

Chapter 5—Soil and Dust Ingestion

caregivers acknowledged geophagy (or more specifically, eating of clay) were ($N = 16$) ages 1 to 4 and ($N = 2$) ages 5 to 12 years. The definition of geophagy used included consumption of clay “on a regular basis over a period of weeks.” U.S. EPA is recommending this 50 g/day value for geophagy. This mean quantity is roughly consistent with a median quantity reported by Geissler et al. (1998) in a survey response study of geophagy in primary school children in Nyanza Province, Kenya (28 g/day, range 8 to 108 g/day; interquartile range 13 to 42 g/day).

Recent studies of pica among pregnant women in various U.S. locations (Corbett et al., 2003; Rainville, 1998; Smulian et al., 1995) suggest that clay geophagy among pregnant women may include children less than 21 years old (Corbett et al., 2003; Smulian et al., 1995). Smulian provides a quantitative estimate of clay consumption of approximately 200–500 g/week, for the very small number of geophagy practitioners ($N = 4$) in that study's sample ($N = 125$). If consumed on a daily basis, this quantity (approximately 30 to 70 g/day) is roughly consistent with the Vermeer and Frate (1979) estimated mean of 50 g/day.

Johns and Duquette (1991) describe use of clays in baking bread made from acorn flour, in a ratio of 1 part clay to 10 or 20 parts acorn flour, by volume, in a Native American population in California, and in Sardinia (~12 grams clay suspended in water added to 100 grams acorn). Either preparation method would add several grams of clay to the final prepared food; daily ingestion of the food would amount to several grams of clay ingested daily.

5.7. REFERENCES FOR CHAPTER 5

- ATSDR (Agency for Toxic Substances and Disease Registry). (2001). Summary report for the ATSDR soil-pica workshop, June 2000, Atlanta, Georgia. Atlanta, GA. <http://www.atsdr.cdc.gov/child/soilpica.html>
- Aufreiter, S; Hancock, R; Mahaney, W; Stambolic-Robb, A; Sanmugadas, K. (1997). Geochemistry and mineralogy of soils eaten by humans. *Int J Food Sci Nutr* 48: 293-305.
- Bartrop, D. (1966). The prevalence of pica. *Arch Pediatr Adolesc Med* 112: 116-123.
- Barnes, RM. (1990). Childhood soil ingestion: How much dirt do kids eat? *Anal Chem* 62: 1023A-1033A.
- Binder, S; Sokal, D; Maughan, D. (1986). Estimating soil ingestion: The use of tracer elements in estimating the amount of soil ingested by young children. *Arch Environ Occup Health* 41: 341-345.
- Black, K; Shalat, SL; Freeman, NCG; Jimenez, M; Donnelly, KC; Calvin, JA. (2005). Children's mouthing and food-handling behavior in an agricultural community on the US/Mexico border. *J Expo Anal Environ Epidemiol* 15: 244-251. <http://dx.doi.org/10.1038/sj.jea.7500398>.
- Bronstein, ES; Dollar, J. (1974). Pica in pregnancy. *J Med Assoc Ga* 63: 332-335.
- Bruhn, CM; Pangborn, RM. (1971). Reported incidence of pica among migrant families. *J Am Diet Assoc* 58: 417-420.
- Calabrese, EJ; Barnes, R; Stanek, EJ; Pastides, H; Gilbert, C; Veneman, P; Wang, X; Lasztity, A; Kostecki, P. (1989). How much soil do young children ingest: An epidemiological study. *Regul Toxicol Pharmacol* 10: 123-137.
- Calabrese, EJ; Stanek, EJ. (1992a). What proportion of household dust is derived from outdoor soil? *Soil Sediment Contam* 1: 253-263.
- Calabrese, EJ; Stanek, EJ. (1993). Soil pica: Not a rare event. *J Environ Sci Health A Tox Hazard Subst Environ Eng* 28: 373-384.
- Calabrese, EJ; Stanek, EJ; Barnes, R. (1997a). Soil ingestion rates in children identified by parental observation as likely high soil ingesters. *Journal of Soil Contamination* 6: 271-279. <http://dx.doi.org/10.1080/15320389709383565>.
- Calabrese, EJ; Stanek, EJ; Barnes, R; Burmaster, DE; Callahan, BG; Heath, JS; Paustenbach, D; Abraham, J; Gephart, LA. (1996). Methodology to estimate the amount and particle size of soil ingested by children: implications for exposure assessment at waste sites. *Regul Toxicol Pharmacol* 24: 264-268. <http://dx.doi.org/10.1006/rtph.1996.0139>.
- Calabrese, EJ; Stanek, EJ; Gilbert, C; Barnes, R. (1990). Preliminary adult soil ingestion estimates: Results of a pilot study. *Regul Toxicol Pharmacol* 12: 88-95.
- Calabrese, EJ; Stanek, EJ; Gilbert, CE. (1991). Evidence of soil pica behavior and quantification of soil ingested. *Hum Exp Toxicol* 10: 245-249.
- Calabrese, EJ; Stanek, EJ, III. (1995). Resolving intertracer inconsistencies in soil ingestion estimation. *Environ Health Perspect* 103: 454-457.
- Calabrese, EJ; Stanek, EJ; Pekow, P; Barnes, RM. (1997b). Soil ingestion estimates for

Chapter 5—Soil and Dust Ingestion

- children residing on a superfund site. *Ecotoxicol Environ Saf* 36: 258-268. <http://dx.doi.org/10.1006/eesa.1996.1511>.
- Calabrese, EJ; Stanek, ES. (1992b). Distinguishing outdoor soil ingestion from indoor dust ingestion in a soil pica child. *Regul Toxicol Pharmacol* 15: 83-85.
- Carlisle, EM. (1980). Biochemical and morphological changes associated with long bone abnormalities in silicon deficiency. *J Nutr* 110: 1046-1056.
- Choate, LM; Ranville, JF; Bunge, AL; Macalady, DL. (2006). Dermal adhered soil: 1. Amount and particle-size distribution. *Integr Environ Assess Manag* 2: 375-384.
- Clausing, P; Brunekreef, B; van Wijnen, JH. (1987). A method for estimating soil ingestion by children. *Int Arch Occup Environ Health* 59: 73-82.
- Cooksey, NR. (1995). Pica and olfactory craving of pregnancy: how deep are the secrets? *Birth* 22: 129-137.
- Cooper, M. (1957). Pica: A survey of the historical literature as well as reports from the fields of veterinary medicine and anthropology, the present study of pica in young children, and a discussion of its pediatric and psychological implications. Springfield, IL: Charles C. Thomas.
- Corbett, RW; Ryan, C; Weinrich, SP. (2003). Pica in pregnancy: does it affect pregnancy outcomes? *MCN Am J Matern Child Nurs* 28: 183-189; quiz 190-181.
- Danford, DE. (1982). Pica and nutrition. *Annu Rev Nutr* 2: 303-322. <http://dx.doi.org/10.1146/annurev.nu.02.070182.001511>.
- Danford, DE. (1983). Pica and zinc. In AS Prasad; AO Cavdar; GJ Brewer; PJ Aggett (Eds.), *Zinc deficiency in human subjects* (pp. 185-195). New York, NY: Alan R. Liss.
- Davis, S; Mirick, DK. (2006). Soil ingestion in children and adults in the same family. *J Expo Sci Environ Epidemiol* 16: 63-75. <http://dx.doi.org/10.1038/sj.jea.7500438>.
- Davis, S; Myers, PA; Kohler, E; Wiggins, C. (1995). Soil ingestion in children with pica: Final report. (U.S. EPA Cooperative Agreement CR 816334-01). Seattle, WA: Fred Hutchinson Cancer Research Center.
- Davis, S; Waller, P; Buschbom, R; Ballou, J; White, P. (1990). Quantitative estimates of soil ingestion in normal children between the ages of 2 and 7 years: Population-based estimates using aluminum, silicon, and titanium as soil tracer elements. *Arch Environ Health* 45: 112-122.
- Dickins, D; Ford, RN. (1942). Geophagy (Dirt Eating) Among Mississippi Negro School Children. *Am Socio Rev* 7: 59. <http://dx.doi.org/10.2307/2086258>.
- Dominy, NJ; Davoust, E; Minekus, M. (2004). Adaptive function of soil consumption: an in vitro study modeling the human stomach and small intestine. *J Exp Biol* 207: 319-324.
- Ferguson, AC; Canales, RA; Beamer, P; Auyeung, W; Key, M; Munninghoff, A; Lee, KT; Robertson, A; Leckie, JO. (2006). Video methods in the quantification of children's exposures. *J Expo Sci Environ Epidemiol* 16: 287-298. <http://dx.doi.org/10.1038/sj.jea.7500459>.
- Ferguson, JH; Keaton, AG. (1950). Studies of the diets of pregnant women in Mississippi: II diet patterns. 103: 81-87.
- Gavrelis, N; Sertkaya, A; Bertelsen, L; Cuthbertson, B; Phillips, L; Moya, J. (2011). An Analysis of the Proportion of the US Population that Ingests Soil or Other Non-Food Substances. *Hum Ecol Risk Assess* 17: 996-1012.
- Geissler, PW; Shulman, CE; Prince, RJ; Mutemi, W; Mnazi, C; Friis, H; Lowe, B. (1998). Geophagy, iron status and anaemia among pregnant women on the coast of Kenya. *Trans Roy Soc Trop Med Hyg* 92: 549-553.
- Glickman, LT; Chaudry, IU; Costantino, J; Clack, FB; Cypess, RH; Winslow, L. (1981). Pica patterns, toxocariasis, and elevated blood lead in children. *Am J Trop Med Hyg* 30: 77-80.
- Grigsby, RK; Thyer, BA; Waller, RJ; Johnston, GA. (1999). Chalk eating in middle Georgia: a culture-bound syndrome of pica? *South Med J* 92: 190-192.
- Groot, ME; Lekkerkerk, MC; Steenbekkers, LPA. (1998). Mouthing behavior of young children: An observational study. Wageningen, the Netherlands: Agricultural University.
- Gulson, BL; Mizon, KJ; Palmer, JM; Patison, N; Law, AJ; Korsch, MJ; Mahaffey, KR; Donnelly, JB. (2001). Longitudinal study of daily intake and excretion of lead in newly born infants. *Environ Res* 85: 232-245.
- Harris, SG; Harper, BL. (1997). A Native American exposure scenario. *Risk Anal* 17: 789-795.
- Hawley, JK. (1985). Assessment of health risk from exposure to contaminated soil. *Risk Anal* 5: 289-302.

Chapter 5—Soil and Dust Ingestion

- Hogan, K; Marcus, A; Smith, R; White, P. (1998). Integrated exposure uptake biokinetic model for lead in children: empirical comparisons with epidemiologic data. *Environ Health Perspect* 106: 1557-1567.
- Hooda, PS; Henry, CJ; Seyoum, TA; Armstrong, LD; Fowler, MB. (2004). The potential impact of soil ingestion on human mineral nutrition. *Sci Total Environ* 333: 75-87. <http://dx.doi.org/10.1016/j.scitotenv.2004.04.023>.
- Hook, EB. (1978). Dietary cravings and aversions during pregnancy. *Am J Clin Nutr* 31: 1355-1362.
- Hwang, YH; Bornschein, RL; Grote, J; Menrath, W; Roda, S. (1997). Environmental arsenic exposure of children around a former copper smelter site. *Environ Res* 72: 72-81. <http://dx.doi.org/10.1006/enrs.1996.3691>.
- Hyman, SL; Fisher, W; Mercugliano, M; Cataldo, MF. (1990). Children with self-injurious behavior. *Pediatrics* 85: 437-441.
- ICRP (International Commission on Radiological Protection). (2003). Basic anatomical and physiological data for use in radiological protection: Reference values. (ICRP Publication 89). New York, NY: Pergamon Press. http://www.elsevier.com/wps/find/bookdescription.cws_home/672826/description#description.
- Johns, T; Duquette, M. (1991). Detoxification and mineral supplementation as functions of geophagy. *Am J Clin Nutr* 53: 448-456.
- Jugdaohsingh, R; Anderson, SH; Tucker, KL; Elliott, H; Kiel, DP; Thompson, RP; Powell, JJ. (2002). Dietary silicon intake and absorption. *Am J Clin Nutr* 75: 887-893.
- Kinnell, HG. (1985). Pica as a feature of autism. *Br J Psychiatry* 147: 80-82.
- Kissel, JC; Shirai, JH; Richter, KY; Fenske, RA. (1998). Empirical investigation of hand-to-mouth transfer of soil. *Bull Environ Contam Toxicol* 60: 379-386.
- Klitzman, S; Sharma, A; Nicaj, L; Vitkevich, R; Leighton, J. (2002). Lead poisoning among pregnant women in New York City: risk factors and screening practices. *Bull NY Acad Med* 79: 225-237. <http://dx.doi.org/10.1093/jurban/79.2.225>.
- Korman, SH. (1990). Pica as a presenting symptom in childhood celiac disease. *Am J Clin Nutr* 51: 139-141.
- Lásztity, A; Wang, X; Viczián, M; Israel, Y; Barnes, RM. (1989). Inductively coupled plasma spectrometry in the study of childhood soil ingestion. Part 2. Recovery. *J Anal At Spectrom* 4: 737-742.
- Manton, WI; Angle, CR; Stanek, KL; Reese, YR; Kuehnemann, TJ. (2000). Acquisition and retention of lead by young children. *Environ Res* 82: 60-80. <http://dx.doi.org/10.1006/enrs.1999.4003>.
- Marmor, M; Glickman, L; Shofer, F; Faich, LA; Rosenberg, C; Cornblatt, B; Friedman, S. (1987). *Toxocara canis* infection of children: epidemiologic and neuropsychologic findings. *Am J Public Health* 77: 554-559.
- Mody, V; Jakhete, R. (1987). Chapter 1: Dust and its control. In *Dust control handbook for minerals processing*. Pittsburgh, PA: U.S. Bureau of Mines. http://www.osha.gov/dsg/topics/silicacrystalline/dust/chapter_1.html.
- NCDC (National Climatic Data Center). (2008). Data set TD3200: U.S. cooperative summary of the day data. Washington, DC: National Oceanic and Atmospheric Administration, National Environmental Satellite, Data and Information Service. Retrieved from <http://www.ncdc.noaa.gov/oa/documentlibrary/surface-doc.html#3200>
- Nelson, S; Greene, T; Ernhart, CB. (1996). *Toxocara canis* infection in preschool age children: risk factors and the cognitive development of preschool children. *Neurotoxicol Teratol* 18: 167-174.
- Obialo, CI; Crowell, AK; Wen, XJ; Conner, AC; Simmons, EL. (2001). Clay pica has no hematologic or metabolic correlate in chronic hemodialysis patients. *J Ren Nutr* 11: 32-36.
- Ozkaynak, H; Xue, J; Zartarian, VG; Glen, G; Smith, L. (2011). Modeled estimates of soil and dust ingestion rates for children. 31: 592-608. <http://dx.doi.org/10.1111/j.1539-6924.2010.01524.x>.
- Powell, JJ; Ainley, CC; Harvey, RS; Mason, IM; Kendall, MD; Sankey, EA; Dhillon, AP; Thompson, RP. (1996). Characterisation of inorganic microparticles in pigment cells of human gut associated lymphoid tissue. *Gut* 38: 390-395.
- Rainville, AJ. (1998). Pica practices of pregnant women are associated with lower maternal hemoglobin level at delivery. *J Am Diet Assoc* 98: 293-296. [http://dx.doi.org/10.1016/S0002-8223\(98\)00069-8](http://dx.doi.org/10.1016/S0002-8223(98)00069-8).
- Robischon, P. (1971). Pica practice and other hand-

Chapter 5—Soil and Dust Ingestion

- mouth behavior and children's developmental level. *Nurs Res* 20: 4-16.
- Shepherd, NA; Crocker, PR; Smith, AP; Levison, DA. (1987). Exogenous pigment in Peyer's patches. *Hum Pathol* 18: 50-54.
- Simpson, E; Mull, JD; Longley, E; East, J. (2000). Pica during pregnancy in low-income women born in Mexico. *West J Med* 173: 20-24; discussion 25.
- Smulian, JC; Motiwala, S; Sigman, RK. (1995). Pica in a rural obstetric population. *South Med J* 88: 1236-1240.
- Stanek, EJ, III; Calabrese, EJ. (1995a). Daily estimates of soil ingestion in children. *Environ Health Perspect* 103: 276-285.
- Stanek, EJ, III; Calabrese, EJ. (1995b). Soil ingestion estimates for use in site evaluations based on the best tracer method. *Hum Ecol Risk Assess* 1: 133-157. <http://dx.doi.org/10.1080/10807039509379998>.
- Stanek, EJ, III; Calabrese, EJ. (2000). Daily soil ingestion estimates for children at a superfund site. *Risk Anal* 20: 627-635.
- Stanek, EJ, III; Calabrese, EJ; Barnes, RM. (1999). Soil ingestion estimates for children in Anaconda using trace element concentrations in different particle size fractions. *Hum Ecol Risk Assess* 5: 547-558.
- Stanek, EJ, III; Calabrese, EJ; Mundt, K; Pekow, P; Yeatts, KB. (1998). Prevalence of soil mouthing/ingestion among healthy children aged 1 to 6. *Journal of Soil Contamination* 7: 227-242.
- Stanek, EJ, III; Calabrese, EJ; Zorn, M. (2001a). Biasing factors for simple soil ingestion estimates in mass balance studies of soil ingestion. *Hum Ecol Risk Assess* 7: 329-355.
- Stanek, EJ, III; Calabrese, EJ; Zorn, M. (2001b). Soil ingestion distributions for Monte Carlo risk assessment in children. *Hum Ecol Risk Assess* 7: 357-368.
- U.S. Department of Commerce. (2008). Table 2: Annual estimates of the population by sex and selected age groups for the United States: April 1, 2000 to July 1, 2007. (NC-EST2007-02).
- U.S. EPA (U.S. Environmental Protection Agency). (1994a). Guidance manual for the IEUBK model for lead in children. (EPA 540/R-93/081).
- U.S. EPA (U.S. Environmental Protection Agency). (1994b). Technical support document: Parameters and equations used in integrated exposure uptake biokinetic model for lead in children (v 099d). (EPA/540/R-94/040). Washington, DC.
- U.S. EPA (U.S. Environmental Protection Agency). (2005). Guidance on selecting age groups for monitoring and assessing childhood exposures to environmental contaminants (final). (EPA/630/P-03/003F). Washington, DC: U.S. Environmental Protection Agency, Risk Assessment Forum. <http://www.epa.gov/raf/publications/guidance-on-selecting-age-groups.htm>.
- U.S. EPA (U.S. Environmental Protection Agency). (2008). Child-specific exposure factors handbook [EPA Report]. (EPA/600/R-06/096F). Washington, DC. <http://cfpub.epa.gov/ncea/cfm/recorddisplay.cfm?deid=199243>.
- U.S. EPA (U.S. Environmental Protection Agency). (2010). SHEDS-multimedia: Details of SHEDS-multimedia version 3: ORD/NERL's model to estimate aggregate and cumulative exposures to chemicals. Research Triangle Park, NC. http://www.epa.gov/heasd/products/sheds_multimedia/sheds_mm.html.
- USDA (U.S. Department of Agriculture). (1999). Soil taxonomy: A basic system of soil classification for making and interpreting soil surveys. Washington, DC. <http://soils.usda.gov/technical/classification/taxonomy/>.
- USDA (U.S. Department of Agriculture). (2008). Web soil survey. Washington, DC. <http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm>.
- Van Dyck, K; Robberecht, H; Van Cauwenbergh, R; Van Vlaslaer, V; Deelstra, H. (2000). Indication of silicon essentiality in humans: serum concentrations in Belgian children and adults, including pregnant women. *Biol Trace Elem Res* 77: 25-32. <http://dx.doi.org/10.1385/BTER:77:1:25>.
- van Wijnen, JH; Clausen, P; Brunekreef, B. (1990). Estimated soil ingestion by children. *Environ Res* 51: 147-162.
- Vermeer, DE; Frate, DA. (1979). Geophagia in rural Mississippi: environmental and nutritional implications. *Am J Clin Nutr* 32: 2129-2135.
- Von Lindern, I; Spalinger, S; Petroysan, V; Von Braun, M. (2003). Assessing remedial effectiveness through the blood lead soil/dust lead relationship at the Bunker Hill Superfund site in the Silver Valley of Idaho.

- Sci Total Environ 303: 139-170.
[http://dx.doi.org/10.1016/S0048-9697\(02\)00352-2](http://dx.doi.org/10.1016/S0048-9697(02)00352-2).
- Ward, P; Kutner, NG. (1999). Reported pica behavior in a sample of incident dialysis patients. *J Ren Nutr* 9: 14-20.
- White, PD; Van Leeuwen, P; Davis, BD; Maddaloni, M; Hogan, KA; Marcus, AH; Elias, RW. (1998). The conceptual structure of the integrated exposure uptake biokinetic model for lead in children. *Environ Health Perspect* 6: 1513-1530.
- Wilson, MJ. (2003). Clay mineralogical and related characteristics of geophagic materials. *J Chem Ecol* 29: 1525-1547.
- Wong, EY; Shirai, JH; Garlock, TJ; Kissel, JC. (2000). Adult proxy responses to a survey of children's dermal soil contact activities. *J Expo Anal Environ Epidemiol* 10: 509-517.
- Wong, MS. (1988) The role of environmental and host behavioural factors in determining exposure to infection with *Ascaris lumbricoides* and *Trichuris trichiura*. (Doctoral Dissertation). University of the West Indies, Faculty of the Natural Sciences, Mona, Kingston, Jamaica.
- Yamamoto, N; Takahashi, Y; Yoshinaga, J; Tanaka, A; Shibata, Y. (2006). Size distributions of soil particles adhered to children's hands. *Arch Environ Contam Toxicol* 51: 157-163.
<http://dx.doi.org/10.1007/s00244-005-7012-y>.
- Zartarian, VG; Streicker, J; Rivera, A; Cornejo, CS; Molina, S; Valadez, OF; Leckie, JO. (1995). A pilot study to collect micro-activity data of two- to four-year-old farm labor children in Salinas Valley, California. *J Expo Anal Environ Epidemiol* 5: 21-34.