquat Toxicol 80:217–227.
Wang LQ, Falany CN, James MD. 2004. Triclosan as a substrate and inhibitor of 3’-phosphoadenosine-5’-phosphosulfate-sulfotransferase and UDP-glucuronosyl transferase in human liver fractions. Drug Metab Dispos 32:1162–1169.
Weber DJ, Rutala WA. 2006. Use of germicides in the home and the healthcare setting: is there a relationship between germicide use and antibiotic resistance? Infect Control Hosp Epidemiol 27:1107–1119.
Wolff MS, Teitelbaum SL, Windham G, Pinney SM, Britton JA, Chelimo C, et al. 2007. Pilot study of urinary biomarkers of phytoestrogens, phthalates, and phenols in girls. Environ Health Perspect 115:116–121.
Yazdankhah SP, Scheie AA, Hoiby EA, Lunestad BT, Heir E, Fotland TG, et al. 2006. Triclosan and antimicrobial resistance in bacteria: an overview. Microbial Drug Resist Mech Epidemiol Dis 12:83–90.
Ye XY, Kulenyik Z, Needham LL, Calafat AM. 2005. Automated on-line column-switching HPLC-MS/MS method with peak focusing for the determination of nine environmental phenols in urine. Anal Chem 77:5407–5413.