A Probabilistic Exposure Assessment for Children Who Contact CCA-Treated Playsets and Decks

Using the Stochastic Human Exposure and Dose Simulation Model for the Wood Preservative Exposure Scenario (SHEDS-Wood)

Draft Final Report

September 25, 2003

Prepared by

V.G. Zartarian[1], J. Xue[1], H. Özkaynak[1], W. Dang[2]
U.S. Environmental Protection Agency
[1] Office of Research and Development, National Exposure Research Laboratory
[2] Office of Pesticide Programs, Antimicrobials Division

G. Glen, L. Smith, C. Stallings
ManTech Environmental Technology, Inc.

Disclaimer
This report has undergone internal EPA review through the Office of Research and Development (ORD) and the Office of Pesticide Programs (OPP). It is currently undergoing additional external review through OPP. Thus, this report should not be considered final until it has been submitted to OPP's Scientific Advisory Panel.

Acknowledgments

We would like to thank Jonathan Chen, Timothy Leighton, Jack Housenger, Norm Cook, Doreen Aviado, and Bart Suhre of the U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxic Substances, Office of Pesticide Programs for assisting with selection of model inputs and reviewing the draft report. We would also like to thank Linda Phillips, Pat Wood, Sharon McCarthy, Nathan Mottl, and Ron Lee of Versar, Inc. for assisting with distribution fitting and model evaluation.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

ACC	American Chemistry Council
ADD	Average Daily Dose
As	Arsenic
ATSDR	Agency for Toxics Substances and Disease Registry
AWPI	American Wood Preservers Institute
BF	Bioavailability Factor
CCA	Chromated Copper Arsenate
CDF	Cumulative Density Function
CDHS	California Department of Health Services
CFA	Consumer Federation of America
CHAD	Consolidated Human Activity Database
CO	Carbon monoxide
CPSC	Consumer Product Safety Comission
Cr	Chromium
CSIS	Consumer Safety Information Sheet
Cu	Copper
EPA	Environmental Protection Agency
ERDEM	Exposure Related Dose Estimation Model
EWG	Environmental Working Group
FIFRA	Federal Insecticide, Fungicide, Rodenticide Act
FQPA	Food Quality Protection Act of 1996
GI	Gastrointestinal
GM	Geometric Mean
GSD	Geometric Standard Deviation
HBN	Healthy Building Network
IPEMA	International Play Equipment Manufacturers Association
LADD	Lifetime Average Daily Dose
NERL	National Exposure Research Laboratory
NHANES	National Health and Nutrition Examination Survey
NHAPS	National Human Activity Pattern Survey
OPPTS	Office of Prevention, Pesticides, and Toxic Substances
OPP	Office of Pesticide Programs
ORD	Office of Research and Development
PBPK	Physiologically-Based Pharmacokinetic
Pr	Probability
RAC	Raw Agricultural Commodity
RED	Re-registration Eligibility Decision
RTI	Research Triangle Institute
SA	Surface Area

SAP	Scientific Advisory Panel
SCS	Soil Contact Survey
SHEDS	Stochastic Human Exposure and Dose Simulation model
SHEDS-Wood	Stochastic Human Exposure and Dose Simulation model for the wood preservative scenario
SOPs	Standard Operating Procedures
TC (Dermal)	Transfer Coefficient
TE (Dermal)	Transfer Efficiency
USPIRG	U.S. Public Interest Research Group

The notation 'cE-b' refers to a value of 'c x 10^{-b}'.

EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency (EPA)'s Office of Research and Development (ORD), National Exposure Research Laboratory (NERL), in collaboration with the U.S. EPA's Office of Prevention, Pesticides, and Toxic Substances (OPPTS), Office of Pesticide Programs (OPP) has conducted a probabilistic exposure and dose assessment on the arsenic (As) and chromium (Cr) components of Chromated Copper Arsenate (CCA). The purpose of this assessment is to help determine the potential health risks to children from contact with CCA-treated wood in playsets and home decks and CCA-contaminated soil around these structures.

In October 2001, OPP presented a proposed deterministic exposure assessment approach, specific to Chromated Copper Arsenate (CCA), to the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) Scientific Advisory Panel (SAP). One of the primary SAP recommendations was to use a probabilistic model to predict variability of absorbed doses for the population of interest. Following the SAP meeting, OPP requested assistance from ORD in developing a probabilistic modeling methodology using NERL's physically-based, Monte Carlo probabilistic Stochastic Human Exposure and Dose Simulation (SHEDS) model. The SHEDS model was refined specifically for the wood preservative scenario, in a version called SHEDS-Wood, and the SHEDS-Wood methodology was presented to the August 30, 2002 SAP. Recommendations from both SAPs have been incorporated to the extent possible in the SHEDS-Wood code, inputs, and methodology to yield the CCA assessment presented in this report. This assessment presents results for absorbed doses (both average daily doses (ADDs) and lifetime average daily doses (LADDs)); it does not report risk estimates. OPP has conducted a separate risk analysis and written a report on children's risks to CCA using the exposure and dose results from the SHEDS-Wood analyses presented here. The CCA exposure and risk assessments will be presented to the SAP in December 2003.

The primary population of interest to OPP for this assessment was children in the United States who have the potential for frequent contact with CCA-treated wood residues and/or CCA-containing soil from public playsets (e.g., at a playground, a school, a daycare center), at a minimum. A subset of these children also contacts CCA-treated wood residues and/or CCA-containing soil from residential playsets and/or residential decks (i.e., at the child's own home or at another home). Results from both groups of children (those who contact public playsets only, and those who contact public and residential playsets) are presented in this report.

Two bounding estimate climate scenarios (warm throughout the year and cold throughout the year) were considered as well as short-term, intermediate-term, and lifetime exposure time frames. Dermal (skin) contact with, and ingestion of, arsenic and chromium in both soil and wood residues were considered for a population of children simulated using time-location-activity diaries from EPA's Consolidated Human Activity Database (CHAD). Model algorithms and input values used by SHEDS-Wood were determined by OPP and ORD. Best available data as determined by the Agency were used for SHEDS-Wood inputs, and in the instances where no data were available, best Agency-derived estimates were used.

Using the refined SHEDS-Wood methodology incorporating comments from the 2002 SAP meeting to the extent possible, the following types of analyses were conducted: (1) variability analyses to determine the range in population estimates; (2) sensitivity analyses using 2 approaches to determine key inputs contributing to predicted population variability; (3) uncertainty analyses using the bootstrap and 2-stage Monte Carlo techniques to determine key variables contributing to uncertainty in model results due to lack of knowledge in model inputs; and (4) special analyses to examine children exposed to public playsets only, age group selection, pica behavior, increased GI absorption, decreased dermal absorption, impact of reducing wood residues, and impact of hand washing after play events. Data and assumptions used in this assessment are provided in this report, in addition to the methodology, results, and discussion.

A summary of the major findings from this assessment is as follows:

- ***The SHEDS-Wood probabilistic analyses for As yielded central (i.e., mean and median) values of LADDs on the order of 10^{-6} to 10^{-5} mg/kg/day, and 95th percentiles on the order of 10^{-5} mg/kg/day (for warm and cold climate bounding scenarios).*** For children who contact playsets and decks, the LADD of As in the cold climate bounding scenario was 2.9 E-6 mg/kg/day (median); 6.0 E-6 mg/kg/day (mean); and 2.1 E-5 mg/kg/day (95%ile). The LADD of As in warm climate was: 6.1 E-6 mg/kg/day (median); 1.1 E-5 mg/kg/day (mean); and 3.9 E-5 mg/kg/day (95%ile).

- ***The SHEDS-Wood probabilistic analyses for As yielded central (i.e., mean and median) values of short- and intermediate-term ADDs on the order of 10^{-5} to 10^{-4} mg/kg/day, and 95th percentiles on the order of 10^{-4} mg/kg/day (for warm and cold climate bounding scenarios).*** The mean, median, and 95th percentiles for total intermediate-term As ADD in the cold climate bounding scenario for children exposed to both playsets and decks were 7.0 E-5 mg/kg/day, 3.1 E-5 mg/kg/day, and 2.4 E-4 mg/kg/day, respectively. The mean, median, and 95th percentiles for total intermediate-term As ADD in the warm climate bounding scenario for children exposed to both playsets and decks were 1.3 E-4 mg/kg/day, 6.8 E-5 mg/kg/day, and 4.5 E-4 mg/kg/day, respectively. For children contacting playsets and decks, the mean, median, and 95th percentiles for total short-term As ADD in cold climate were 6.7 E-5 mg/kg/day, 2.5 E-5 mg/kg/day, and 2.2 E-4 mg/kg/day, respectively. The mean, median, and 95th percentiles for total short-term ADD in warm climate were 1.3 E-4 mg/kg/day, 6.5 E-5 mg/kg/day, and 4.7 E-4 mg/kg/day, respectively.

- ***The SHEDS-Wood probabilistic analyses for Cr yielded central (i.e., mean and median) values of short- and intermediate-term ADDs on the order of 10^{-5} to 10^{-4} mg/kg/day, and 95th percentiles on the order of 10^{-4} mg/kg/day (for warm and cold climate bounding scenarios).*** For children who contact both playsets and decks, the mean, median, and 95th percentiles for total intermediate-term Cr ADD in cold climate were 7.4 E-5 mg/kg/day, 3.4 E-5 mg/kg/day, and 2.6 E-4 mg/kg/day, respectively. The mean, median, and 95th percentiles for total intermediate-term Cr ADD in warm climate were 1.2 E-4 mg/kg/day, 5.9 E-5 mg/kg/day, and 4.4 E-4 mg/kg/day, respectively. For children who contact both playsets and decks, the mean, median, and 95th percentiles for total short-term Cr ADD in cold climate were 6.9 E-5 mg/kg/day, 3.0E-5 mg/kg/day, and 2.5 E-4 mg/kg/day, respectively. The mean, median, and 95th percentiles for total short-term Cr ADD in warm climate were 1.2 E-4 mg/kg/day, 5.6 E-5 mg/kg/day, and 4.3 E-4 mg/kg/day, respectively.

- ***The most significant exposure route for the population of interest for most scenarios (As and Cr, warm and cold scenarios, all time periods) was residue ingestion via hand-to-mouth contact, followed by dermal residue contact, soil ingestion, and dermal soil contact.*** Children with doses in the upper tails of the population distribution exhibited higher contact with public playsets, wood residues, dermal transfer coefficients, and GI absorption for residues, and fewer hand washings per day. The soil ingestion pathway became more important than residue ingestion when residues were assumed to be reduced by 90% or 99.5%.

- ***Four of the highest ranked variables that appeared in both sensitivity and uncertainty analyses were: wood surface residue-to-skin transfer efficiency; wood surface residue levels; fraction of hand surface area mouthed per mouthing event; and GI absorption fraction for residues.*** Other important variables for sensitivity analyses include average number of days per year a child plays around CCA-treated playsets and frequency of hand washing. Other key variables for uncertainty analyses include daily soil ingestion rate, average fraction of non-residential time a child plays on/around CCA-treated playsets, and frequency of hand washing.

- ***In general, there were 2-3 orders of magnitude in variability of predicted population dose estimates, and a factor of 4 in the uncertainty of predicted population dose estimates.*** The population variability was due primarily to variability in activity patterns, in wood residues, and in exposure and dose factors related to the residue ingestion route. The uncertainty results were due primarily to uncertainty in the key variables (e.g., wood surface residue-to-skin transfer efficiency; wood surface residue levels; fraction of hand surface area mouthed per mouthing event; and GI absorption fraction for residues). Data were available for most of the key model inputs identified with sensitivity and uncertainty analyses; however, there were few or no data for many inputs. In particular, information specific to average number of days per year a child plays on or around a residential or public CCA-treated playset or a home deck was not available. Similarly, information was not available on the fraction of time a child is actually contacting a CCA treated playset or deck when he or she is on or around a CCA treated playset or deck. Very limited data were available on pica soil ingestion rates of children which could be used to quantify short or long-term pica soil ingestion rates of the studied population. Multi-day and multi-year time-activity diaries for young children and spatial and temporal variability of soil and residue concentrations were also poorly known. Thus, to evaluate and improve the accuracy of model results, it is important for future studies to obtain longitudinal time- activity diary information on children and collect spatial and temporal measurements of residue and soil concentrations on or near CCA treated playsets and decks.

- ***Special simulations conducted to examine children exposed to public playsets only, age group selection, pica behavior, increased GI absorption, decreased dermal absorption, impact of reducing wood residues, and hand washing after play events did not significantly impact the baseline results, except for the impact of greatly reducing wood residues.***

  - Dose values for children exposed only to public playsets were similar to those for children without decks and to the playset component of the dose for children with decks.
  - Assuming that 7-13 year-olds have 25%, 50%, 75%, 100% the absolute CCA absorbed dose (before adjusting for body weight) of 1-6 year-olds doses, the total As LADD in mg/kg/day (warm climate bounding scenario) is 1.1, 1.2, 1.3, and 1.4 times higher for 1-13 year-olds than for 1-6 year-olds, respectively, based on the mean and median.
  - Children with pica soil ingestion behavior have about 2-3 times higher absorbed mean dose (totaled over all pathways considered) of As as non-pica children from CCA-treated playsets and decks.
  - Assuming a mean As relative bioavailability of 100% rather than 27% results in doses that are about 1.8 times higher.
  - Assuming a mean As dermal absorption rate of 0.01% rather than 3%: For children without decks in the warm climate scenario, the mean and median LADD were 37% and 33% lower, respectively, for the children with lower assumed dermal absorption rate. For children with decks in the warm climate scenario, the mean and median LADD were 30% and 26% lower, respectively, for the children with lower assumed dermal absorption rate. For children without decks in the cold climate scenario, the mean and median LADD were 8% and 23% lower, respectively, for the children with lower assumed dermal absorption rate. For children with decks in the cold climate scenario, the mean and median LADD were 11% and 7% lower, respectively, for the children with lower assumed dermal absorption rate.
  - For children who contact both playsets and decks, the mean and median LADD were both reduced by a factor of 6 when residues were reduced by 90%. For children without decks, the mean LADD was reduced by a factor of 7 and the median by a factor of 6 when playset residues only were reduced by 90%.
  - For children who contact both playsets and decks, the mean LADD was reduced by a factor of 14 and the median by a factor of 17 when residues were reduced by 99.5%. For children without decks, the mean LADD was reduced by a factor of 11 and the median by a factor of 13 when residues were reduced by 99.5%.
  - For children who contact both playsets and decks, the total mean and median LADD were reduced by a factor of 1.3, respectively, assuming hand washing following exposure. For children without decks, the reduction factors were 1.7 for the mean and 1.4 for the median.
  - For children who contact both playsets and decks, the total mean and median LADDs were reduced by a factor of 7, assuming 90% residue reduction and hand washing following exposure. For children without decks, the reduction factors for the mean and median were 7 and 6, respectively.
  - For children who contact both playsets and decks, the total mean and median LADDs were reduced by factors of 12 and 18, respectively, assuming 99.5% residue reduction and hand washing following exposure. For children without decks, the reduction factors for the mean and median were 11 and 15, respectively.

- ***SHEDS-Wood CCA probabilistic results compare well to a deterministic CCA assessment conducted by Gradient Corporation, and SHEDS-Wood upper percentiles compare well to deterministic Consumer Product Safety Commission estimates.*** SHEDS-Wood variability results (bounding estimates for warm and cold climates), based on inputs and algorithms developed independently of the other models, are within a factor of 2 of the Gradient (2001) results for all pathways and aggregate dose. The upper percentiles for the SHEDS-Wood warm climate scenario are close to the CPSC results for the residue ingestion pathway considered by CPSC. CDHS (1987) results appear to be higher than the others because the single term combining surface concentrations, hand area, and transfer efficiency is higher than the comparable product in the other models. Roberts and Ochoa (2001) results appear to be higher than the other model results in part because they assume exposure 365 days per year. EWG (2001) results appear to be higher than the SHEDS-Wood results because of assumed replenishment of residues on hands after dermal contact, higher assumed relative bioavailability of residues, and higher assumed soil ingestion rates. Exponent (2001) results appear to be lower than other model results because they only allow one contact day per year, whereas the other models have a typical range of 50-150 contact days. Multiplying the Exponent residue ingestion result by 100 gives results that are close to the other model results.

INTRODUCTION

Chromated Copper Arsenate (CCA) wood preservatives containing Chromium (Cr), Copper (Cu), and Arsenic (As) as pesticidal compounds protect wood from deterioration. They are predominantly used to pressure treat lumber intended for outdoor use in constructing a variety of residential landscape and building structures, as well as home, school, and community playground equipment. Children may potentially be exposed to the pesticide residues remaining on the surfaces of the treated wood structures as well as the residues leached into the surrounding soil. The U.S. Environmental Protection Agency (EPA) is aware of increased concerns raised by the general public and state regulatory agencies regarding the safety of CCA-treated wood for residential applications. The children's exposure and dose assessment presented herein evaluates exposure routes and pathways anticipated as realistic, considering activity patterns and behavior of young children near residential playsets, public playsets, and residential decks. Children's exposure may occur through touching CCA-treated wood and CCA-contaminated soil near treated wood structures, mouthing hands after touching CCA-treated wood, and eating CCA-contaminated soil. Since the EPA determined that the As and Cr components of CCA pose the most significant toxicity concerns in comparison to Cu, which is not a recognized or suspected carcinogen, the Agency focused on evaluating potential adverse short-, intermediate-, and lifetime exposures and non-cancer/cancer risks to children from As (non-cancer and cancer) as total As, and from Cr (non-cancer only) as total Cr (Cr (VI) is undetectable from existing residue studies (ACC, 2003a)). The SHEDS (Stochastic Human Exposure and Dose Simulation) model developed by the EPA's Office of Research and Development (ORD), National Exposure Research Laboratory (NERL) was selected by the EPA's Office of Prevention, Pesticides, and Toxic Substances (OPPTS), Office of Pesticide Programs (OPP) to conduct the probabilistic children's exposure and dose assessment for CCA that is presented in this report.

BACKGROUND

History of CCA Issue

Inorganic arsenic is a known Group A carcinogen and hexavalent chromium (VI) is a probable carcinogen through the inhalation route. Regulatory actions involving inorganic arsenical wood preservatives, including CCA, began nearly 25 years ago. An administrative review process was initiated in 1978 to consider whether the registration of certain wood preservative chemicals (pentachlorophenol; coal tar, creosote and coal tar neutral oil; and inorganic arsenicals) should be canceled or modified. An Amended Notice of Intent to Cancel announcing these changes was published in the Federal Register of January 10, 1986 (Vol. 51, No. 7). The wood preservative industry agreed to a voluntary Consumer Safety Information Sheet (CSIS) to educate consumers in proper use, handling, and precautionary practices for treated wood. In 2002, EPA recommended that the revised CSIS be attached on treated wood to warn the consumer of the risk of exposure to carcinogenic arsenic from treated wood.

In October, 2001 OPP submitted a preliminary deterministic exposure assessment for selective internal/external peer review comment as an interim report intended to address child residential "playground" exposures exclusively and seeking guidance from the FIFRA Scientific Advisory Panel (SAP). The panel recommended that OPP perform a more comprehensive assessment by using a probabilistic model which would provide to risk assessors and managers information about high-end population percentiles for regulatory decision making, as well as identification of data gaps for further data collection efforts and model refinement and evaluation.

This assessment is separate from the review of occupational exposures to CCA. The EPA is near completion of this evaluation under the reregistration process within OPP. Once OPP completes the reregistration review for CCA, it will release the Reregistration Eligibility Decision (RED) document for Chromated Arsenicals, which will include a more comprehensive assessment of the potential human and environmental exposures/risks attributed to the use of CCA-treated wood and related inorganic chromated arsenical pesticides. It is anticipated that the outcome of OPP's human health assessment will be pivotal in the risk management and reregistration eligibility decisions for CCA.

On March 17, 2003 the US Consumer Product Safety Commission (CPSC) held a Commission Briefing to respond to the petition from the Environmental Working Group (EWG) and the Healthy Building Network (HBN) to ban the CCA treated wood being used in playground equipment and review the safety of CCA-treated wood for general use. After briefing the Commissioners and the public on their deterministic risk assessment, CPSC deferred their decision on the petition pending the final EPA decision. On March 17, 2003 the registrants of CCA wood preservatives signed an agreement with the EPA for voluntary cancellation of treated wood for residential use effective December 31, 2003. Nationwide, however, approximately 70% of single family homes have existing pressure-treated decks and porches (Shook and Eastin, 1996), and approximately 14% of public playground equipment is made with treated wood (not necessarily all CCA-treated, however; CFA and US PIRG, 2002). The potential for exposure to pesticide residues remaining on the surfaces of the existing aged treated wood structures as well as to the residues leached into the surrounding soil still poses child health hazard concerns.

Stochastic Human Exposure and Dose Simulation (SHEDS) Model

Overview of SHEDS Model

The SHEDS model, developed by EPA's Office of Research and Development, National Exposure Research Laboratory, is a probabilistic, physically-based model that simulates aggregate human exposures and doses (i.e., via inhalation, dietary, dermal, and non-dietary routes) for population cohorts and multi-media, multipathway chemicals of interest. SHEDS-related research has been in development since 1998, with the first publication on the SHEDS model for pesticides (SHEDS-Pesticides) in 2000 (Zartarian et al., 2000a). A number of technical presentations on SHEDS research have been made at various national and international conferences and workshops (Özkaynak and Zartarian, 1999; Özkaynak et al., 1999; Zartarian et al., 1999a,b; 2000b; 2001a, b, c; Zartarian et al., 2002 b, c, d).

At the request of OPP in November, 2001, NERL developed a modified stand-alone version of SHEDS, called SHEDS-Wood, specifically for the wood preservative scenario. This uses the same general approach as the aggregate SHEDS model, but focuses on children's exposure and absorbed dose to wood preservatives on playsets and decks via the dermal and non-dietary ingestion routes, which are relevant to the CCA analysis. For the August 30, 2002 OPP FIFRA SAP, the SHEDS-Wood Version 1 code, a user-friendly interface, and a technical and user manual were prepared (Zartarian et al., 2002a; Stallings et al., 2002).

Figure 1 illustrates the general approach of the SHEDS-Wood model. SHEDS-Wood simulates individuals from the user-specified population cohort by selecting daily sequential time/location/activity diaries from surveys contained in EPA’s Consolidated Human Activity Database (CHAD). CHAD diaries are generally recorded for 1 or several days. To simulate longitudinal activity patterns, SHEDS-Wood simulates, for each individual in an age-gender cohort, 365 days by sampling 8 CHAD diaries representing 1 person from each of 4 seasons and 1 person from each of 2 day categories (weekend and weekday); fixing 5 weekday dairies and 2 weekend diaries; and then repeating the 7 day activity patterns within each season. Note that while the diaries are repeated, the exposure contacts are determined randomly day-to-day as a subset of suitable diary activities, and therefore do not generally repeat. The specification of exposure events over the year is based on user-specified information.

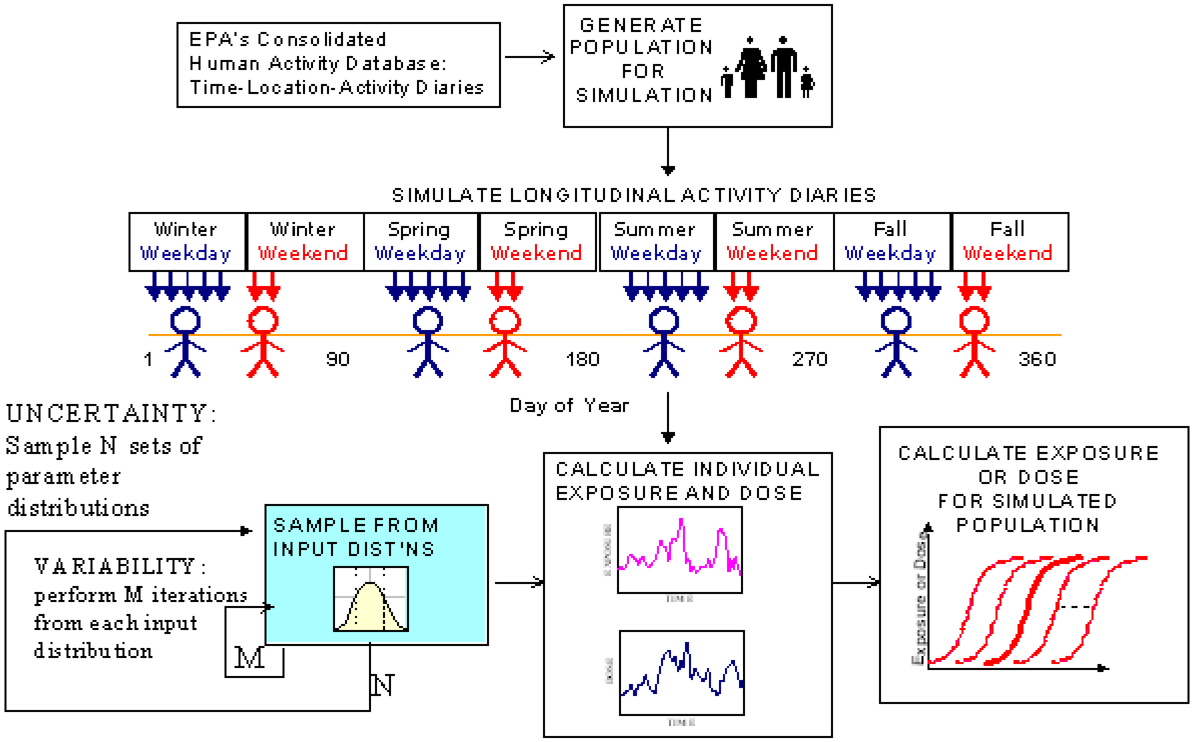


Figure 1. General SHEDS model approach.

Exposure time series are then computed as the basis of the SHEDS-Wood exposure and dose calculations. These can be displayed as plots of instantaneous exposure (mass, concentration, or mass loading at the external human boundary) against time. The time series preserve within-day peaks and variability as an individual moves throughout his or her day. These exposure profiles can yield toxicologically relevant dose profiles, and ultimately, improved risk estimates. The exposure profiles can be constructed separately for the dermal contact and non-dietary ingestion pathways. The time step is the duration of the CHAD diary location-activity combinations (1 minute to 1 hour).

Environmental media residues and concentrations are sampled and assigned for every exposure event for a given individual whose exposures and doses are simulated. Using pathway-specific exposure equations, SHEDS-Wood then combines, for each activity and location, the assigned residue values with randomly sampled exposure factors from their probability distributions, thus generating longitudinal multi-day exposure profiles for each pathway. These estimates are combined with daily absorption rates to obtain pathway-specific absorbed dose profiles. Once the dose profiles are obtained, they can be summed across routes and pathways to yield an individual's aggregate dose profile for the chemical of interest.

Metrics of interest (e.g., peak, time-averaged, time-integrated) are extracted from the individual's profiles, and the process is repeated thousands of times using Monte Carlo sampling to obtain population distributions. This approach allows identification of the relative importance of routes, pathways, and model inputs. Sensitivity analyses are conducted using stepwise regression and correlation methods to identify the relative importance of different routes and model inputs. Uncertainty analyses are conducted on input variables for which uncertainty distributions are provided. Model evaluation is conducted by comparing SHEDS model results against other model estimates and available exposure and/or biomonitoring data.

SHEDS-Wood considers both variability and uncertainty in model inputs and outputs. Cullen and Frey (1999) distinguish between variability and uncertainty as follows. Variability is defined as the heterogeneity of values over time (e.g., hand-to-mouth frequency), space (e.g., soil concentrations), or different members of a population (e.g., body weight). Uncertainty is defined as the lack of knowledge about the "true" value of a quantity, lack of knowledge about which of several alternative model representations best describes a biological/chemical/physical/other mechanism of interest, or lack of knowledge about which of several alternative probability density functions should represent a quantity of interest. In SHEDS-Wood, 'variability' refers to the spread of exposure and dose estimates (primarily ADD and LADD) across the simulated individuals; 'uncertainty' refers to the effects on exposure and dose of the lack of knowledge about inputs.

The SHEDS-Wood user has the option of conducting single stage Monte Carlo sampling to assess the variability in exposure or dose for a population of interest (expressed as population percentiles), or two-stage Monte Carlo sampling to evaluate uncertainty along with variability (expressed as a range of values for each percentile). Generally, a model run in two-stage Monte Carlo sampling consists of generating N simulations each comprised of M iterations, which produces a family of N predicted distributions of population exposures and doses. The entire process of a single sampling of uncertain parameters, followed by repeated sampling from the variability parameters, is referred to as a simulation (MacIntosh et al., 1995). For the CCA wood assessment, SHEDS utilized a bootstrap approach (see Methods section) to establish the uncertainty distributions. In the first stage, for each input variable, one parameter pair was drawn from the distribution generated from multiple bootstrap runs. In the second stage, repeated samples were drawn from distributions defined by the parameter pairs selected in the first stage.

The SHEDS-Wood Version 1 methodology went through a successful SAP model review August 30, 2002. As indicated in the following section, the 2002 SAP meeting comments (panel and public) have been incorporated for SHEDS-Wood Version 2, which has been applied as part of OPP's risk assessment for CCA-treated wood (Dang, 2003). The algorithms, methods, inputs, and results for the CCA exposure and dose assessment are discussed in this report.

Advantages of SHEDS-Wood Model

SHEDS is one of the few aggregate probabilistic exposure models that has been developed to help address EPA requirements under the Food Quality Protection Act of 1996 (FQPA). For making regulatory decisions about pesticides (including wood preservatives) OPP's approach has been to evaluate and use all modeling tools that are appropriately peer reviewed and that use criteria stated in existing policy documents. SHEDS-Wood was selected for the CCA assessment because it underwent a formal SAP model review and was developed specifically to address the wood preservative exposure scenario. Other deterministic models have been developed to assess children's exposures and doses to CCA-treated wood (CDHS, 1987; Exponent 2001; EWG 2001; Gradient Corporation 2001; CPSC 2003a; Roberts and Ochoa, 2001). There are a number of advantages of SHEDS-Wood including the following:

- uses a probabilistic approach as recommended by the 2001 SAP (SHEDS was one of the recommended models)
- addresses both variability and uncertainty in model inputs and outputs (other models recommended by the 2001 SAP can not currently perform a multi-dimensional analysis separating variability and uncertainty)
- generates time series of exposure with high resolution of results (order of minutes to hours) that can linked to physiologically-based pharmacokinetic (PBPK) models for dose estimation and that preserve variance/covariance structure that would be helpful in a full aggregate assessment
- accounts for dermal removal by bathing and washing, and dermal carryover from one event to the next
- links hand-to-mouth ingestion with dermal hand exposure
- allows for assessing impact of exposure reduction scenarios such as reduced residues and hand washing after play events
- set up to incorporate data from future diary surveys designed to collect more specific information on activities related to deck and playset contact.
- comprehensive sensitivity analyses allow for identification of critical model inputs and factors contributing the most to model predictions.

The results of SHEDS-Wood for the CCA assessment presented in this report are for absorbed doses (both average daily doses (ADDs) and lifetime average daily doses (LADDs)), not risk estimates. OPP has used these SHEDS-Wood ADD and LADD results as part of a separate risk analysis and written a corresponding report (Dang, 2003) on children's projected risks to CCA. The results in this exposure report will also be used in the Agency to help identify additional data needs for future wood preservative exposure and dose assessments.

Changes to SHEDS-Wood Since the August 30 2002 SAP Meeting

The SAP recommendations in FIFRA SAP (2001) and FIFRA SAP (2002) were incorporated into this assessment to the extent possible and provided the justification for developing a probabilistic modeling assessment methodology for the wood preservative exposure scenario. Public comments from the 2002 SAP meeting were also addressed to the extent possible. Tables 1 and 2 summarize the changes to the SHEDS-Wood code and the analyses conducted since the 2002 SAP meeting, respectively. Appendix 1 provides a summary of the 2002 SAP comments and how they were addressed in the revised version of SHEDS-Wood.

Table 1. Summary of SHEDS-Wood Code Changes Since August 2002 SAP Meeting

Code Changes to Address SAP Panel Member Comments

- Use new probabilities, based on Los Angeles Harvard longitudinal data, for switching between high, medium, and low potential exposure categories (based on outdoor time).
- Let the user fix the start date for a given simulation that will be set the same for all people, to preserve season-specific differences.
- Allow use of Beta, Weibull, and Gamma distributions.
- Revise body weight and surface area equations based on NHANES III to update the body weight and hand size monthly rather than annually.
- For residue dermal exposures, replace the transfer efficiency and fraction of skin contacted per time with user-specified distributions.
- Change the SHEDS-Wood approach for bathing events by allowing a variable number of days between baths.
- Uncertainty analyses now sample parameter pairs, rather than independently sampling each parameter.
- GI tract voiding now occurs at 6 a.m. as opposed to midnight.

Code Changes to Address Internal ORD Review

- Check the maximum dermal load once per time step. Add counters to record how often the maximum is exceeded and how much chemical is removed.
- Drop references to SHEDS-Wood input variable for deck/playset co-occurrence.
- Revise hand-mouth transfer equation for deck and playset residue to include exponential function.
- Revise dermal exposure equations to include fraction of total body surface area that is unclothed, and fraction of bare skin contacting soil and residues per time.
- Check that each simulated child has the potential for contact with playsets away from home.
- On wood contact days, select a subset of the potential outdoor time contact events to actually become contacts and apply new methodology for assigning fraction of contact time for each contact event.
- Alter mapping from CHAD locations to SHEDS-Wood categories, to include daycare centers as possible contact locations and remove a number of other CHAD locations for potential playset contact where playsets are unlikely to be found.
- Alter the definition of seasons in SHEDS-Wood to correspond to calendar seasons.
- Include a tracking variable to compare SHEDS-Wood estimates of daily absorption (dermal and GI) versus user-specified inputs for daily absorption rate
- Maximum dermal loading is now based on surface concentrations and transfer efficiency.

Code Changes to Address Public Comments

- Insert a check to verify that each assembled composite diary has some time outdoors away from home (i.e., "oth_out" time). If not, then delete it and construct a new one.
- Allow separate dermal absorption fractions for soil and residues.

Note: For certain sensitivity, uncertainty, and special analyses, the model code was slightly altered to effect these runs. These alterations are not included as part of the baseline SHEDS-Wood model code and therefore are not listed in this table.

Table 2. Summary of Analyses Conducted Since August 2002 SAP Meeting.

Analyses to Address SAP Panel Member Comments

- Examine impact of geographic location and season in CHAD diaries on time spent outdoors.
- Examine absorbed dose profiles for lowest and highest exposed children to see differences and assess whether the extremes are reasonable.
- Conduct analyses for children 1-13 years to assess sensitivity of age group on results.
- Conduct simulations to assess impact of input distribution selection.
- Conduct sensitivity analyses by fixing an activity diary
- Conduct separate analysis for children who exhibit pica soil ingestion behavior.
- Conduct sensitivity analyses by varying each variable up or down by 1 standard deviation.
- Compare distribution of total time outdoors for 1 to 6 year-olds in CHAD against total time outdoors for children 1 to 6 years who specified that they spent time outdoors in playgrounds.
- Conduct analyses to show how composite 1-year diaries are generated with respect to consistency of high, medium, and low potential exposure groups (within year and year-to-year).
- Conduct sensitivity analyses on distributions used for key inputs.
- Examine the impact of removing the intercept from the regression in sensitivity analyses.
- Justify sample size for bootstrap sampling
- Justify use of 8 diaries for longitudinal activity patterns

Analyses to Address Public Comments

- Assess stability of model results based on sample sizes used for variability
- Compare SHEDS-Wood model/results to other models/results

Additional Analyses Conducted by ORD

- Examine impact of lowering dermal absorption and increasing GI absorption based on new data
- Examine impact of exposure mitigation scenarios (hand washing, wood residue reduction, combination)
- Assess effects of change to the maximum dermal loading
- Compare results for children exposed to public playsets only to those also exposed to residential CCA treated wood.

METHODS

Overview of the SHEDS-Wood Modeling Approach for CCA

Details of the SHEDS-Wood methodology for the CCA assessment are described in the following sections. The information is organized in terms of model scenarios, approach, algorithms, selected input values, and methods used for analyses of model results. Sensitivity and uncertainty of SHEDS-Wood model results and comparison of variability results to those provided by earlier CCA modeling analyses performed by other independent groups are subsequently presented.

Model scenarios for the CCA analysis selected here represent 1 to 6 year-old children who contact As or Cr residues from CCA-treated public playsets and/or CCA-containing soil resulting from these playsets. A subset of these children also contacts home playsets or decks with CCA residues and/or CCA-containing soil around these residential structures. The CCA analysis is performed for both the warm and cold climate bounding scenarios in estimating short-term, intermediate-term, and lifetime (for As) absorbed doses resulting from: dermal contact with As or Cr residues on CCA treated playsets or decks; dermal contact with As or Cr in CCA-containing soil around treated playsets or decks; ingestion of CCA containing soil near treated playsets or decks; and ingestion of wood residues from CCA treated playsets and decks, via the hand-to-mouth pathway.

SHEDS-Wood calculates the predicted exposure and dose to As and Cr using age and gender representative time-location-activity diaries for 1-6 year old children. The diaries are organized sequentially in order to assign the daily exposures of each simulated child to As and Cr residues from CCA-treated playsets or decks over a multi-year exposure period. Time-location-activity diaries are selected from EPA's CHAD database to represent weekday and weekend exposure patterns of children by season, age and gender group over the course of a year. The diaries are further classified in terms of high, medium, and low potential exposure categories based on reported time spent outdoors. These categories are used to allow more consistent matching of children's diaries across different seasons and years based on typical behavior of children in terms of their outdoor activities. Each of the diaries selected represents different macroactivities of children over the course of a 24-hour period. These macroactivities typically last a few minutes to an hour, during which time potential contact with a CCA-treated playset or deck may occur. The macroactivities reported in CHAD are not sufficiently detailed to indicate exactly when contact with CCA-treated wood occurs. Therefore, the model establishes contact probabilistically in a subset of the macroactivities that take place in suitable locations (such as playgrounds). Pathway-specific exposure and dose time profiles are then generated from the sequence of contact events. The sequential processing of diaries allows the modeling of dynamic uptake and removal processes from the skin and GI tract of As and Cr. The time profiles are aggregated to daily values to calculate short-term, intermediate-term, and lifetime dose.

SHEDS-Wood allows the user flexibility in the specification of scenarios through the setting of input descriptors. These include variables that determine when contact occurs, the concentrations on wood surfaces and in nearby soil, the amount transferred to the skin and ingested, and the absorption rates. These variables are represented in terms of probability distributions. While in certain cases it may be desirable to allow correlations between model inputs, the available studies tend to focus on individual variables rather than joint distributions. Thus, most inputs to SHEDS-Wood are assumed to be independent because of this lack of data.

In general, a variability analysis is conducted by randomly generating individuals in age-gender categories on a population-weighted basis. Values for input variables are determined by single stage Monte Carlo sampling from the user-specified variability distributions. While any sample selected this way would be a random sample from the population, larger sample sizes produce a clearer picture of the population variability. Model results are provided both with statistical summary tables showing means, medians, and selected percentiles, and figures displaying predicted cumulative density functions (CDFs). Results are then analyzed in order to determine the dominant pathways and model inputs.

Sensitivity analyses examine the effects of input variables on the results. Various approaches were employed, including systematic adjustment of individual input variables, stepwise regression, and correlation analysis. Two methods of systematic adjustment (both up and down) were chosen; inputs were adjusted by a factor of two with one method and by a factor of one standard deviation with the other.

SHEDS-Wood uses the two stage Monte Carlo sampling capability described above to quantify uncertainty in model estimates. In the CCA application, estimates of the uncertainty in the parameters of input variables were derived using a bootstrap approach. Each uncertainty iteration alters the set of parameters for the probability distribution for every input variable. Two stage Monte Carlo sampling is computationally intensive due to the need to generate a large number of variability distributions. For example, if 1000 individuals are used in the stage one sampling (the variability distribution), and the second stage uses 500 sets of input distributions; then 500,000 simulated individuals must be generated.

The graphical analysis of uncertainty takes two forms. One involves displaying three complete variability distributions (CDFs), namely the variability distributions corresponding to the 5^{th}, 50^{th}, and 95^{th} percentile as ranked by their medians. The horizontal axis represents percentiles of the population variability. The vertical distances between the three curves represent uncertainty in each percentile of the variability distribution. The other type of graph displays three selected variability percentiles (the 5^{th}, 50^{th}, and 95^{th}) from each of the 300 uncertainty runs. Here the horizontal axis represents percentiles of the uncertainty distribution, while the vertical separation between the curves measures variability.

Special analyses were handled by SHEDS-Wood in the CCA assessment on a case by case basis, usually without changing the model code. Most commonly, a specific input variable was altered in a pre-defined manner to account for some hypothetical action. For example, the potential effect of sealants to CCA-treated wood was modeled by reducing wood residue concentrations.

Model Scenarios for CCA Study

Population Definition

The primary population of interest to OPP for this assessment was children in the United States who might frequently contact CCA-treated wood residues and/or CCA-containing soil from public playsets (e.g., at a playground, a school, a daycare center), at a minimum. A subset of these children also contacts CCA-treated wood residues and/or CCA-containing soil from residential playsets and/or residential decks (i.e., at the child's own home or at another home). Results from both groups of children (those who contact public playsets only, and those who contact public and residential playsets) are presented in this report.

EPA's focus is on estimating the risk to children from various primary sources of CCA-treated wood that children may contact. The population considered in this assessment, with public playsets as the primary focus and residential as the secondary focus, was selected for several reasons. It is believed that more young children are exposed to CCA-treated public playsets than residential playsets because of more potential time on public playsets at schools and daycare centers; thus, public playsets may affect a larger population of children. There are also more data available for public playsets than residential playsets. Further, the particular focus by CPSC and other groups has been playground playsets.

We do not know whether (or how) children's activity patterns are different from activity diaries used by SHEDS-Wood for certain high-risk groups (e.g., children with autism, Down syndrome). If they are not different, then the upper tails of the SHEDS-Wood distributions may reflect these cases. If they are different, we do not have activity data to adequately address these special groups at this time. A separate analysis, however, was conducted for children with pica soil ingestion behavior and is presented in this report.

Age Group Selection

The deterministic OPP assessment presented to the SAP in 2001 (FIFRA SAP, 2001) assumed an exposure duration of 6 years spent on playgrounds over a lifetime as a central tendency value, based on EPA Risk Assessment Guidance for Superfund (US EPA, 2001a). The California Department of Health Services (CDHS) assumed children visit playgrounds over an 8-year period (CDHS, 1987). Exponent (2001) assumed the most appropriate age range to assess potential risks for a playground scenario would be 1-12 years. The Consumer Product Safety Commission (CPSC, 2003a) assumed that children are likely to play on playground equipment between the ages of 2-12 years, but defined "critical playground users", i.e., "the most 'at risk' group" to be children aged 2 to 6 years because children most likely to ingest CCA wood residues from hand-to-mouth contact are younger than 7 years based on Freeman et al. (2001).

The primary age group considered in this probabilistic assessment is 1-6 year-old children because of limited activity data and presumed limited activity on playsets from 0-1 year, and because of presumed lower mouthing behavior for children older than 6 years. However, as suggested by the August 2002 SAP, analyses were conducted (for the lifetime probabilistic As scenario) for children 1-13 years to assess the sensitivity of selected age group on model results. The SHEDS-Wood code was designed to handle different input distributions for hand-to-mouth frequency and hand washing frequency; however, the small sample sizes necessitated using the same distribution for each age between 1 and 6 years. Body weights are varied in the model monthly. Model inputs and results for the age group sensitivity analysis are given in the Special Analyses sections below.

Upper and Lower Bound Climate Scenarios

Because of data limitations, time-location-activity diaries in EPA's CHAD (Consolidated Human Activity Database; McCurdy et al., 2000; http://www.epa.gov/chadnet1) used to simulate the population in SHEDS-Wood can not guarantee that the model is correctly representing the target population's conditional distributions (i.e., given age and gender) for region (urban, suburban, rural), climate, likelihood of contact (based on home type, school and preschool attendance, use of parks and areas with structures, etc.), and other personal exposure-related behaviors. Because geographic location is related to seasonal temperature, time spent outdoors, clothing habits, and a number of other factors affecting SHEDS-Wood results, analyses were conducted using a mixed effects model to examine the impact of geographic location and season in CHAD diaries on time spent outdoors. It was found that the total sample size for children 1-13 years is 7680, and 5071 of these (67%) are missing state information. Although CHAD diaries are stratified by season for each 1-year simulation per person, there are not enough data to support stratification by the other variables listed above.

Given this lack of data, the current approach is to conduct separate "warm climate" and "cold climate" simulations, modifying inputs such as surface area of unclothed skin and time spent on playsets and decks. Because these inputs are not specified for different seasons (since temperature in seasons is location-dependent), the warm climate and cold climate model runs represent two extremes for non-zero exposure: warm climate clothing and time on playsets/decks throughout the year, or cold climate clothing and time on playsets/decks throughout the year. Thus, they can be considered "bounding" scenarios. For cold climate scenarios it was assumed that children spend fewer days per year on/around treated wood, and that only hands and face are exposed; for warm climate scenarios it was assumed that children spend more time on/around treated wood, and that hands, face, arms, legs, and sometimes feet and torso are exposed. While these assumptions may not be realistic for all areas of the U.S., they suggest bounding estimates for the entire U.S. population of children. More data for activity patterns in each state would allow us to refine the SHEDS-Wood model and generate analyses that reflect geography-dependent exposures more realistically.

Time Periods

For the CCA assessment presented in this report, three exposure time periods were considered: short-term (represented in SHEDS-Wood by a 15 day averaging time), intermediate-term (represented in SHEDS-Wood by a 90 day averaging time), and lifetime (6 or 13 years of exposure over a 75-year lifetime).

Exposure Pathways

According to CPSC (2003a), based on data provided by the American Chemistry Council (ACC) and the American Wood Preservers Institute (AWPI) in a public comment to CPSC on September 11, 2001, the primary uses of CCA-Treated Lumber are outdoor decks (32%), marine applications (16%), and landscaping including playground equipment (12%). Other possible sources of exposure to CCA according to this report are highway materials (9%), fencing (8%), house framing (6%), utility poles (5%), permanent wood foundations (1%), pilings (1%), other (e.g., bed liners for utility trailers, cooling towers, shoring for excavations) (8%), and export (2%). It has also been reported that ~1% of all CCA-treated wood is used specifically for playground equipment (US EPA, transcript of the SAP Open Meeting, October 23, 2001, Volume I, p. 39) and that 14% of all public playsets are made of wood that may be pressure treated (CFA and USPIRG, 2002). For the SHEDS-Wood CCA assessment, uses of CCA on wood structures were considered in conjunction with children's activities (i.e., primary sources of CCA-treated wood that children typically contact) to select decks and playground equipment as the sources considered.

There are eight primary exposure pathways considered in SHEDS-Wood: dermal soil contact near decks; dermal residue contact from decks; soil ingestion near decks; residue ingestion from decks (via the wood-to-hand-to-mouth pathway); dermal soil contact near playsets; dermal residue contact from playsets; soil ingestion near playsets; and residue ingestion from playsets (via the wood-to-hand-to-mouth pathway). Dermal exposure can also be computed separately for hands and body, and results can be aggregated for decks and playsets, as well as over all pathways. As pointed out by the CPSC (2003a), it is possible in extreme cases that pre-schoolers may occasionally directly mouth portions of a wood play structure, though this behavior is not likely to be frequent for most playground users. Inhalation exposure to particulates for children present during sandblasting of CCA-treated surfaces is another potential pathway. Such less common pathways are not included in the CCA assessment presented in this report. Other potential sources of exposure not included in this assessment or in CCA assessments by other risk assessors include picnic tables, porch railings and uprights, contact with pets and objects that have contacted treated wood, and tracked-in residues and soil containing CCA.

SHEDS-Wood Approach for Computing Exposure and Dose

Generating the Simulated Population of Interest with CHAD Diaries

The SHEDS-Wood model simulates individuals by selecting daily sequential time-location-activity diaries from surveys contained in EPA's CHAD (Consolidated Human Activity Database; http://www.epa.gov/chadnet1; McCurdy et al., 2000), weighted by age and gender using weights from the U.S. Census (U.S. Census Bureau, 2000). Age and gender variables are used because they are important predictors for time spent outdoors (Graham and McCurdy, 2003). Other variables were not used because only a few are common across all CHAD surveys and because finer divisions would reduce the number of diaries available for random sampling.

Because the population of primary interest to OPP here is children who contact CCA-treated wood, and because the sample size in CHAD for children with reported time in playgrounds was too small for modeling, all CHAD diaries for children ages 1 to 6 years with reported time outdoors, (approximately 200 children in each age-gender cohort) were provided to SHEDS-Wood. The distribution of total reported time outdoors for 1 to 13 year-olds in CHAD was compared against total time outdoors for 1 to 13 year-olds who specified that they spent time outdoors in playgrounds (the assumption is that children who visit playgrounds represent children in the population of interest). These two distributions were similar in shape and magnitude (Figure 2), which justifies the use of all diaries with reported time outdoors.

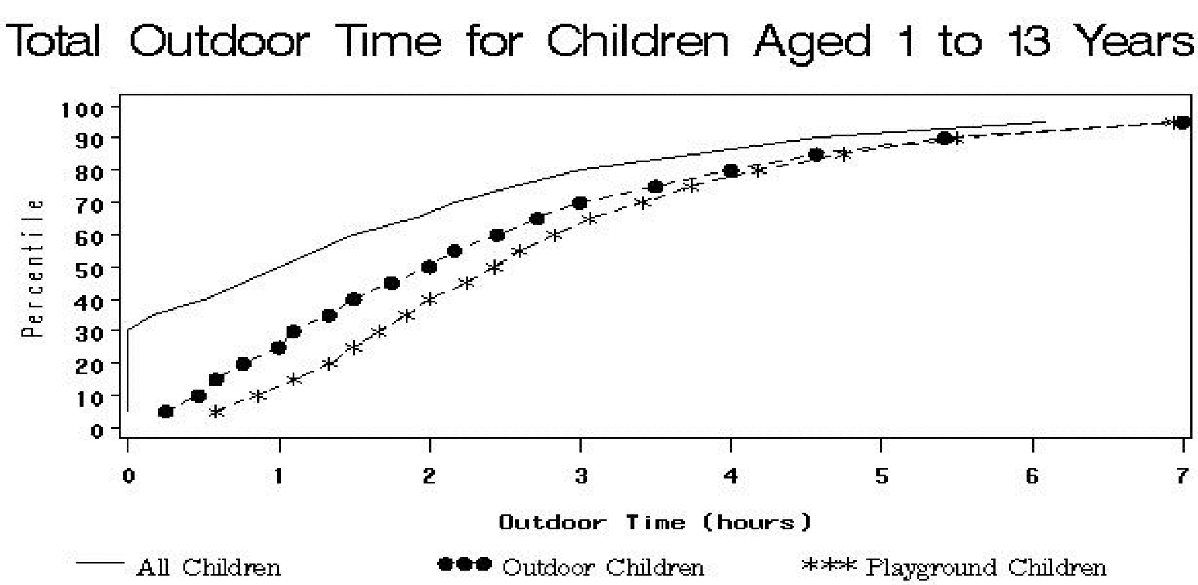


Figure 2. Comparison of Outdoor Time for CHAD Children with Reported Outdoor Time versus CHAD Children With Reported Playground Time.

Summary of CHAD information on playground activities

There are four studies in CHAD that provide children's diaries for ages 1-6 years: (1) University of Michigan (http://www.isr.umich.edu/frc/childevelopment/home.html), 61% of available diaries for ages 1-6 years; (2) National Human Activity Pattern Survey (NHAPS; Klepeis et al., 1995; Tsang and Klepeis 1996), 18%; (3) California children's study (Wiley et al., 1991),15%; and (4) Cincinnati study (Johnson, 1989), 6%. The Michigan study reported time in outdoor locations away from home, but did not divide this any further. This study had a very large number of activity codes, but none that describe the use of playsets or other specific playground activities.

The NHAPS study location codes that are relevant to playgrounds include 'Time spent on school grounds or playgrounds' and 'Time spent in other outdoor locations'. Only 4% of the NHAPS children's diaries report any time in 'school grounds or playgrounds'. If parks are included, a total of 9.6% of children visit one or the other. Using NHAPS activity codes, 25% of the children report at least one event of type 80, which includes any of the following activities: Sports lessons; Football, basketball, baseball, and similar sports; tennis, squash, and similar racket games; swimming and water sports; skiing, skating, roller skating; frisbee, catch, playing at playground; boxing, wrestling; gymnastics; golf, miniature golf; bowling, pool, ping pong pinball; yoga; hiking, walking for pleasure; cycling; horseback riding; march in parades. Without any differentiation among these activities, it is difficult to estimate the amount of playground time. The number of children who report this activity category while in parks, school grounds or playgrounds is 4% (28 out of 706 children).

The California children's study used a coding system much like NHAPS. The relevant location codes are 34=park or playground; and 40=other outdoor location. The likely activity codes are 80=outdoor sports, 81=outdoor leisure, 811=unspecified outdoor play. 44% of children had one or more code 80 events, 1.2% had code 81, and 35% had code 811. Using location codes, 34.4% had code 34 and 11% had code 40, and 40.3% had one or the other. For the combination of activity and location, 18.2% of diary days had at least one event with activity code 80 in either location 34 or 40, and 9% had code 811 in 34 or 40. Most of the code 80 events are team sports of one kind or another, so perhaps at most 10% of the children engaged in unspecified play in parks or playgrounds.

The Cincinnati data were oriented to CO (carbon monoxide) exposure, and focused on indoor and in-vehicle locations. All outdoor locations were lumped together. The activities were originally handwritten by the respondents and are not available. These were coded into categories relevant to CO exposure. The categories that might contain playset activity are 'Active sports, games, and exercise' and 'Other active leisure'. Note that the majority of respondents in Cincinnati were adults and so the categories do not reflect activities specific to children.

Reporting children's contact with playground equipment was only incidental (at best) for all the studies in CHAD. The disparate nature of these studies is reflected in the wide variability of the playground visitation statistics given above. Based on this examination, it was concluded that CHAD was inadequate for estimating the time children spend using playsets (see the "average # days/yr a child plays on/around a residential CCA-treated playset" section below).

Classification into "High", "Medium," or "Low" Potential Exposure Categories

The potential for exposure to CCA-treated products is assumed to be higher for diaries with larger amounts of time in outdoor locations. It is known (Xue et al., 2003) that longitudinal activity patterns for children show autocorrelation in the amounts of outdoor time from day to day. Therefore, both the activity diaries and the simulated children were stratified into three categories, namely "high-", "medium-", or "low-" potential exposure, based on total time outdoors. The available diaries that form each cohort pool (a combination of age, gender, season, and weekend/weekday) are ranked in SHEDS-Wood by their outdoor time; the top one-third become the 'high' group, the middle one-third are the 'medium' group, and the bottom one-third are the 'low' group.

Before any diary is selected, each simulated child for a given age and gender is randomly assigned with equal probability (1/3) to the 'high', 'medium', or 'low' potential exposure category. This reflects the overall behavioral tendency for that child. However, this does not imply that the child has a correspondingly high (or medium, or low) outdoor time on every day of the year. If children remained within their designated group on every day of the simulation, the result would be a tri-modal distribution of mean exposure, with a cluster of exposures around the mean for each group. Instead, it is recognized that a child belonging to the 'high' group will tend to have a high outdoor time on most days, but not all days. However, a child is assigned to the same category from one year to the next.

To assess these category shift probabilities, the results from a Harvard time activity dataset for total outdoor time (Xue et al., 2003) were analyzed; the study contained multiple, sequential days of data for each child. First, the children were classified into high, medium, and low groups, based on the total outdoor time over the entire study. Then the data were re-analyzed to determine how frequently children in each of the three overall groups were in the top, middle, and lowest thirds of outdoor time on any given day. It was found, for example, that children who were in the 'high' group overall had a 48% chance of being in the top one-third on any given day, while having a 34% chance of being in the middle third on any given day, and an 18% chance of being in the lowest one-third on any given day. The full set of probabilities used in SHEDS-Wood are those shown in Table 3.

The SHEDS-Wood approach is a compromise between assigning a child to a group and never departing from it (thus generating a population exposure profile with three modes) versus resampling the activity group daily (thus always generating an "average" child over the course of a year). Based on the probabilities in Table 3 SHEDS-Wood allows different diary types (high, medium, or low) to be chosen for weekends and weekdays within a season and allows them to change from season to season. This method of modeling behavioral tendencies leads to a wider, more realistic variability in exposure among children than would be found if the diaries were randomly drawn without regard to outdoor time, yet does not result in the creation of three distinct clusters in the exposure distribution. The three groups overlap, so that children in the 'high' group may sometimes receive lower exposures than some of the highest children from the 'middle' group. An example of how this scheme is executed in the model is provided in the next section.

Table 3. Probabilities for Assigning Children to Low, Medium, or High Potential Exposure Categories

	Probability for low outdoor time on given day	Probability for median outdoor time on given day	Probability for high outdoor time on given day
Low yearly average time outdoors	0.52	0.32	0.16
Medium yearly average time outdoors	0.30	0.38	0.32
High yearly average time outdoors	0.18	0.34	0.48

Generating 1-Year Activity Patterns for Individuals

To estimate longitudinal exposures and doses in SHEDS-Wood, longitudinal (1 year and beyond) activity patterns are required. However, most of the studies in CHAD are cross-sectional, representing snapshots of one day's activities in a person's life. This poses challenges for simulating longitudinal activity patterns. Two extreme options are to assume either an individual has the same activity pattern every day of the year or to assume independent activities over consecutive days. The alternate approach taken by SHEDS-Wood is intended to better represent both intra- and inter-person variability (Figure 3). Eight CHAD diaries from the same age-gender cohort are used to simulate a child's year. These eight diaries consist of two from each of the four seasons, one sampled on a weekend and the other on a weekday (Monday-Friday). Note that since there are roughly 200 diaries per age-gender cohort, and these are divided into 24 categories (3 outdoor time groupings * 4 seasons * weekend/weekday), each category only averages about 8 available diaries for selection. For each child that is modeled, one diary is selected for winter weekday, one for winter weekend, then one for spring weekday, and so on. These diaries must match age and gender, and are randomly selected from the 'high', 'medium', or 'low' potential exposure groups using the probability table discussed earlier. For a multi-year simulation, this process is repeated each year

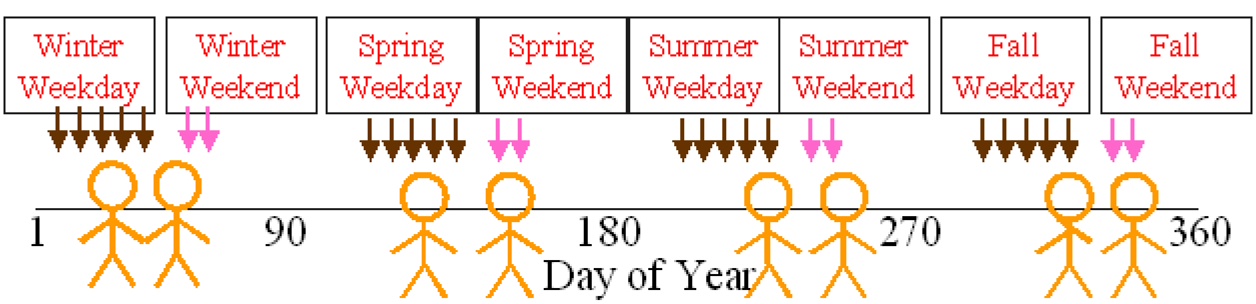


Figure 3. SHEDS approach for simulating one-year activity patterns.

using the appropriate diaries for that age group.

For example, suppose a lifetime simulation is conducted. Each child is randomly assigned a gender using the population weights, and is randomly assigned to one of the ‘high’, ’medium’, or ‘low’ potential exposure groups (1/3 chance for each). For specificity, suppose a child is selected to be female and ‘high’ potential exposure. The child starts at age 1 year and first is assigned a diary selected from all available winter weekday diaries for 1-year-old females. There is a 48% chance that the selected diary will be drawn from the top one-third of these diaries as ranked by their outdoor time, a 34% chance of drawing one of the diaries ranked in the middle third, and an 18% chance of drawing one of the diaries ranked in the lowest one-third. Similar draws are made independent of the previous ones for the other seven season-day type combinations for the given age (1 year old).

A composite activity diary is assembled from these eight by concatenating copies according to the season and weekdays on the calendar. For simulation periods shorter than one year, the start date is selected at random, subject to the requirement that the stop date occurs within the same year. Continuing with the previous example (a lifetime simulation for a female), if January 1 falls on Monday, then a copy of the selected winter weekday diary is used. The next four days will use copies of the same diary, followed by two copies of the selected winter weekend diary. This pattern is repeated until the season changes, at which point the diaries selected for spring are used. The composite activity diary for age 1 year will consist of 365 (or 366) days of activities, although only eight distinct daily patterns are used. Similarly, another eight diaries are selected and assembled into a full year for age 2 years, but none of these diaries will be the same as those used for age 1 year since distinct (non-overlapping) diary pools are used for each year of age.

For assembling longitudinal diaries, Xue et al. (2003) suggest that eight days per year spread evenly across seasons is a reasonable number to use in that it captures most of the relationship between intra- and inter-personal variability with respect to daily time spent outdoors, based on a Southern California study of 160 children. Day of week (that is, weekend or weekday) and season of year are the most important variables for compiling a longitudinal diary.

It is important to note that while the same CHAD diary is used repeatedly within a year, this does not mean that the contacts with treated wood are the same from day to day. As explained below, a random subset of the potential contact time with playsets and/or decks becomes simulated contact time, and this subset varies from day to day.

Assigning Contact Days for Individuals

The method of assembling CHAD diaries into a year-long activity diary creates a variable number of contact days (i.e., days in which the child contacts a playset or deck). Because the model is being applied to a population which by definition has contact during a year with non-home playsets at a minimum, any year-long diaries with no “public playset locations” (i.e., those ‘non-home outdoors’ CHAD location codes in which public playsets may be present (Table 4)) are eliminated, and another diary is generated. This could occur if none of the 8 diaries used to generate the 1-year activity profile contain any time spent in possible public playset locations.

The number of public playset contact days per year in SHEDS-Wood depends on two things: (1) the number of days with time in a possible public playset location; and (2) the probability of contact actually occuring on those diary days. The average one-year CHAD diary for 1-6 year-olds has 185 days with possible public playset time, ranging from 25 to 366 days (with 366 days corresponding to all 8 diaries containing public playset time, in a leap year). These numbers represent possible contact days; the user sets the fraction of possible contact days that become simulated contact days. The second condition is randomly determined, based on the input variable "average number of days per year with public playset contacts." If this is set to 126 (as in the warm climate CCA scenario), then each day with possible public playset time has a 126/185 chance of being an actual contact day (about 68%). In this manner, some diaries will end up with few or no contact days and some with more than 126, but the mode of the distribution for a large number of simulated individuals will be 126 per year. If it is set to 54 (as in the cold scenario), then each day with public playset time has a 54/185 chance of being an actual contact day (about 29%). 185 is the largest possible value for the mean number of public playset contact days across all 1-6 year-old CHAD children, although individual children may have more (up to 366 contact days).

Table 4. CHAD Locations Assumed as Locations for Potential Playset Contact

Location Code	Location Description
Suitable CHAD locations for home deck or home playset contact	
30200	Residence, outdoor
30210	Your residence, outdoor
30219	Your residence, other outdoor
30220	Other's residence, outdoor
30229	Other's residence, other outdoor
Suitable CHAD locations for public (non-home) playset contact	
32800	Childcare facility
32810	Childcare facility, house
32820	Childcare facility, commercial
35000	Other outdoor, general
35100	Sidewalk / street / neighborhood
35110	Within 10 yards of street
35500	Amusement park
35600	School grounds / playgrounds
35610	School grounds
35620	Playground
35800	Park / golf course
35810	Park
36300	Other outdoor

For home decks and home playsets, a similar approach is taken for determining contact days. That is, for diaries with outdoor residential locations, probability of contact occurring on those days is determined by the user-specified average number of days per year contacting decks or home playsets divided by 260, the average number of days per year with a non-zero amount of suitable time (meaning time in CHAD locations in which home deck or home playset contact may occur; see Table 4). This means the user may set the mean number of deck and/or home playset contact days to any number between zero and 260. Again, individual children are not limited to 260 and may have up to the full 365 contact days per year.

Assigning Exposure Events within a Contact Day for Individuals

An exposure event is defined as a CHAD "macroactivity" location in which simulated contact with a playset and/or a deck occurs. Exposure is defined here as contact between the chemical and the person, expressed as mass at contact site (skin, GI tract). Exposure events have varying duration, between 1 and 60 minutes (the average event while a child is awake lasts 30 minutes). If individuals have both decks and playsets at home, then both can be contacted within the same macroactivity, but the total contact time cannot exceed the duration of the event. The CHAD diaries are not detailed enough to indicate all playset or deck contacts, so these must be randomly generated as a subset of the macroactivity events that occur in suitable locations (i.e., CHAD locations with potential exposure to a home playset, public playset, or home deck). The SHEDS-Wood model utilizes user-supplied inputs to determine the frequency of deck and playset contacts.

For each 1-year diary, the model steps through the sequence of diary activities in chronological order, assigning exposure events based on the diaries and the relevant model inputs. SHEDS-Wood includes ten inputs that affect the likelihood of contact days and exposure events within contact days. These are shown in Table 5.

On each contact day (meaning a day which has non-zero time in locations assumed to have a playset or deck and that passes the probability check, as described above), there may be one or perhaps several macroactivity events in suitable locations. If there is only one suitable macroactivity, then by necessity it must be an exposure event. If there are several, then some but not necessarily all of them will become exposure events. This is determined randomly day to day, based on the number of suitable events and the fraction of suitable time that is to be exposure time. Therefore, even though the same CHAD diary is used for several calendar days, the number and the duration of exposure events may vary from day to day.

Table 5. Summary of SHEDS-Wood Variables That Affect Likelihood of Contact Events

Variable	Meaning
playsetHm_pr	Probability of a child having a CCA-treated playset at home
deck_pr	Probability of a child having a CCA-treated deck at home
playdayaw_day	Average number of days per year with contact with non-home playsets
playdayhm_day	Average number of days per year with contact with home playsets
deckday_day	Average number of days per year with contact with home decks
playtimeaw_pr	Fraction of time in suitable locations spent on/near non-home playsets
playtimehm_pr	Fraction of time in suitable locations spent on/near home playsets
decktimehm_pr	Fraction of time in suitable locations spent on/near home decks
playtimesurfCt_pr	Fraction of time on/near playset that is on playset (as opposed to near)
decktimesurfCt_pr	Fraction of time on/near deck that is on deck (as opposed to near)

Within a single diary day, the actual contact events are determined randomly; they are a subset of the diary events in suitable locations. The method attempts to balance three considerations: (1) the average contact time per day should match the amount requested by the user; (2) the contacts should vary from day to day, even if the same CHAD diary is used; (3) on days with a large number of events in suitable locations for contact, the number of actual contact events should be kept relatively small. For each diary event in a suitable location for contact, two decisions must be made. The first is whether any contact occurs or not. The second, if the first decision indicates contact, is the fraction of the event duration that is to be designated as contact time.

Let N be the number of macroactivity events in suitable locations on a given day; this is not user specifiable but is determined from the selected CHAD diary. Let F be the user-specified fraction of time in suitable locations that is to become contact time. There are actually three values for F, one for public playsets (sampled from the input distribution for ‘playtimeaw_pr’), one for home playsets (sampled from ‘playtimehm_pr’), and the final one for home decks (sampled from ‘decktimehm_pr’). The three checks are independent, except as noted below. For each check, there are three cases, depending on the number of suitable diary events for the particular type of contact (public playset, home playset, or deck) on the given diary day. If N<=2, a time fraction F of each suitable event is labeled as contact time. If 2<N<6, each suitable event has a probability of F^0.5 of being designated as a contact, and similarly the fraction of the event duration that becomes contact time is also F^0.5. For N>=6, the probability for a suitable event to be an exposure event is F, and the entire duration of the selected events becomes contact time. Since contact is probabilistic, a special case occurs if the final event of the day is reached without any prior contacts. Then, the final event must be a contact event in order to ensure that a designated contact day actually has a contact. In this case, the contact time is set to a fraction F of the event duration.

These rules ensure that every designated contact day has at least one exposure event, and that over the day, the contact time averages a fraction F of the time in suitable locations, for any values of N and F. These rules are intended to prevent a large number of short duration contacts from being realized. For instance, if N=10 and F=0.5, then these rules give a probability of 0.5 for each suitable event becoming a contact event, and each contact lasts the full event duration. If instead N=4 and F=0.5, then each suitable event has a probability of 0.71 of becoming a contact event, and if it does, then 71% of the event duration becomes contact time. Finally, if there is only one suitable event on the diary day, then it has a 100% chance of becoming a contact event (since this day has already been selected as a contact day), and 50% of the event duration becomes contact time. In all these cases, the contact time averages 50% of the total time in suitable locations, in agreement with the value of F. The only exception to these rules comes when a child has both a home deck and a home playset; the exception occurs as follows: (a) the given diary day is selected as a contact day for both; (b) a single diary event is selected as a contact event for both the playset and the deck; and (c) the sum of the two contact times as determined above exceeds the total event duration. In this case, the contact times are reduced so that they sum to the event duration, since it is assumed that the child cannot be contacting both simultaneously.

The probabilities listed above are conditional on the event being possible. For example, the average number of days per year with deck contact is the average over only those children who actually have a home deck. The ones without decks are not included in this probability. Similarly, the fractions of time only apply on days when contact is already determined to have occurred. For example, if 'playtimeaw_pr' were set to 0.3, this would mean that on a day designated for non-home playset contact, then (on average) 30% of the time spent in suitable locations would be spent on or near a CCA-treated playset. On non-contact days the fraction is obviously 0%, even if some time is spent in suitable locations on the diary. The last two variables listed in Table 5 divide the contact time into contact with wood surface residues (when 'on') and contact time with contaminated soils (when 'near').

Modeling an Individual's Exposure and Dose Time Profiles

Exposure time profiles (i.e., time series) for individuals are the basis of the SHEDS-Wood exposure and absorbed dose calculations. These can be viewed as plots of instantaneous exposure against time that preserve within-day peaks and variation through time as an individual moves throughout his or her day (Figure 4). The SHEDS-Wood approach of tracking exposures and various removal processes through time allows for the development of a more complete picture of the source-to-dose relationship. For example, the effect of changes in behavior such as the frequency and timing of hand washing and bathing events on the exposure-dose relationship can be investigated. Also, the generation of exposure time profiles that preserve variability of an individual's exposure within a day allows for estimation of dose via pharmacokinetic (PK) or physiologically-based pharmacokinetic (PBPK) models. The 2002 SAP recommended using the absorption fraction approach rather than a PK or PBPK model for the CCA assessment. Thus, for this SHEDS-Wood assessment route-specific daily absorption fractions were applied to each route-specific exposure profile to obtain absorbed dose profiles. Absorbed dose is defined here as the amount of chemical entering the blood after dermal and/or gastrointestinal (GI) absorption.

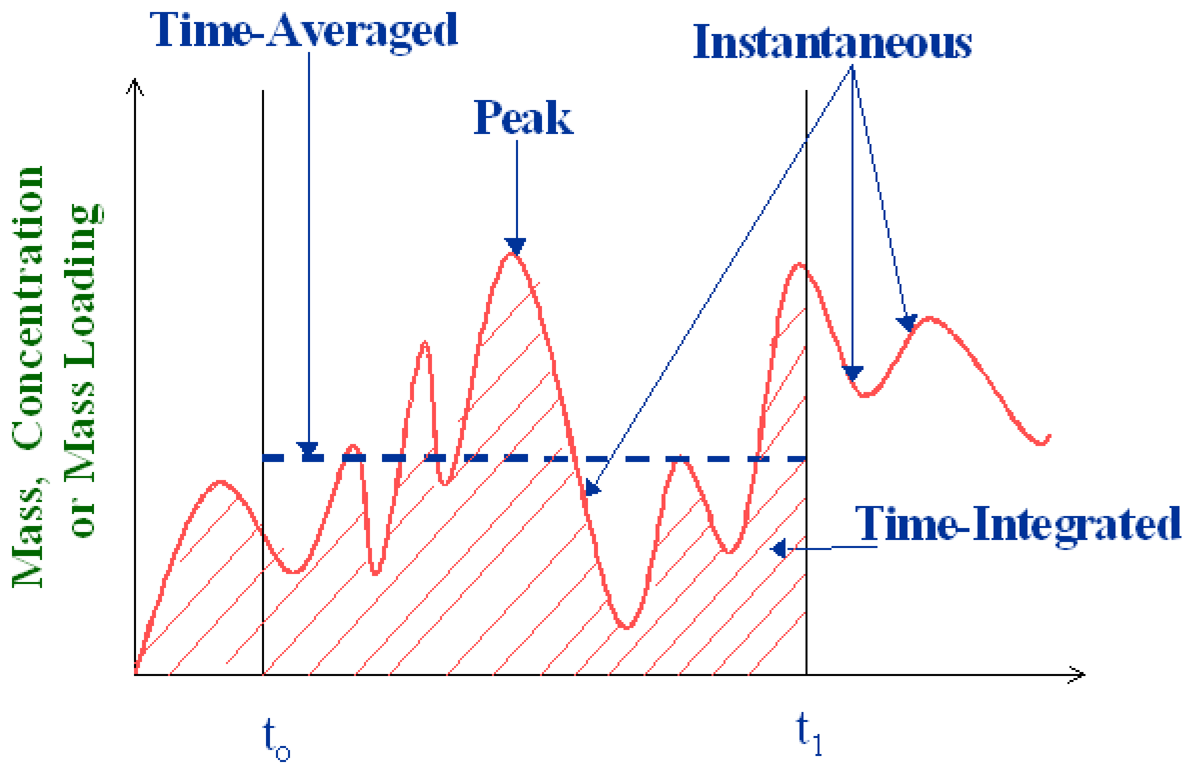


Figure 4. Hypothetical exposure profile for an individual.

Appendix 2 details how exposure is calculated during a contact event. In summary, each contact event is treated as a whole and is not subdivided into finer events. For each process affecting the cumulative exposure, an adjustment reflecting the total addition or subtraction for that process is made once per event. These adjustments are generally proportional to the duration of the event.

SHEDS-Wood allows exposure to be retained in succeeding events after it is contacted, until it is removed. Thus, the exposure for each event depends on the exposure retained from the prior event. The exposure can be viewed as a time series which changes as a result of each event, as shown in Figures 5 to 9. Note that the model generates a time series for each exposure variable: namely, dermal residue on hands, dermal residue on body, dermal soil on hands, dermal soil on body, ingested residue, and ingested soil. While not shown in Figures 5 to 9, the model internally distinguishes between the exposure resulting from deck contact and playset contact, so there are actually twelve exposure variables (and hence 12 exposure time series) generated for each person simulated. Note that while the basic activity diary is repeated on both days in these figures, the contact events differ on the two days.

Figure 5 illustrates the current dermal exposure loading from contact with wood surface residues over a sample two day period for a single child. The horizontal axis is time, measured in hours from the start of the period shown. Both the hand and body exposures increase whenever a deck or playset is contacted. The hand exposure subsequently decreases suddenly (due to hand washing or bathing) or at a moderate rate (due to hand-to-mouth activity), except when the child is sleeping. The body exposure is not affected by either hand washing or hand-to-mouth activity, and decreases suddenly only during bathing. At all times when exposure is present, it decreases slowly due to dermal absorption; however, this rate is slow (typically 1%-2% per day), and so is hardly noticeable on this figure.

Figure 6 resembles Figure 5, except that it shows the current dermal exposure loading resulting from contact with contaminated soil. Since the soil is adjacent to the wood structures, and the removal processes are similar (washing, bathing, absorption, and hand-to-mouth activity), the general shape of the time series is similar to that in Figure 5. Several of the modeling parameters for soil exposure differ from residue exposure, so the numerical levels of the exposure are different in the two figures.

Figure 7 shows the gastroinestinal (GI) tract exposure loading resulting from hand-to-mouth transfer of residues, as a function of time. Once the child is awake and has dermal hand exposure, there is a fairly constant transfer from the hands to the GI tract. Once the child sleeps, this transfer stops and the GI tract loading is reduced by absorption into the bloodstream. The rate constant for GI tract absorption is substantially higher than for dermal absorption, so the decrease in GI tract exposure due to absorption is easily seen in the Figure. Once per day at 6 a.m. (hour 30 on this Figure), the GI tract is voided, dropping the exposure to zero.

Figure 8 shows the GI tract exposure resulting from ingestion of contaminated soil. Note that direct soil ingestion and soil-to-hand-to-mouth transfer are not distinguished in this model; both are treated as direct ingestion. Thus, the GI tract exposure only increases when the child is at a deck or playset, as these are the only places assumed to have contaminated soil, and direct soil ingestion affects the GI tract exposure immediately. This is in contrast to the residue ingestion, which happens via hand-to-mouth transfer and may involve a time delay after the initial dermal exposure contact. The absorption of GI tract soil exposure and the daily voiding at 6 a.m. are similar to the effects seen in Figure 7 for residues.

The SHEDS-Wood model calculates the amount of the exposure that is absorbed into the bloodstream during each event. This can happen on the skin (dermal absorption) or in the gastrointestinal tract. Absorption into the body is one of several competing removal processes for the exposure; thus, the absorbed dose is not simultaneous with the contact with the source. Figure 9 illustrates how the absorbed dose increases over time. At the start of each day (at midnight), the model records the accumulated dose for the prior day and resets the dose to zero. The dose entering the bloodstream during each diary event is calculated as described by the equations in Appendix 2, and the result is added to the running total for the day. Note that in this model absorption is a continual process that is not confined to occur only during contact events. Absorption will cease only if all the dermal and GI tract exposures happen to be zero simultaneously, and will start again once any exposure is non-zero.

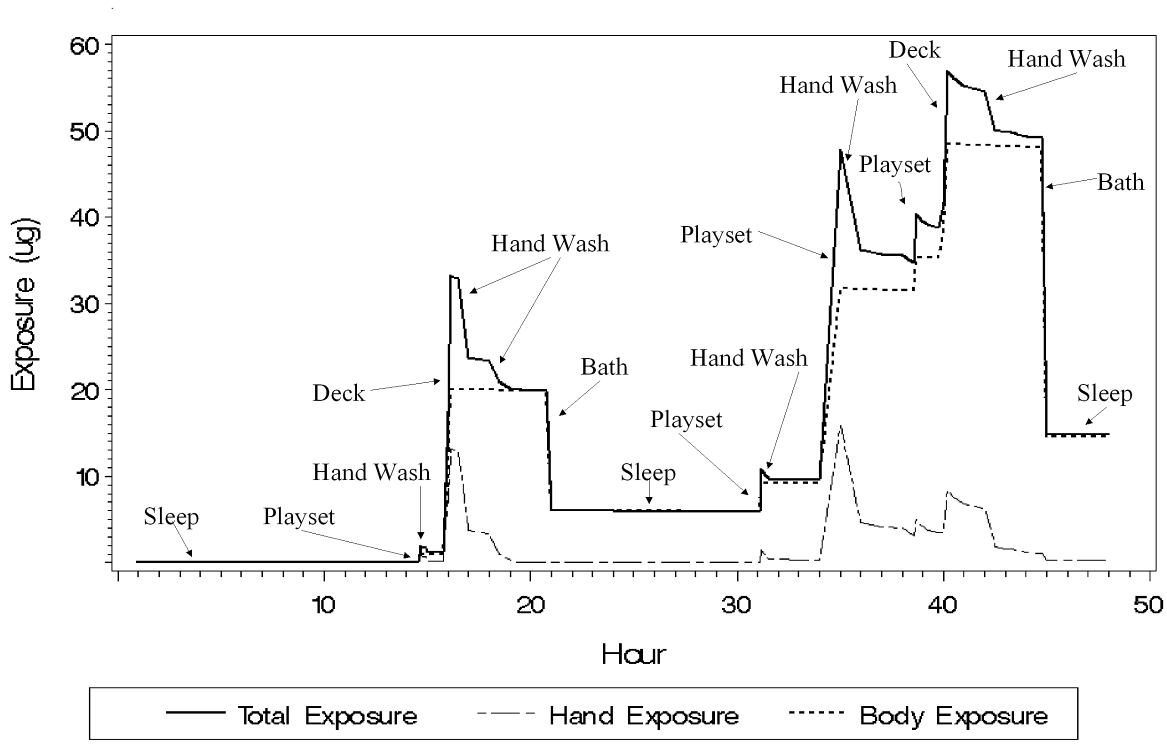


Figure 5. Dermal exposure from surface residue.

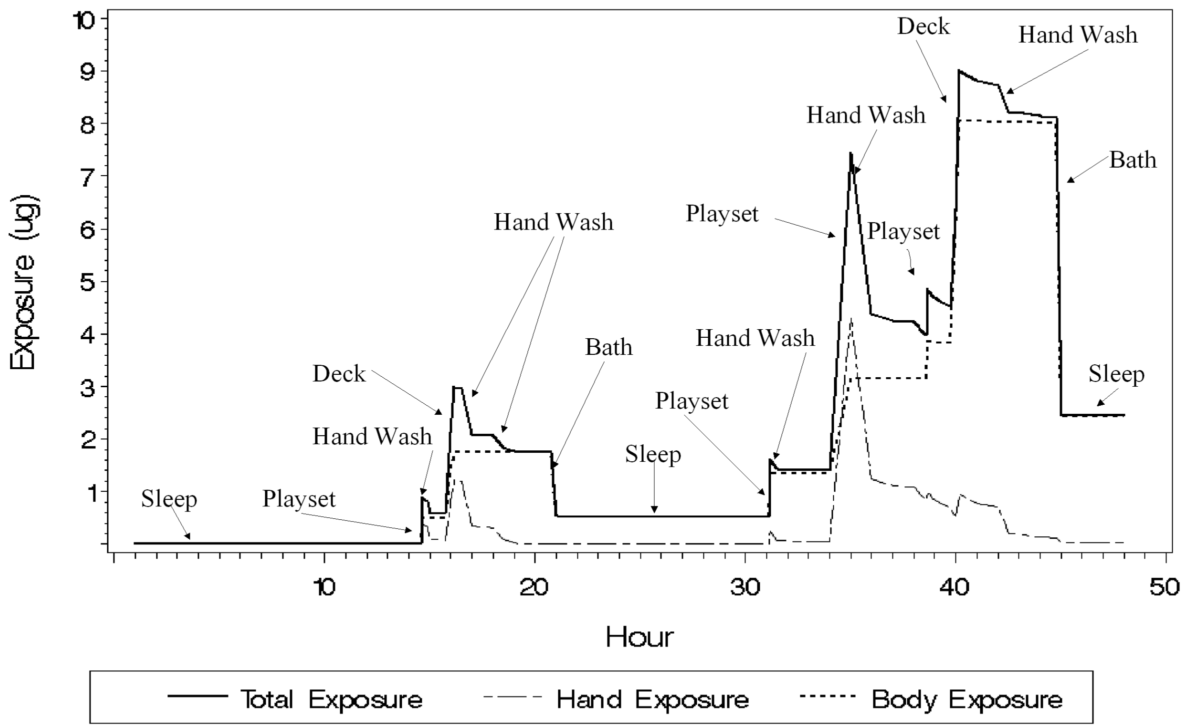


Figure 6. Dermal exposure from soil.

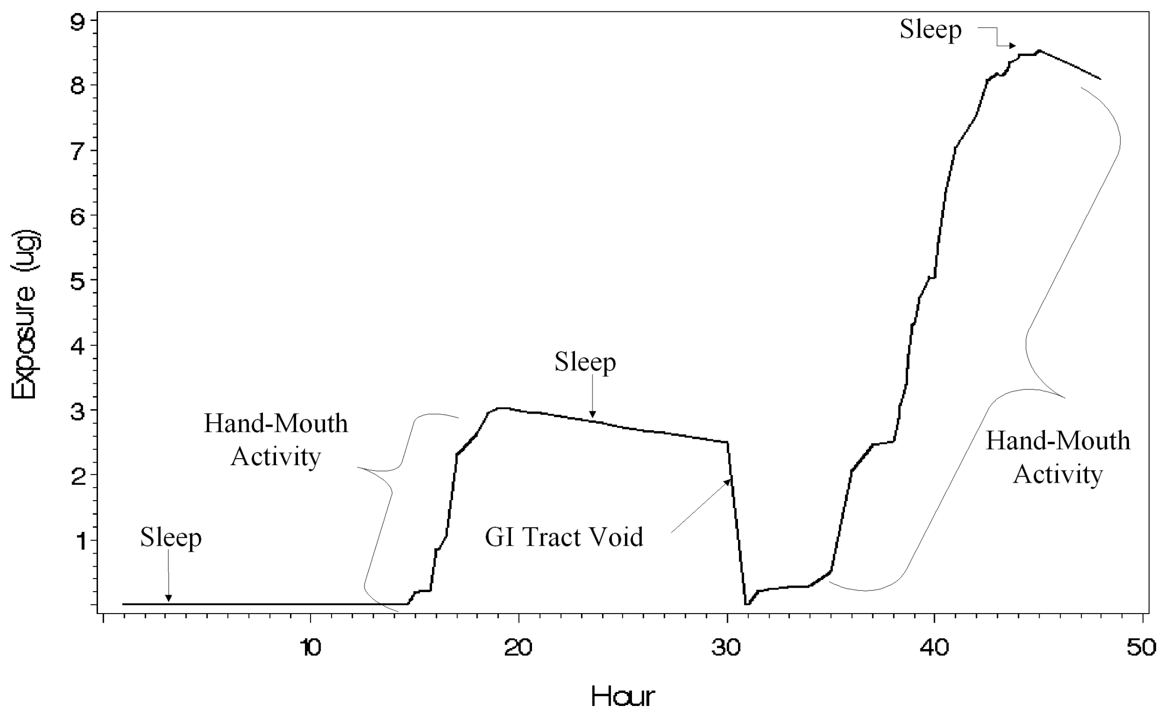


Figure 7. GI tract exposure from residue ingestion.

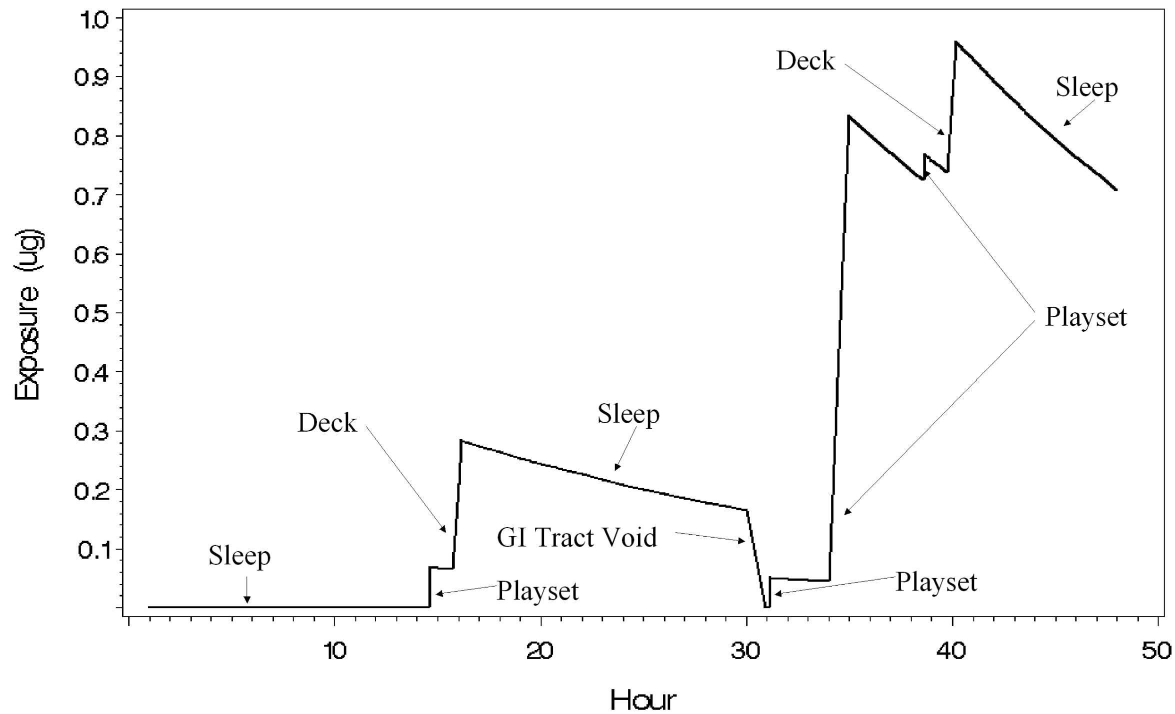


Figure 8. GI tract exposure from soil ingestion.

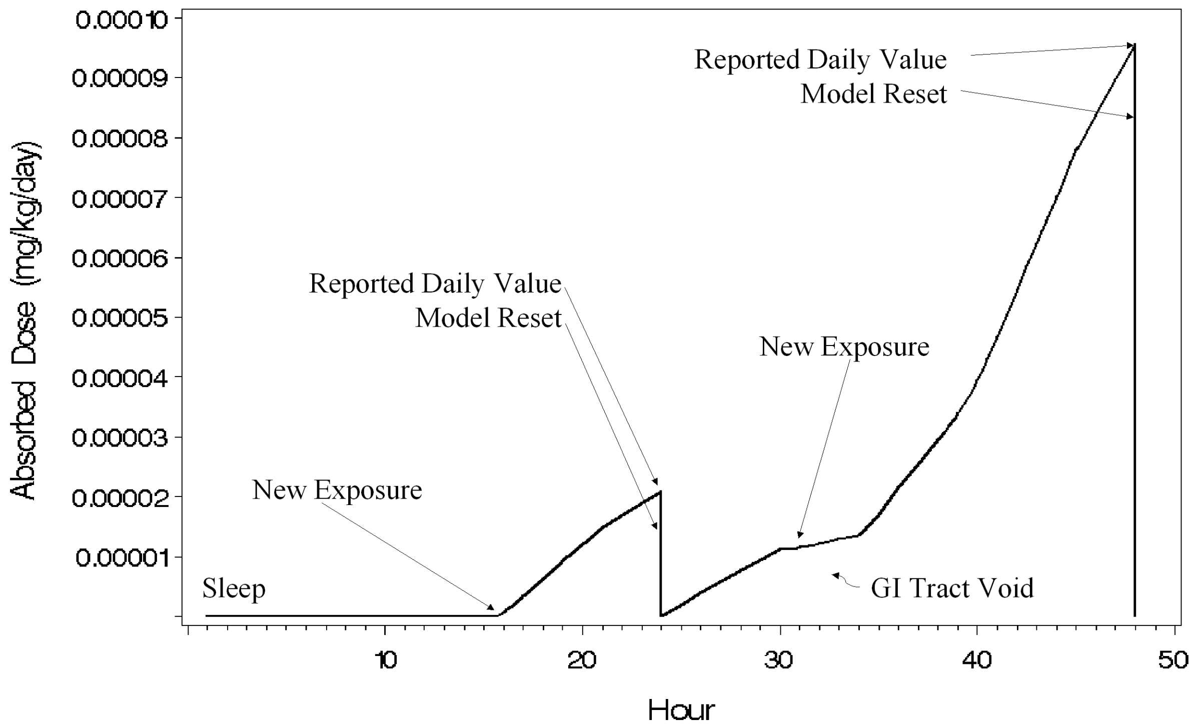


Figure 9. Daily cumulative total absorbed dose.

Absorbed Dose Estimation in SHEDS-Wood

SHEDS-Wood converts user-specified daily dermal absorption fractions to hourly absorption rate constants by dividing by 24. The daily GI absorption rate is assumed to be the absolute bioavailability (i.e., the bioavailability of chemical in the residue or soil matrix), computed as the relative bioavailability (pig study data used for As; 100% assumed for Cr) multiplied by the bioavailability of the chemical in water (assumed to be 100% for As and Cr). For absorption via the gastrointestinal tract, the daily absorption fraction is divided by 12. This assumes there are 12 hours on average between the time of ingestion and the time when the GI loading is eliminated. Some ingestion events will result in more hours of absorption time, and some will have less, thus removing most of the bias. The dermal divisor differs from the GI tract divisor to reflect the different fates of the chemical on the skin versus after ingestion. For the dermal route, the chemical is allowed to remain on the skin until it is removed (e. g., by bathing), whereas the model forces a voiding of the gastrointestinal tract once a day (at 6 am). Thus, dermal exposure and hence dermal absorption may continue from day to day, while exposure and absorption from ingestion is time limited and cannot extend beyond 24 hours. The divisors (24 and 12) were tested in trial model runs and found to generate the appropriate daily absorption rates. Note, however, that the user-specified daily dermal absorption rate represents the rate in the absence of competing removal processes at the skin surface (hand mouthing, hand washing, bathing). Model simulations revealed that if the user enters a mean of 3% for the daily dermal absorption rate, the net modeled rate is approximately 1%. This is consistent with 2001 SAP recommendation to use 2-3% based on Wester et al. (1993), acknowledging that the real-world value would probably be closer to 1% due to physical removal processes prior to absorption through the skin surface (FIFRA SAP, 2001).

Fixed and Varying Inputs

Some SHEDS-Wood input variable values vary from event to event, day to day, month to month, and/or child-to-child; others are fixed across events, months, days, and/or children. Table 6 summarizes how frequently each variable value is sampled from distributions by the code. Some inputs, such as the soil-skin adherence factor, soil ingestion rate, soil concentrations contacted, and surface residues, are assumed to be fixed for a given child from day to day and from year to year, though in reality these could vary for a given child. In essence, these simplification decisions were based on the likelihood that inter-child variability would be much greater than intra-child variability, and whether sufficient data are available to vary these parameters for a given child in the assessment. For example, variability in environmental concentrations is typically much greater across geographic locations than across time for a given location.

Table 6. Summary of How Frequently Each SHEDS-Wood Variable Changes in the CCA Assessment

SHEDS-Wood Variable for CCA Assessment	Frequency of Change in Variable Value
Body weight [kg]	Every month for a given child within a year and year-to-year
Total body surface area [m^2]	Every month for a given child within a year and year-to-year
Fraction children* with a CCA-treated home playset [-]	Does not change
Average fraction of residential outdoor time a child* plays on/around a CCA-treated residential playset (on days when the child* plays on/around a CCA-treated residential playset) [-]	Varies child-to-child
Average #days/yr a child* plays on/around a residential CCA-treated playset [days/yr]	Does not change
Average fraction of non-residential** outdoor time a child* plays on/around a CCA-treated public playset (on days when the child* plays on/around a CCA-treated public playset)[-]	Varies child-to-child
Average #days/yr a child* plays on/around a CCA-treated public playset [days/yr]	Does not change
Fraction of time a child* on/around a CCA-treated playset is on the playset itself versus on the ground near the playset [-]	Varies event-to-event and child-to-child
Fraction of children* who have a CCA-treated residential deck [-]	Does not change
Average fraction of residential outdoor time a child* plays on/around a CCA-treated residential deck (on days when the child* plays on/around a CCA-treated residential deck) [-]	Varies child-to-child

SHEDS-Wood Variable for CCA Assessment	Frequency of Change in Variable Value
Average #days/yr a child* plays on/around a CCA-treated residential deck [days/yr]	Does not change
Fraction of time a child* on/around a CCA-treated home deck is on the deck versus on the ground near the deck [-]	Varies event-to-event for a given child; changes child-to-child
Soil arsenic concentrations near CCA-treated playset [mg/kg]	Varies child-to-child
Soil chromium concentrations near CCA-treated playset [mg/kg]	Varies child-to-child
Wood surface arsenic residues on CCA-treated playset [µg/cm^2]	Varies child-to-child
Wood surface chromium residues on CCA-treated playset [µg/cm^2]	Varies child-to-child
Soil arsenic concentrations near CCA-treated deck [mg/kg]	Varies child-to-child
Soil chromium concentrations near CCA-treated deck [mg/kg]	Varies child-to-child
Wood surface arsenic residues on CCA-treated deck [µg/cm^2]	Varies child-to-child
Wood surface chromium residues on CCA-treated deck [µg/cm^2]	Varies child-to-child
Dermal hand transfer coefficient [cm^2/hr]	Varies child-to-child
Fraction of total body (non-hand) skin surface area that is unclothed [-]	Varies day-to-day; also varies child-to-child
Fraction of unclothed body (non-hand) skin S.A. contacting soil per exposure event [-]	Varies event-to-event for a given child; also varies child-to-child
Fraction of hand skin S.A. contacting soil per exposure event [-]	Varies event-to-event for a given child; also varies child-to-child
Fraction of unclothed body (non-hand) skin S.A. contacting residues per exposure event [-]	Varies event-to-event for a given child; also varies child-to-child
Fraction of hand skin S.A. contacting residues per exposure event [-]	Varies event-to-event for a given child; also varies child-to-child
Daily soil ingestion rate [mg/day]	Varies child-to-child
Soil-skin adherence factor [mg/cm^2]	Varies child-to-child
Maximum dermal loading for hands [µg/cm^2]	Varies child-to-child
Maximum dermal loading for body [µg/cm^2]	Varies child-to-child
Fraction of hand surface area mouthed per mouthing event [-]	Varies child-to-child
Frequency of hand-mouth activity per hour [#/hr]	Varies event-to-event for a given child; also varies child-to-child
Average number of hand-washing events per day [#/day]	Varies child-to-child
Hand-washing removal efficiency [-]	Varies child-to-child
Bathing removal efficiency [-]	Varies child-to-child
Typical number of days between baths [days]	Varies child-to-child
Hand-to-mouth dermal transfer fraction [-]	Varies event-to-event for a given child; also varies child-to-child
Dermal absorption fraction per day for arsenic residues [1/day]	Varies child-to-child

SHEDS-Wood Variable for CCA Assessment	Frequency of Change in Variable Value
Dermal absorption fraction per day for arsenic in soil [1/day]	Varies child-to-child
Dermal absorption fraction per day for chromium residues [1/day]	Varies child-to-child
Dermal absorption fraction per day for chromium in soil [1/day]	Varies child-to-child
GI absorption fraction per day for arsenic residues [1/day]	Varies child-to-child
GI absorption fraction per day for chromium residues [1/day]	Varies child-to-child
GI absorption fraction per day for arsenic in soil (BF) [1/day]	Varies child-to-child
GI absorption fraction per day for chromium in soil (BF) [1/day]	Varies child-to-child

*A child is defined here as a child in the United States who contacts CCA-treated wood residues and/or CCA-containing soil from public playsets (e.g., at a playground, a school, a daycare center), at a minimum. A subset of these children also contacts CCA-treated wood residues and/or CCA-containing soil from residential playsets (i.e., at the child's own home or at another child's home) and/or residential decks.

**A non-residential location refers to CHAD locations where it is assumed that a public CCA-treated playset may be present.

Generating Lifetime Route-Specific Exposure and Dose Time Profiles for Individuals

The lifetime exposure and dose profiles for each individual are constructed by stringing together six age-specific profiles, selected at random but taking into consideration the potential exposure class and gender of the individual, and then adding zero annual exposure for ages 7 to 75 years (Figure 10). To determine the lifetime exposure for each individual, activity diaries are matched by age, gender, and potential exposure for a six year span. To provide consistency from year to year in the behavior of each child, each child is classified as a low-, middle-, or high- potentially exposed child, based on the amount of time spent in outdoor locations, as described above. The category of potential exposure remains the same for all six years. To assemble a composite activity diary that represents the child, the diaries belonging to the same category as the child are preferentially selected. In this way, a child who spends a relatively long period of time outdoors (that is, potentially in contact with treated wood) at one age will also have a relatively high time outdoors at other ages.

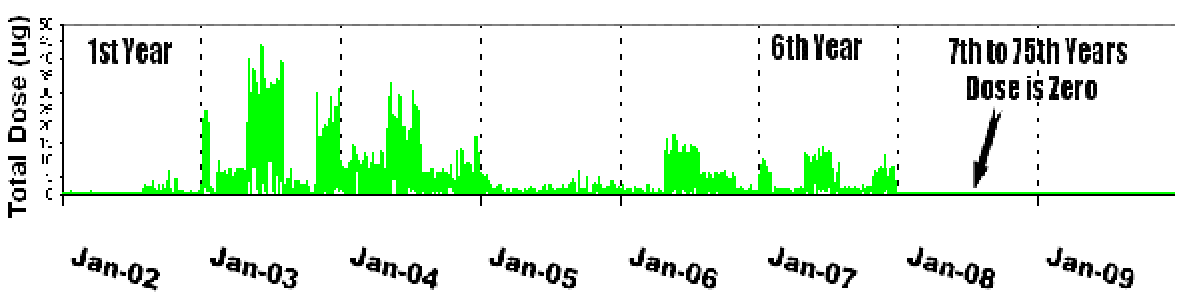


Figure 10. Example SHEDS-Wood dose profile from which LADD is computed.

Estimating Time-Averaged Exposures and Doses of Individuals for Different Time Periods

To obtain short-term average daily dose (ADD) estimates, SHEDS-Wood uses the 1-year absorbed dose profile for each individual, selects a 15-day period (since short-term is defined as up to a month) within the given year, and determines average absorbed dose for that period. For intermediate-term estimates, SHEDS-Wood uses a random 90-day period (since intermediate-term is defined as up to 6 months). The simulation can start on a user-specified fixed date for all individuals in the simulation, to preserve season-specific differences. Starting at uniform random dates over the year would average the exposure over seasonal differences and inflate the variability of the results. To determine lifetime average daily dose (LADD), SHEDS-Wood averages the daily dose over the lifetime dose profile simulated using the approach described in the previous section.

The event-based time profiles for exposure and dose produce very large data sets. A one-year diary contains a variable number of macroactivity events, usually between 12,000 and 15,000, and for each event there are numerous input and output exposure and dose variables to be evaluated. A variability run may consist of several thousand such profiles, and an uncertainty run will be larger still (typically hundreds of replications of separate variability runs). For practical reasons, SHEDS-Wood tracks the ADD or LADD (total and pathway-specific) for each individual before proceeding to the next person. This permits the display of results such as the fraction of dose originating from the various SHEDS-Wood pathways.

Generating Population Estimates for Absorbed Dose

The steps described above are for estimating the absorbed dose for a single child. To obtain population estimates SHEDS-Wood repeats this process many times using 1-stage or 2-stage Monte Carlo simulation (Cullen and Frey, 1999) for variability results only or both variability and uncertainty analyses, respectively (Figure 11). Statistical weights derived from the United States Census (U.S. Census Bureau, 2000) are applied so that population sampling is proportional by age and gender to reflect the U.S. population. The population CDFs reflect variability of doses due to differences in both the time children 1-6 years old spend contacting treated wood and nearby soil and exposure factors that affect how much of the chemical reaches and enters a child's body after contact. In addition to producing CDFs and summary statistics tables for ADD and LADD for As and Cr (in warm and cold scenarios) and the 3 time periods mentioned above, SHEDS-Wood computes the contribution to absorbed dose from each of the exposure pathways.

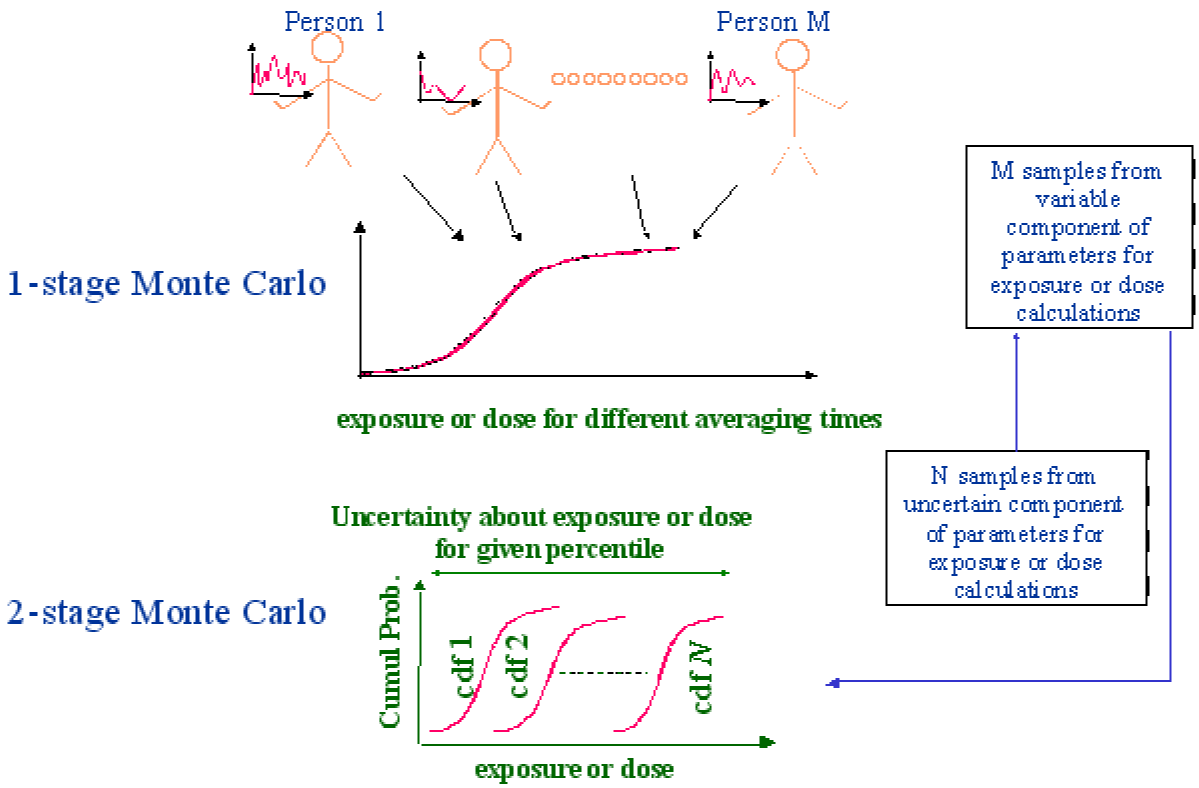


Figure 11. SHEDS estimation of population absorbed dose using 1-stage or 2-stage Monte Carlo sampling.

SHEDS-Woods Inputs for CCA Study

Assigning Variability Distributions to Model Inputs

For variables where data were available, Weibull (e.g., hand-to-mouth frequency) or lognormal distributions (e.g., soil concentrations, surface residues, surface residue-skin transfer efficiency, soil ingestion rate, soil-skin adherence factor, frequency of hand washing) were fit to the data using the method of moments or the maximum likelihood estimator. Goodness-of-fit tests (Kolmogorov-Smirnov, Cramer-von Mises, Anderson-Darling and Chi-Square) were applied to verify the selection. Appendix 3 illustrates graphically the variability (and uncertainty) distributions for each SHEDS-Wood variable.

Use of Beta Distributions for Fractional Inputs

2002 SAP members discouraged the use of uniform distributions (FIFRA SAP, 2002). Thus, for fractional input variables (i.e., values between 0 and 1) in the CCA assessment, beta distributions were fit. These variables were: average fraction of outdoor time a child plays on/around CCA-treated structure; fraction time a child on/around treated playset or deck is on the structure itself vs. on ground within 2 feet of the structure; fraction of total body (non-hand) skin surface area that is unclothed; fraction of bare skin contacting residues per time; fraction hand surface area mouthed; washing removal efficiency; and dermal and GI absorption fractions. The selection of a beta distribution for these fractional variables was based on analyses comparing fits with normal, lognormal, triangular, and beta distributions (Figure 12).

If few data or only summary statistics were available for a fractional variable, the beta distributions were generally fit by setting up a "foundational triangle" distribution with a peak at the mean and a maximum and minimum determined by adding and subtracting twice the standard deviation from the mean. Samples were then generated from this triangle, and then a beta distribution fit to these samples. In response to comments received at the 2002 SAP review, it was desired to expand beyond the lognormal and triangular distributions for situations where an asymmetric distribution was desired. To accomplish this, the triangular distribution was used as a base from which to extend distributions. A symmetric triangle was preferred because the inputs were typically summary statistics, not the actual data. While the peak in reality could have been shifted either to the left or right of the mean, there was no basis for assuming this. In one case (fraction of bare skin on the body contacting soil), the subtraction of twice the standard deviation placed the minimum below 0, so it was reset to 0. In another instance (fraction of hand contacting soil), the addition of twice the standard deviation placed the maximum above 1, so it was reset to 1. For these cases, the "foundational triangle" was constructed to be asymmetric.

In certain instances, summary statistics available in the literature were not as directly applicable. In such cases, we sought advice from knowledgeable researchers with respect to what they had found in new studies yet to be published (*e.g.*, fraction of body unclothed in warm climate) or how the available summary statistics might relate to CCA (*e. g.*, saliva removal efficiency).

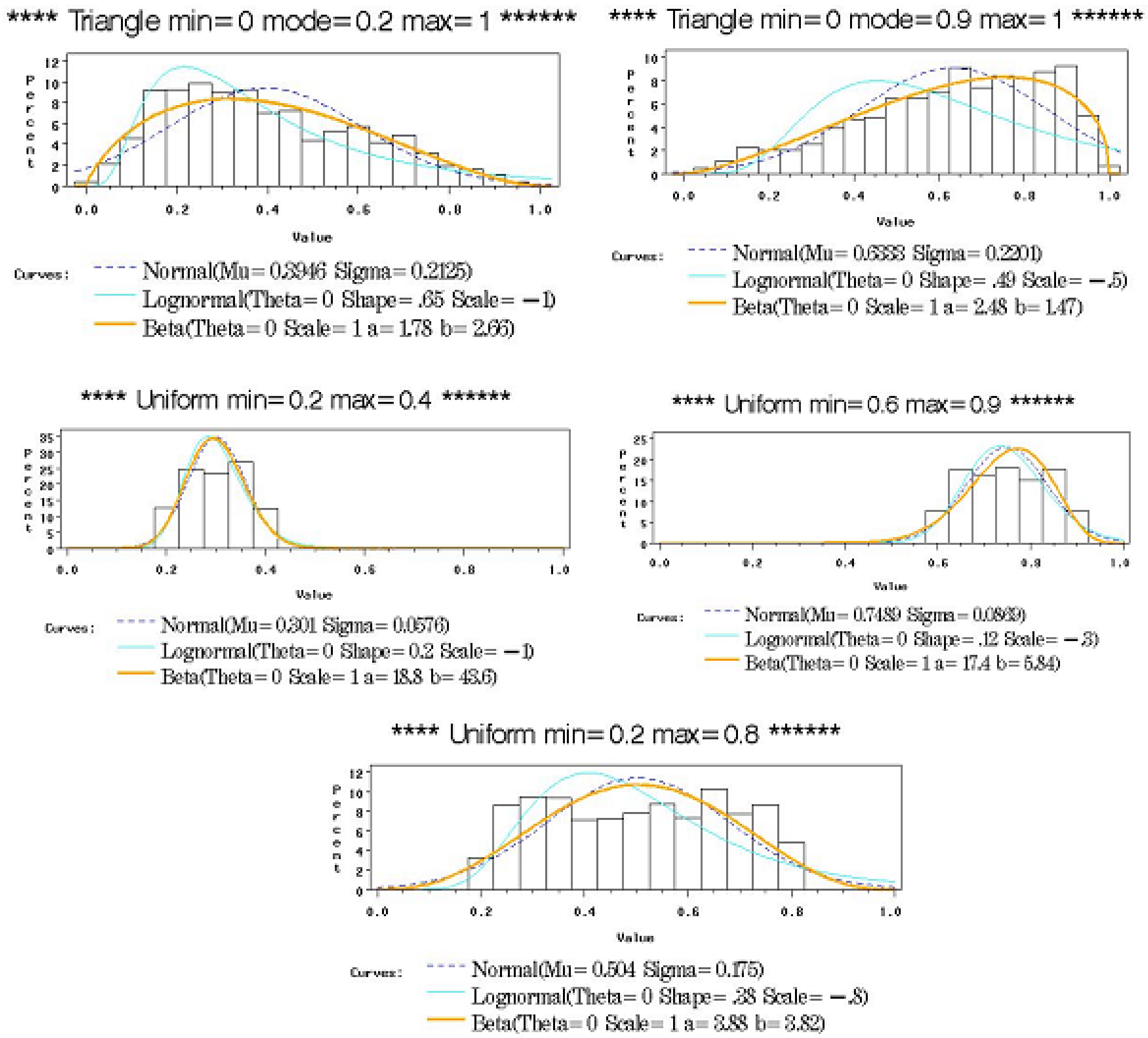


Figure 12. Analyses to support use of Beta Distribution for fractional input variables.

The use of the mean ± two standard deviations to form the "foundational triangle" had the following appeal. It is known from a simple application of the Chebyshev inequality that at least 75% of the population of the parameter of interest should be contained between the bounds of the triangle. Indeed, given the reasonable assumption of a unimodal distribution for these parameters, the actual fraction of the population captured by the triangle should be somewhat higher. Thus, anchoring the beta distribution by fitting it to samples from the "foundational triangle" resulted in: (1) capturing the vast majority of the desired distribution without either terminating it abruptly or allowing tail probabilities that were heavier than the available information justified; and (2) obtaining a unimodal beta distribution with a mode in the vicinity of the triangle's peak, which generally corresponded to a mean value based on published studies.

Since the minimum and maximum of the desired beta distribution were fixed at 0 and 1, the method of moments could have been applied. A comparison of estimation by the method of moments to the "foundational triangle" indicated that the method of moments gave heavier tails for the estimated distributions and also yielded a J-shaped beta distribution.

Sources of Data and Assigned Distributions for Model Inputs

As discussed above, time-location-activity diaries used to simulate individuals' activity patterns were obtained from CHAD. Micro-activity data (e.g., hand-to-mouth contact frequency, surface area of hands mouthed) were derived from available videography data. Input values for various other exposure factors used in the SHEDS-Wood exposure algorithms were based on OPP's Residential Exposure Standard Operating Procedures (SOPs) (US EPA, 2001), recommendations by OPP's FIFRA Scientific Advisory Panel (FIFRA SAP 2001; 2002), EPA's Child-Specific Exposure Factor Handbook (US EPA, 2002), peer-reviewed publications, or best Agency-derived estimates if no data were available.

Data for As and Cr residues on wood surfaces and in soil around playsets and decks were obtained from ACC, CPSC, and various published studies that were reviewed and analyzed by OPP (see Versar 2002). A summary of distributions used in SHEDS-Wood is shown in Table 7. Table 8 summarizes how SHEDS-Wood used CPSC, ACC, and Environmental Working Group (EWG) data in the CCA Assessment, Table 9 compares those three data collection studies, Table 10 summarizes As and Cr residue data from ACC, and Table 11 summarizes As and Cr residue data from CPSC. Warm climate scenario distributions for As soil concentrations near CCA-treated playsets and decks were fit to Solo-Gabriel et al. (2001) warm weather data for playsets and decks, respectively. Cold climate scenario distributions for As soil concentrations near CCA-treated playsets were fit to cold weather data from Canada studies (Riedel et al., 1991; Doyle and Malaiyandi, 1992; Malaiyandi, 1993) and a Connecticut study (Stilwell, 1998); for decks, Stilwell (1998) data were used. Warm climate scenario distributions for Cr soil concentrations near CCA-treated playsets and decks were also fit to Solo-Gabriel et al. (2001) warm weather deck data. Cold climate scenario distributions for Cr soil concentrations near CCA-treated playsets were fit to cold weather data from Doyle and Malaiyandi (1992); for decks, data from Stilwell (1998), Doyle and Malaiyandi (1992), and Malaiyandi (1993) cold weather soil Cr data for decks were used.

Warm and cold climate scenario distributions for As and Cr residue concentrations on CCA-treated decks used new wood and hand wipe residue data collected by ACC from CCA-treated decks (ACC, 2003b). Warm and cold climate scenario distributions for As and Cr residue concentrations on CCA-treated residues used the new ACC deck data for corresponding variables. CPSC (2003b,c) cold weather As data were also used for wood surface As residues on CCA-treated decks.

Table 12 contains a complete summary of input values and variability distributions for SHEDS-Wood input variables used in the CCA children's probabilistic exposure modeling assessment for various model scenarios conducted (warm and cold climates; arsenic and chromium). The justifications for all values and sources of information are given below. For those inputs that are used directly in the exposure equations, the variable name (as it appears in the equations in Appendix 2) is given in parentheses.

Table 7. Variability Distributions for Arsenic and Chromium Residues and Soil Concentrations Used in SHEDS-Wood CCA Assessment

	Arsenic Wood Residues [μg/cm^2]		Arsenic Soil Concentrations [μg/g]		Chromium Wood Residues [μg/cm^2]		Chromium Soil Concentrations [μg/g]	
	PLAYSET	**DECK**	**PLAYSET**	**DECK**	**PLAYSET**	**DECK**	**PLAYSET**	**DECK**
COLD	lognormal (0.258,1.97)	lognormal (0.258,1.97)	lognormal (1.6,3.68)	weibull (1.2,89)	lognormal (0.356,1.72)	lognormal (0.356,1.72)	lognormal (6.7,3.9)	lognormal (19.9,4.3)
WARM	lognormal (0.228,2.24)	lognormal (0.228,2.24)	lognormal (29.97,1.64)	weibull (1.1,41.9)	lognormal (0.278,2.1)	lognormal (0.278,2.1)	lognormal (32.4,1.88)	lognormal (22.2,2.77)

Table 8. Use of CPSC, ACC, and EWG Data in SHEDS-Wood CCA Assessment

Type of Data	Source of Data	Summary of Study	How Data were used in SHEDS-Wood	Notes
Hand wipe residues	ACC [1]	Wetted hand rubs were performed for 25 wood decks. Transfer efficiency terms were derived by comparing hand wipe results to wood block residue results.	Variability distribution fit to raw data for numerator of transfer efficiency term used in dermal residue exposure equations	Divided hand load data by actual hand S.A. because it was assumed saturation
	CPSC [2]	Dry hand wipes were performed on 8 residential wood decks. The wood was wiped in 10 cycles of back and forth rubbing. Transfer efficiency terms were derived by comparing hand wipe results to wood block residue results.	Variability distribution fit to raw data for numerator of transfer efficiency term used in dermal residue exposure equations; used for cold climate As model runs	Divided hand load data by hand S.A. (140 cm^2) because it was assumed saturation
Wood block residues	ACC	Wood block residues were measured for 25 wood decks using wetted polyester wipes.	(1) Variability distribution fit to raw data for denominator of transfer efficiency term used in dermal residue exposure equations (2) Wood residue data used in dermal residue exposure equations (combined with transfer efficiency)	Divided by total wood surface area wiped because saturation was not reached

Type of Data	Source of Data	Summary of Study	How Data were used in SHEDS-Wood	Notes
	CPSC	Wood block residues were measured for 12 playgrounds and 8 residential wood decks. Dry and wet polyester wipes as well as HDPE wipes were used.	(1) Variability distribution fit to raw data for denominator of transfer efficiency term used in dermal residue exposure equations (2) Wood residue data used in dermal residue exposure equations (combined with transfer efficiency) Used for cold climate As model runs	Divided by total wood surface area wiped because saturation was not reached
	EWG [3]	EWG distributes arsenic test kits to interested homeowners who want to know levels of arsenic in their wood structures. Participants are provided with wipe kits and a questionnaire. Data from the analysis of the wipes and from the questionnaires form the basis of this study. (112 decks, 135 playsets, 14 picnics, and 2 wooden sandboxes.)	Uncertainty only because of (1) sample collection methods, (2) potential high uncertainty due to the inconsistency of pressure being applied on the surface of wood, (3) no control samples were reported, (4) lack of transfer efficiency data, (5) different methods than other studies, (6) high geometric standard deviation	
Maximum dermal loading	ACC	Same as for hand wipe residues	Used hand load data at 20 passes	
	CPSC	Same as for hand wipe residues	Used hand load data at 20 passes	
GI for As in soil	ACC	As in soil fed to juvenile swine in swine feed	Variability distributions fit to raw data	
GI BF for As residues	ACC	As in residues fed to juvenile swine in swine feed	Variability distributions fit to raw data	

Footnotes Table 8.

[1]American Chemistry Council (ACC) submitted the study "Assessment of Exposure to Metals in CCA-Preserved Wood: Full Study" to US EPA's Office of Pesticide Programs on June 20, 2003.

[2]Consumer Product Safety Commission (CPSC) memorandum "Determination of Dislodgeable Arsenic Transfer to Human Hands and Surrogates from CCA-Treated Wood," January 23, 2003.

[3]Environmental Working Group (EWG), 2002. "All Hands on Deck." And EWG, 2001. "Home Testing Kit for Arsenic Treated Wood." Brochure.

Table 9. Comparison of EWG, CPSC, and ACC Studies

Parameter	EWG[1]	CPSC[2]	ACC[3]
Information Sources	Environmental Working Group, 2002. All Hands on Deck. EWG, 2001. Home Testing Kit for Arsenic Treated Wood. Brochure. EWG also provided a spreadsheet containing arsenic home test data dated August 10, 2002.	Consumer Product Safety Commission, 2003. Statistical Analysis of CCA-Treated Wood Study Phase IV. Memorandum from Mark Levenson, Division of Hazard Analysis, to Patricia Bittner, Project Manager, January 24, 2003. Also refer to similar memos for Phases I–III. Consumer Product Safety Commission, 2003. Chromated Copper Arsenate (CCA) Pressure Treated Wood Analysis—Expoloratory [sic] Studies Phase I and Laboratory Studies Phase II. Memorandum from David Cobb, Chemist, to Patricia Bittner, Project Manager, January 2003. Consumer Product Safety Commission, 2003. CCA-Treated Wood Field Study—Phases III and IV. Memorandum from David Cobb, Chemist, and Dwayne Davis, Chemist, to Patricia Bittner, Project Manager, January 2003.	RTI International, 2003. Assessment of Exposure to Metals in CCA-Preserved Wood: Full Study. Prepared for the American Chemistry Council.

Parameter	EWG[1]	CPSC[2]	ACC[3]
Study Background	EWG distributes arsenic test kits to interested homeowners who want to know levels of arsenic in their wood structures. Participants are provided with wipe kits and a questionnaire. Data from the analysis of the wipes and from the questionnaires form the basis of this study.	In response to a petition to ban the use of CCA-treated wood in playground equipment, this study was conducted, which evaluated the risk to children from exposure to CCA-treated wood.	RTI prepared this study for the American Chemistry Council (CCA Task Force).
Sampling Dates	Sampling kits were available starting November 2001, and the report date is August 2002. More specific information could not be found.	Could not be found in report.	Could not be found in report.
Related Studies	Soil samples taken near wooden structures were also examined.	Preliminary studies to determine arsenic levels at a screening level, to develop a test method, and to determine the relationship between surrogate wipes and human hand wipes.	A preliminary study was performed to optimize methods for sampling boards. Data from a mini-study of 5 decks was incorporated with the new data from this study (20 decks) and the full set of 25 was used in analysis. Samples were also analyzed for hexavalent chromium and copper.

Parameter	EWG[1]	CPSC[2]	ACC[3]
		Wooden Structures	
CCA-Treated Structures Sampled	112 decks, 135 playsets, 14 picnic tables, and 2 wooden sandboxes	12 playgrounds, 8 residential decks	25 sets of deck wood (southern yellow pine, with CCA retention of 0.4 lb/ft^3)
Control Structures Sampled	None reported	3 untreated playgrounds	20 untreated boards for negative control 20 recently treated boards for positive control
Age of structures	2 months to 30 years	6 months to 18 years	1 year to over 5 years
Sealer Treatment Used?	About 30% of structures are known to be either painted, stained, or sealed	Believed to be used on 50% of structures	No
Geographic Location	45 states	Washington DC metropolitan area	12 sets from Pittsburgh, PA area, 10 from Gainesville, FL area, 3 from Atlanta, GA area

Parameter	EWG[1]	CPSC[2]	ACC[3]
		Sampling Methods	
Wipe Material	Wet wipes used (material not reported)	For playgrounds, dry and wet polyester wipes used. For residential decks, human hand wipes, dry and wet polyester wipes, and a high-density polyethylene (HDPE) wipe used. The wipes were all 4.5" x 4.5".	4" x 4" polyester wipes were used, as well as hand wipes.
Pressure Applied When Wiping	Instructions to the participant asked that an even pressure be applied.	For cloth wipes, a 1,100 gram disk was attached to each cloth wipe to ensure uniform pressure, and the disk was slid over the 400 cm^2 designated area. Memo notes that pressure may be uneven for hand wipes.	A 1,100 gram steel square block delivering a pressure of about 17.2 g/cm^2 was attached to each cloth wipe to ensure uniform pressure. Weights were also added to the back of participants' hands.
Wipe Method	A plastic template was placed on the wood structure. Wood was then wiped in an overlapping "S" pattern, then wiped again in the perpendicular direction, and then wiped at the corners. Instructions to the participants did not specify the number of back-and-forth cycles to use.	The wood was divided into equal segments. The wood was then wiped (by either fabric or hand) in 10 cycles of back-and-forth rubbing. Both 10- and 20-cycle hand rub samples from residential decks were obtained to compare differences between 10- and 20-cycles. To collect samples from hand rubs, the hand that was used for rubbing was rinsed with 100 mL of 5% acetic acid, wiped with a polyester wipe that had been wetted with 100 mL of 5% acetic acid, and then rinsed a second time with 100 mL of 5% acetic acid. The rinse wipe and second rinse	Deck boards were dismantled and transported to the test facility. Boards were selected randomly from a deck; however, boards that were badly warped, had splits or large knotholes, were painted, stained, or waterproofed, or otherwise not "normal" were not selected for use. Wipe tests were performed in duplicate on sections 12.5 x 40 cm. Testing was only performed once boards had dried out (if they were wet). Wipes were wetted with a saline solution. A weight was placed on the cloth and then pulled back and forth

Parameter	EWG[1]	CPSC[2]	ACC[3]
		were collected as a sample.	across wood blocks 10 times. The block was then rotated 90° and 10 more passes were made. For hand rubs, hands were first wetted with saline solution. A weight was placed on the back of the hand and 20 passes were made over the wooden blocks. Hands were rinsed with a total of 140 mL hand rinse. Hands were then wiped with a cloth, which was also submitted for analysis. Control samples were analyzed both on-site and off-site for arsenic, to determine if boards became cross-contaminated as a result of their transport.

Parameter	EWG[1]	CPSC[2]	ACC[3]
		Analytical Methods	
Analytical Method	Standard Method 3113B	Wipes were extracted with 10% nitric acid at 60°C for 15–24 hours. The samples were analyzed for arsenic using inductively coupled plasma atomic emission spectroscopy.	Cloth wipes were placed into 50-mL polypropylene plastic centrifuge tubes immediately following sampling. 25 mL of 10% GFS redistilled trace element grade nitric acid was added to each tube, and the tubes were placed in a shaking hot water bath at 60°C for 12 hours. Tubes were removed from the bath and mixed, and deionized water was added to bring the total volume to 50 mL. These samples were sent for analysis. Analytical method used to determine total chromium, copper, and arsenic is based on EPA SW846 Method 6020.
LOD/LOQ	Not reported. Non-detects are assumed to equal 0.	The method detection limit was 0.02 ppm. Non-detects are assumed to equal 0.	4.8 µg/wipe. Non-detects were ignored for statistical analysis.

Parameter	EWG[1]	CPSC[2]	ACC[3]
		Conclusions	
Mean Arsenic Levels in CCA-Treated Structures[5]	0.485 µg per cm^2 wood surface area	Playgrounds: 38.8 µg per dry polyester wipe (0.297 µg/cm^2 wipe area), 72.9 µg per wet polyester wipe (0.558 µg/cm^2 wipe area), 7.6 µg hand estimate (calculated from dry polyester value using conversion factor of 0.20) Residential Decks: 42.5 µg per dry polyester wipe (0.325 µg/cm^2 wipe area), 91.0 µg per wet polyester wipe (0.697 µg/cm^2 wipe area), 7.7 µg per hand wipe, 11.5 µg per HDPE wipe	2.15 µg per cm^2 (polyester wipe) 0.061 µg per cm^2 (hand wipe)
Mean Arsenic Levels in Control Samples[5]	No control samples reported	Playgrounds 0.30 µg per dry polyester wipe 0.82 µg per wet polyester wipe	Untreated Boards (Neg. Control)[5]: 0.00 µg per cm^2 wet polyester wipe (on-site), 0.0158 µg per cm^2 wet polyester wipe (post-trip) Recently Treated Boards (Pos. Control): 5.08 µg per cm^2 wet polyester wipe (on-site), 6.32 µg per cm^2 wet polyester wipe (post-trip)
Sealant Effect[4]	Based on Mann-Whitney non-parametric test (95% confidence level), arsenic levels in structures treated with sealant 6 months ago or longer are indistinguishable from untreated structures.	Memo notes that the relationship between arsenic levels and sealer treatment in playgrounds “appears to be complex.”	Sealant not used on samples.

Parameter	EWG[1]	CPSC[2]	ACC[3]
Age of Structure[4]	No correlation between age of structure and arsenic levels.	Memo notes that the relationship between arsenic levels and age of structure in playgrounds “appears to be complex.”	Based on calculated Spearman correlation coefficients, there is a statistically significant inverse relationship between age and hand sample results ($p<0.00001$).
Other Results[4]	Forty percent of backyards tested had concentrations of arsenic in the soil at levels exceeding the EPA’s Superfund cleanup level (20 ppm).	Varying the hand contact by increasing the number of hand cycles from 10 to 20 increased the arsenic level by 18%. However, this was found to be statistically insignificant (95% confidence interval). Off the three cloths used, the dry polyester showed the strongest correlation with the hand wipes. A conversion factor of 0.20 was determined (i.e., multiply dry polyester value by 0.20 to get hand wipe estimate).	A regional difference was detected, with higher concentrations being found in the northern regions of the US. A conversion factor of .0196 was determined. A conversion factor of 0.153 was also determined, if one wishes to use the arsenic value expressed as µg arsenic per wood area sampled, rather than µg arsenic per wipe area.

[1]EWG (Environmental Working Group) Environmental Working Group, 2002. “All Hands on Deck.” And EWG, 2001. “Home Testing Kit for Arsenic Treated Wood. Brochure.”

[2]CPSC (Consumer Product Safety Commission) memorandum “Determination of Dislodgeable Arsenic Transfer to Human Hands and Surrogates from CCA-Treated Wood” January 23, 2003

[3]ACC (American Chemistry Council) submitted the study “Assessment of Exposure To Metals In CCA-Preserved Wood: Full Study” to US EPA’s Office of Pesticide Programs on June 20, 2003

[4]Unless otherwise noted, no statistical method was reported.

[5]Many of the untreated boards used in the ACC study were not wrapped during handling and appear to have been cross-contaminated by contact with other boards. In addition, the ACC study, in calculating mean concentrations for the untreated boards, ignored values below the method detection limit for the purposes of statistical analysis. The value shown in this table is for those boards that were wrapped, and it was assumed that boards with arsenic concentrations below the MDL had concentrations equal to 0. In addition, the values have been put into terms of µg/cm^2 wipe area, rather than as they were reported (µg/wipe). It should be noted, however, that none of the non-control sample boards were wrapped during handling.

Table 10. Summary of Arsenic and Chromium Residue Data from 2003 ACC (RTI) Report

	Location	N	Geo. Mean	Geo. St. Dev.	Min.	Max.
Arsenic Residue Concentration from 2003 ACC (RTI) Report						
Distributions for deck block wipe data	PA	348	0.277	1.742	0.072	6.574
	FL & GA	378	0.228	2.242	0.046	5.084
Distributions for maximum hand loading from decks	PA	341	0.052	2.506	0.003	2.189
	FL & GA	362	0.033	2.516	0.002	1.037
Transfer efficiency distributions for decks	PA	341	0.186	2.516	0.007	2.361
	FL & GA	362	0.140	2.372	0.004	3.374
Chromium Residue Concentration from 2003 ACC (RTI) Report						
Distributions for deck block wipe data	PA	348	0.356	1.722	0.086	5.120
	FL & GA	378	0.278	2.104	0.071	3.013
Distributions for maximum hand loading from decks	PA	341	0.050	2.546	0.002	1.678
	FL & GA	362	0.029	2.481	0.002	0.883
Transfer efficiency distributions for decks	PA	341	0.139	2.494	0.005	1.636
	FL & GA	362	0.104	2.376	0.007	2.227

A statistical analysis was conducted based on the arsenic and chromium data provided in the Assessment of Exposure in CCA-Preserved Wood: Full Study, prepared for the American Chemistry Council by RTI International, June 20, 2003 (ACC 2003a). For hand wipe data, wipe and rinse results were combined to yield a total hand value. The parameters for distributional analyses were block wipe dislodgeable residue, maximum hand loading, and transfer efficiency. The results are provided here.

Table 11. Summary of Arsenic Residue Data from 2003 CPSC Report

	Location	N	Geo. Mean	Geo. St. Dev.	Min.	Max.
Distributions for deck block wipe data	DC	32	0.12	3.41	0.010	1.29
Distributions for maximum hand loading from decks	DC	32	0.04	3.33	0.003	0.45
Transfer efficiency distributions for decks	DC	32	0.34	2.89	0.035	1.94

Table 12. Summary of SHEDS-Wood Input Values and Selected Variability Distributions for CCA Exposure and Dose Assessment

SHEDS-Wood Input Variable for CCA Assessment	Scenario	Selected Variability Distribution	Mean	Stdev	Median	p25	p75	Comments
Fraction of children with a CCA-treated home playset [-]		point (0.08)						Agency-derived estimate based on personal communications with IPEMA, CFA, USPIRG
Average fraction of residential outdoor time a child plays on/around a CCA-treated residential playset (on days when the child plays on/around a CCA-treated residential playset) [-]	WARM	beta (1.1,0.36)	0.753	0.275	0.870	0.588	0.981	based on CHAD diary data
	COLD	beta (1.3,0.34)	0.793	0.249	0.905	0.669	0.988	“
Average #days/yr a child plays on/around a residential CCA-treated playset [days/yr]	WARM	point (126)						Agency-derived estimate based on SCS-II play day data and rain day assumptions
	COLD	point (54)						“
Average fraction of non-residential outdoor time a child plays on/around a CCA-treated public playset (on days when the child plays on/around a CCA-treated public playset)[-]	WARM	beta (1.1,0.36)	0.753	0.275	0.870	0.588	0.981	based on CHAD diary data
	COLD	beta (1.3,0.34)	0.793	0.249	0.905	0.669	0.988	“
Average #days/yr a child plays on/around a CCA-treated public playset [days/yr]	WARM	point (126)						Agency-derived estimate based on SCS-II play day data and rain day assumptions
	COLD	point (54)						“

SHEDS-Wood Input Variable for CCA Assessment	Scenario	Selected Variability Distribution	Mean	Stdev	Median	p25	p75	Comments
Fraction of time a child on/around a CCA-treated playset is on the playset itself versus on the ground near the playset [-]		beta (12.35,12.12)	0.505	0.0990	0.505	0.436	0.573	Agency-derived estimate
Fraction of children who have a CCA-treated residential deck [-]		point (0.5)						Shook and Eastin (1996); U.S. Census (2000)
Average fraction of residential outdoor time a child plays on/around a CCA-treated residential deck (on days when the child plays on/around a CCA-treated residential deck) [-]	WARM	beta (1.1,0.36)	0.753	0.275	0.870	0.588	0.981	based on CHAD diary data
	COLD	beta (1.3,0.34)	0.793	0.249	0.905	0.669	0.988	"
Average #days/yr a child plays on/around a CCA-treated residential deck [days/yr]	WARM	point (126)						Agency-derived estimate based on SCS-II play day data and rain day assumptions
	COLD	point (54)						"
Fraction of time a child on/around a CCA-treated home deck is on the deck versus on the ground near the deck [-]		beta (39.2,4.3)	0.901	0.0448	0.907	0.875	0.934	Agency-derived estimate
Soil arsenic concentrations near CCA-treated playsets ($C_{soil,\ playset}$) [mg/kg]	WARM	lognormal (29.97,1.643)	33.9	17.9	30.0	21.4	41.9	Solo-Gabriele et al. (2001)
	COLD	lognormal (1.6,3.68)	3.74	7.90	1.60	0.663	3.85	Riedel et al. (1991)
Soil chromium concentrations near CCA-treated playsets ($C_{soil,\ playset}$) [mg/kg]	WARM	lognormal (32.38,1.88)	39.5	27.7	32.4	21.1	49.6	Solo-Gabriele et al. (2001)
	COLD	lognormal (6.7,3.9)	16.9	39.2	6.69	2.67	16.8	Doyle and Malaiyandi (1992)

SHEDS-Wood Input Variable for CCA Assessment	Scenario	Selected Variability Distribution	Mean	Stdev	Median	p25	p75	Comments
Wood surface arsenic residues on CCA-treated playsets ($SR_{res,\ playset}$) [µg/cm²]	WARM	lognormal (0.228,2.24)	0.316	0.304	0.228	0.133	0.394	ACC (2003b)
	COLD	lognormal (0.258,1.97)	0.325	0.249	0.258	0.163	0.407	ACC (2003b); CPSC (2003a,b)
Wood surface chromium residues on CCA-treated playsets ($SR_{res,\ playset}$) [µg/cm²]	WARM	lognormal (0.278,2.10)	0.366	0.313	0.278	0.169	0.459	ACC (2003b)
	COLD	lognormal (0.356,1.72)	0.412	0.240	0.356	0.247	0.513	ACC (2003b)
Soil arsenic concentrations near CCA-treated decks ($C_{soil,\ deck}$) [mg/kg]	WARM	Weibull (1.057,41.9)	41.0	38.8	29.6	12.9	57.0	Solo-Gabriel et al. (2001)
	COLD	Weibull (1.2,89)	83.7	70.0	65.6	31.5	117.	Stilwell (1998)
Soil chromium concentrations near CCA-treated decks ($C_{soil,\ deck}$) [mg/kg]	WARM	lognormal (22.2,2.77)	37.3	50.2	22.2	11.2	44.2	Stilwell (1998); Doyle and Malaiyandi (1992); Malaiyandi (1993)
	COLD	lognormal (19.9,4.3)	57.6	154.	20.0	7.46	53.2	Doyle and Malaiyandi (1992)
Wood surface arsenic residues on CCA-treated decks ($SR_{res,\ deck}$) [µg/cm²]	WARM	lognormal (0.228,2.24)	0.316	0.304	0.228	0.133	0.394	ACC (2003b)
	COLD	lognormal (0.258,1.97)	0.325	0.249	0.258	0.163	0.407	ACC (2003b); CPSC (2003a,b) wood block residues
Wood surface chromium residues on CCA-treated decks ($SR_{res,\ deck}$) [µg/cm²]	WARM	lognormal (0.278,2.10)	0.366	0.313	0.278	0.169	0.459	ACC (2003b) using wood block residues in warm weather
	COLD	lognormal (0.356,1.72)	0.412	0.240	0.356	0.247	0.513	ACC (2003b) using wood block residues in cold weather

SHEDS-Wood Input Variable for CCA Assessment	Scenario	Selected Variability Distribution	Mean	Stdev	Median	p25	p75	Comments
Arsenic residue-skin transfer efficiency ($TE_{surf\text{-}skin}$) [-]	WARM	lognormal (0.143,2.33)	0.205	0.209	0.143	0.0809	0.253	ACC (2003b) warm weather data, dividing hand load data by wood load data
	COLD	lognormal (0.197,2.55)	0.305	0.361	0.197	0.105	0.371	ACC (2003b) and CPSC (2003a,b) cold weather data (hand wipe divided by wood wipe)
Chromium residue-skin transfer efficiency ($TE_{surf\text{-}skin}$) [-]	WARM	lognormal (0.106,2.33)	0.152	0.155	0.106	0.0599	0.187	ACC (2003b) warm weather data, dividing hand load data by wood load data
	COLD	lognormal (0.140,2.45)	0.209	0.234	0.140	0.0764	0.256	ACC (2003b) cold weather data (hand wipe divided by wood wipe)
Fraction of total body (non-hand) skin surface area that is unclothed ($F_{uncl,\ body}$) [-]	WARM	beta (3,6.7)	0.309	0.141	0.295	0.202	0.402	U.S. EPA (2002) for % total SA by body part; Wong et al. (2000) for assumed % of body part exposed to soil; O'Rourke(2003) for clothing scenarios
	COLD	point (0.05)						assumed only face exposed other than hands; Wong et al. (2000)
Fraction of hand skin S.A. contacting residues per time ($F_{contact,\ res,\ hand}$) [per 20 min]		beta (9.4,3.3)	0.740	0.118	0.753	0.664	0.829	Kissel et al. (1998); we assumed same contact rate for residues and soil
Fraction of unclothed body (non-hand) skin S.A. contacting residues per time ($F_{contact,\ res,\ body}$) [per 20 min]		beta (3.1,16.5)	0.158	0.0805	0.146	0.0979	0.206	based on Kissel et al. (1998), Figure 1; we assumed same contact rate for residues and soil
Fraction of hand skin S.A. contacting soil per time ($F_{contact,\ soil,\ hand}$) [per 20 min]		beta (9.4,3.3)	0.740	0.118	0.753	0.664	0.829	Kissel et al. (1998); we assumed same contact rate for residues and soil

SHEDS-Wood Input Variable for CCA Assessment	Scenario	Selected Variability Distribution	Mean	Stdev	Median	p25	p75	Comments
Fraction of unclothed body (non-hand) skin S.A. contacting soil per time ($F_{contact, soil, body}$) [per 20 min]		beta (3.1,16.5)	0.158	0.0805	0.146	0.0979	0.206	based on Kissel et al. (1998), Figure 1; we assumed same contact rate for residues and soil
Daily soil ingestion rate (IR_{soil}) [mg/day]	Typical child	lognormal (31,4), <500 mg/day	60.6	80.5	29.8	11.9	73.4	Stanek and Calabrese (2000); Stanek et al. (2001)
	Pica child	lognormal (31,4), >500 mg/day	962.	758.	735.	590.	1046.	ATSDR (2001)
Soil-skin adherence factor ($Adh_{soil-skin}$) [mg/cm^2]		lognormal (0.11,2)	0.140	0.109	0.110	0.0688	0.175	Holmes et al. (1999); Kissel et al. (1996)
Fraction of hand surface area mouthed per mouthing event ($F_{hand-mouth}$) [-]		beta (3.7,25)	0.129	0.0615	0.120	0.0834	0.165	Leckie et al. (2000) data for frequency of mouthing events for different surface area categories, and assuming each finger 10% of hand, surface area palm mouthed 25%, 1 partial finger 5%
Frequency of hand-mouth activity per hour (N_{hm}) [-]		Weibull (0.73,6.93)	8.45	11.75	4.21	1.27	10.86	Leckie et al. (2000); Zartarian et al. (1998); Reed et al. (1999); Tulve et al. (2002)
Hand-washing events per day [#/day]		lognormal (3.74,2.63)	5.96	7.43	3.73	1.95	7.17	Wong et al. (2000); Tsang and Klepeis (1996); Freeman et al. (2001); Kissel (2003)
Hand-washing removal efficiency (F_{hw}) [-]		beta (32,22)	0.593	0.0662	0.594	0.548	0.638	Wester et al. (1993)
Bathing removal efficiency (F_{bath}) [-]		beta (17.1,5.1)	0.770	0.0874	0.778	0.715	0.834	Wester et al. (1993)

SHEDS-Wood Input Variable for CCA Assessment	Scenario	Selected Variability Distribution	Mean	Stdev	Median	p25	p75	Comments
Hand-to-mouth dermal transfer fraction *($F_{hm\text{-}remov}$)* [-]		beta (14.5,4.1)	0.780	0.0935	0.790	0.721	0.849	based on triangular using Camann et al. (1995) data; Lewis (2003) personal communication; and 100% as min, mode, and max
Dermal absorption rate for arsenic residues *($AbsR_{dermal,\ res}$)* [1/day]		beta (50,1611)	0.0301	0.0042	0.0299	0.0272	0.0328	Wester et al. (1993); FIFRA SAP (2001)
Dermal absorption rate for arsenic in soil *($AbsR_{dermal,\ soil}$)* [1/day]		beta (50,1611)	0.0301	0.0042	0.0299	0.0272	0.0328	Wester et al. (1993); FIFRA SAP (2001)
Dermal absorption rate for chromium residues *($AbsR_{dermal,\ res}$)* [1/day]		point (0.01)						FIFRA SAP (2001)
Dermal absorption rate for chromium in soil *($AbsR_{dermal,\ soil}$)* [1/day]		point (0.01)						FIFRA SAP (2001)
GI absorption rate for arsenic residues *($AbsR_{ingest,\ res}$)* [1/day]		beta (4.7,12.5)	0.273	0.105	0.264	0.197	0.341	ACC (2003c)
GI absorption rate for chromium residues *($AbsR_{ingest,\ res}$)* [1/day]		point (1.0)						FIFRA SAP (2001)
GI absorption rate for arsenic in soil *($AbsR_{ingest,\ soil}$)* [1/day]		beta (11.4,13)	0.467	0.0989	0.466	0.398	0.535	ACC (2003d)
GI absorption rate for chromium in soil *($AbsR_{ingest,\ soil}$)* [1/day]		point (1.0)						FIFRA SAP (2001)

Notes for Table 12

(1) “Child” and “children” refer to children 1–6 years old in the United States who contact CCA-treated wood residues and/or CCA-containing soil from public playsets (e.g., at a playground, a school, a daycare center), at a minimum. A subset of these children also contacts CCA-treated wood residues and/or CCA-containing soil from residential playsets (i.e., at the child’s own home or at another child’s home) and/or residential decks.

(2) Playing “around” a wood structure (i.e., playset or deck) is defined as play within 2 feet of the structure, since that is the distance in which CCA-contaminated soil has been identified.

(3) A non-residential location refers to CHAD locations where it is assumed that a public CCA-treated playset may be present.

(4) The variability distributions are parameterized as follows:

Lognormal (a, b) indicates a lognormal distribution with geometric mean exp(μ) = a and geometric standard deviation exp(σ) = b. Under a logarithmic transformation, this is a normal (μ, σ) distribution.

Beta (a, b) indicates a beta distribution with minimum=0 and maximum=1, with PDF given by $f(x) = x^{a-1} (1-x)^{b-1} \Gamma(a+b) / (\Gamma(a) \Gamma(b))$, for $0 <= x <= 1$.

Weibull (a,b) indicates a Weibull distribution with shape parameter ‘a’ and scale parameter ‘b’. The PDF is $f(x) = a b^{-a} x^{a-1} \exp[(-x/b)^a]$

No statistical population parameters are provided for variables that are set to point values.

Body weight and total body surface area (body weight = BW, surface area = SA)

To calculate children's body weight and surface area for this assessment, a modified Lifeline™ model approach was used (The Lifeline Group, Inc., 2001). This involves equations for body weight, height, and surface area that preserve correlations among those parameters between different ages for a given person. The 2002 SAP pointed out that using more detailed body weight for one year old children would be better than using an average body weight to reflect the rapid growth, metabolism, and other changes specific to this age group. Thus, body weight, height, and age were reanalyzed from NHANES III (http://www.cdc.gov/nchs/about/major/nhanes/datalink.htm#NHANESIII) data so that height, body weight, and surface area change in SHEDS-Wood by month (rather than by year) for ages 1-6 years.

Fraction children with CCA-treated home playset [-]

This variable is the product of the fraction of children in the population with a home playset, and the fraction of home playsets that are CCA-treated. Various organizations were contacted about the first term, including the International Play Equipment Manufacturers Association (IPEMA), the U.S. Public Interest Research Group (USPIRG), the Consumer Federation of America (CFA), and the Consumer Product Safety Commission (CPSC). These groups did not know of available data. Personal communication with Mr. Bill Duffy, Administrator of IPEMA suggested use of 0.5 as an upper bound. Thus, for the first term, we assumed 0.1-0.5.

Of 1,037 public playgrounds surveyed, "almost 14% of the playgrounds surveyed contained wood that may be pressure treated" and "some pressure treated wood may contain chromated copper arsenate" (CFA and USPIRG, 2002). The authors of that report both thought that the fraction of home playsets with treated wood is higher than 0.14, but had no data to suggest how high (Weintraub and Cassady, personal communication). We assumed for the second term, i.e., fraction of home playsets that are CCA-treated, 14% as lower bound and 28% as upper bound (factor of 2 for lack of data).

Combining the lower bounds of both terms and the upper bound of both terms gives a range of 0.014-0.14. Thus, we assumed a mean of 8% for a point estimate to use in the SHEDS-Wood variability runs.

Average fraction of residential outdoor time a child plays on/around a CCA-treated residential playset (on days when the child plays on/around a CCA-treated residential playset) [-]

To estimate a distribution for this variable, CHAD diaries were stratified by month and analyzed for children ages 1-6 years to obtain the ratio of reported playground time divided by reported total outdoor non-residential time on days with reported playground events. This was used as a surrogate for the analogous residential variable. For warm climate this yielded a beta distribution with alpha parameter 1.1 and beta parameter 0.36 (mean 0.753, standard deviation 0.275, median 0.870, 25th percentile 0.588, and 75th percentile 0.981). For cold climate this yielded a beta distribution with alpha parameter 1.3 and beta parameter 0.34 (mean 0.793, standard deviation 0.249, median 0.905, 25th percentile 0.669, and 75th percentile 0.988). Although these are not statistically significantly different, we used the separate distributions for warm and cold climate based on stratifying CHAD diaries by month.

Average #days/yr a child plays on/around a residential CCA-treated playset [-]

As noted above (*Summary of CHAD information on playground activities*), the CHAD diaries were reviewed for information on this variable, but were not found to be suitable for this purpose. The CHAD codes are not specific to playground activities. Furthermore, the CHAD studies are cross-sectional and include a large number of children who either do not have access to a playground or simply do not regularly visit one. Thus, CHAD would underestimate the playground time for the children in the population of interest. The following approach was taken instead.

For warm climate we assumed that the children play on public playsets 7 days a week minus the 32% number of rained-out days (based on National Weather Service data used in CPSC 2003a), using the 50%ile from Soil Contact Survey (SCS)-II warm weather play day data (Kissel, 2003, personal communication). Thus, on any given day when the child goes to an "outdoor other" location, the child has a 68% probability of playing on a playset. On average, this would give 0.68*185 days = 126 days (185 is the number of days, on average, that a child has “outdoor other” location in their diaries using the longitudinal approach), with an upper bound of 0.68*365 days=248 days (i.e., all 8 diaries selected for longitudinal diary creation have outdoor other location) and a lower bound of 0.68*26=18 days (i.e., 1 weekend or season diary selected for longitudinal diary creation has outdoor other location).

For cold climate we assumed that the children play on public playsets 3 days per week minus the 32% rained-out days, using the 50%ile from SCS-II cold weather play day data. Thus, on any given day when the child goes to a non-residential location in CHAD, the child has a 68%*3/7=29% probability of playing on a playset. On average, this would give 0.29*185 days = 54 days, with an upper bound of 0.29*365 days=106 days (all 8 diaries selected for longitudinal diary creation have outdoor other location) and a lower bound of 0.29*26 =8 days (1 diary selected for longitudinal diary creation has outdoor other location).

Only a point estimate is needed in SHEDS-Wood for this variable; it is divided by 185 to obtain a probability. The variability comes from the diaries. A year-long diary in SHEDS-Wood has a variable number of days per year with non-residential time. The values used in SHEDS-Wood for this assessment were 54 in cold climate and 126 in warm climate.

The numbers used in SHEDS-Wood for this variable are consistent with those assumed in other studies. EWG (2001) assumed children ages 6 months through 5 years play on play structures 3 days a week, or 156 days per year (EWG, 2001). CDHS (1987) assumed an exposure frequency of 130 days/yr on playgrounds (5 times/week, 26 weeks/yr) as a central tendency. Midgett (2003) as part of the CPSC (2003a) assessment suggested a range of 104 visits/yr to 230 /yr, with 156 as central tendency. Gradient (2001) assumed 31 day-equivalents/yr.

Average fraction of non-residential outdoor time a child plays on/around a CCA-treated public playset (on days when the child plays on/around a CCA-treated public playset)[-]

To estimate a distribution for this variable, CHAD diaries were stratified by month and analyzed for children ages 1-6 years to obtain the ratio of reported playground time divided by reported total outdoor non-residential time on days with reported playground events. For warm climate this yielded a beta distribution with alpha parameter 1.1 and beta parameter 0.36 (mean 0.753, standard deviation 0.275, median 0.870, 25th percentile 0.588, and 75th percentile 0.981). For cold climate this yielded a beta distribution with alpha parameter 1.3 and beta parameter 0.34 (mean 0.793, standard deviation 0.249, median 0.905, 25th percentile 0.669, and 75th percentile 0.988). Although these are not statistically significantly different, we used the separate distributions for warm and cold climate based on stratifying CHAD diaries by month.

Average #days/yr a child plays on/around a CCA-treated public playset [-]

For lack of data, the same values were used for this variable as for "*average #days/yr a child plays on/around a residential CCA-treated playset [-]*" described above.

Fraction of time a child on/around a CCA-treated playset is on the playset itself versus on the ground near the playset [-]

No data are available for the variable, so an Agency-derived best estimate was used. We assumed that, on average, time spent on playsets and time spent on the ground within 2 feet of playsets occurs with equal durations. We fit a triangular distribution with minimum 0.25, mode 0.5, maximum 0.75, as in the 2002 SAP, then fit to the triangular distribution a beta distribution with bounds at 0 and 1 and parameters 12.35 and 12.12 (mean 0.505, standard deviation 0.099, median 0.505, 25th percentile 0.436, 75th percentile 0.573).

The definition of "near the playset" here is 2 feet, based on Stilwell (1998) which showed that metals were detected up to 15 inches away from decks, and an earlier study by Degroot et al. (1979), which showed with CCA that both As and Cr showed a sharp decline in concentrations from 0 inches to about 18 inches away from the wood structure.

Fraction of children who have a CCA-treated residential deck [-]

Shook and Eastin (1996) reported that 70% of all single family homes in the U.S. have a treated deck (85% of all single family homes in US have a deck or deck-like structures (patio, balcony, porch, etc.), and 82.5% of those are considered treated lumbers). We assumed those are CCA-treated. According to the 2000 US Census, 62% of 1-6 year-olds live in single-family versus other homes. Assuming 10% of the other 38% of children in non-single family homes have CCA-treated decks yields a point estimate of 0.5 (0.7*0.62+0.1*0.38) which was used in SHEDS-Wood.

Average fraction of residential outdoor time a child plays on/around a CCA-treated residential deck (on days when the child plays on/around a CCA-treated residential deck) [-]

For lack of data, the same values were used for this variable as for *"average fraction of residential outdoor time a child plays on/around a CCA-treated residential playset (on days when the child plays on/around a CCA-treated residential playset) [-]"* described above.

Average #days/yr a child plays on/around a CCA-treated residential deck [-]

For lack of data, the same values were used for this variable as for "*average #days/yr a child plays on/around a residential CCA-treated playset [-]"* described above.

Fraction of time a child on/around a CCA-treated home deck is on the deck versus on the ground near the deck [-]

No data were available for this variable, so an Agency-derived best estimate was used. It was assumed that, on average, children who play on/around decks spend 90% of their time on the deck itself versus the ground near the deck. For variability, we fit a beta(39.2,4.3) by first fitting a triangular with minimum 0.8, peak 0.9, and maximum 1.0. For this beta distribution the mean is 0.901, standard deviation 0.0448, median 0.907, 25th percentile 0.875, 75th percentile 0.934. For playsets, we assumed a 50-50 split on average between time on wood and time on soil. Agency opinion was that a greater fraction of time would be spent on decks than on playsets for time spent on/around decks and playsets, respectively.

Soil Arsenic concentrations near CCA-treated playset ($C_{soil, playset}$) [mg/kg]

For warm climate, a lognormal distribution with geometric mean 29.97 and geometric standard deviation of 1.643 was fit, based on analyses of Solo-Gabriel et al. (2001) data for warm weather. For cold climate, a lognormal distribution with geometric mean 1.6 and geometric standard deviation of 3.68 was fit, based on analyses of cold weather data from Riedel et al.(1991). These cold climate distributions are consistent with ACC (2002) As soil concentration data with geometric mean (GM) 3.32 and geometric standard deviation (GSD) 2.81 combined from California and Virginia cities.

Soil Chromium concentrations near CCA-treated playset ($C_{soil, playset}$) [mg/kg]

For warm climate, a lognormal distribution with geometric mean 32.38 and geometric standard deviation of 1.88 was fit, based on analyses of Solo-Gabriel et al. (2001) playset soil data for warm weather. For cold climate, a lognormal distribution with geometric mean 6.7 and geometric standard deviation of 3.9 was fit, based on analyses of Doyle and Malaiyandi (1992) data. These cold climate distributions are consistent with ACC (2002) As soil concentration data with GM 3.32 and GSD 2.81 combined from California and Virginia cities.

Wood surface Arsenic residues on CCA-treated playset ($SR_{res,\ playset}$) [ug/cm2]

Arsenic deck residues (based on wood block residue data) from ACC (2003b) for warm climate scenario were used to obtain a lognormal (0.228, 2.24) distribution. Both ACC (2003b) and CPSC (2003b,c) wood block residue data for the cold climate scenario were used to obtain a lognormal(0.258, 1.97) distribution.

Wood surface Chromium residues on CCA-treated playset ($SR_{res,\ playset}$) [ug/cm2]

Cr deck residues (based on wood block residue data) from ACC (2003b) for the warm climate scenario were used to obtain a lognormal(0.278,2.10) distribution; similarly the cold climate Cr deck residues were fit to obtain a lognormal(0.356, 1.72) distribution.

Soil Arsenic concentrations near CCA-treated deck ($C_{soil,\ deck}$) [mg/kg]

For the warm climate scenario a Weibull(1.057, 41.9) distribution was fit based on analyses of Solo-Gabriel et al. (2001); while for the cold climate scenario a Weibull(1.2,89) distribution was fit based on analyses of Stilwell (1998).

Soil Chromium concentrations near CCA-treated deck ($C_{soil,\ deck}$) [mg/kg]

For the warm climate scenario a lognormal(22.2,2.77) distribution was fit based on Stilwell (1998), Doyle and Malaiyandi (1992), and Malaiyandi (1993). For the cold climate scenario a lognormal(19.9,4.3) distribution was fit, based on Doyle and Malaiyandi (1992).

Wood surface Arsenic residues on CCA-treated deck ($SR_{res,\ deck}$) [ug/cm2]

For the warm climate scenario a lognormal(0.228,2.24) distribution was fit to ACC (2003b) data (using wood block residues), and for the cold climate scenario a lognormal(0.258,1.97) distribution was fit to both ACC (2003b) and CPSC data (2003b,c; using wood block residues).

Wood surface Chromium residues on CCA-treated deck ($SR_{res,\ deck}$) [ug/cm2]

For the warm climate scenario a lognormal(0.278,2.10) distribution was fit using ACC (2003b) data (based on wood block residue data) for warm weather. For the cold climate scenario a lognormal(0.356,1.72) distribution was fit from their cold weather data (using wood block residues).

Arsenic residue-skin transfer efficiency ($TE_{surf\text{-}skin}$) [-]

ACC (2003b) warm weather data was used by dividing hand load data by wood load data to obtain a lognormal(0.143,2.33) distribution for the warm climate scenario. For the cold climate scenario both ACC (2003b) and CPSC (2003b,c) cold weather data (hand wipe divided by wood wipe) were used to obtain a lognormal(0.197,2.55) distribution.

Chromium residue-skin transfer efficiency ($TE_{surf-skin}$) [-]

ACC (2003b) warm weather data were used by dividing hand load data by wood load data to obtain a lognormal(0.106,2.33) distribution for the warm climate scenario. A lognormal(0.140,2.45) distribution was obtained for the cold climate scenario (using cold weather hand load divided by wood load data).

Fraction of total body (non-hand) skin surface area that is unclothed (F_{uncl})

Table 8-3 from the Child-Specific Exposure Factors Handbook (US EPA, 2002) lists percent total surface area by body part, mean, minimum, maximum for each ages 1-4, 6, 9, 12 years, for head, trunk, arms, hands, legs, and feet. Wong et al. (2000) assumed for soil exposure face 5%, hands 6%, short pants 13%, short sleeves 6%, no shirt 38% (M), halter top 30% (F), no shoes 7%, low socks 3%, and no socks 6%.

New clothing scenario data for an EPA STAR grant (# R827443) project entitled "Vulnerability of Young Children to Organophosphate Pesticides and Selected Metal through intermittent exposures in Yuma County, Arizona" (O'Rourke, 2003, personal communication) indicates that in warm weather short sleeve T-shirt, above-knee shorts, socks, and shoes is a typical clothing scenario, which would yield an average value of 5%+13%+6%+3% = 0.27. A lower bound would correspond to zero exposure, and an upper bound to a clothing scenario of no shirt, bare feet, above-knee shorts (5%+13%+38%+7%+6% = 0.69). For the warm climate scenario the foundational triangle distribution was established with these values (min=0.0, peak=0.27, max=0.69). Then a beta distribution was fit, yielding beta(3, 6.7) with a mean of 0.309, standard deviation 0.141, median 0.295, 25th percentile 0.202, and 75th percentile 0.402.

For the cold climate scenario, we assumed that only the face is exposed (other than the hands) and used a point estimate of 0.05.

Fraction of hand skin surface area contacting residues per time ($F_{contact, res, hand}$) [rate per 20 min]

Kissel et al. (1998) used a fluorescent tracer to study the soil loading on 12 children, wearing short pants and short sleeves, playing in soil for 20 minutes. Figure 1 from this paper indicates a mean 75%, 95% CI: 65%-85%. Based on the mean and standard deviation, and a sample size of 12, we fit a beta(9.4, 3.3) with mean 0.740, std 0.118, median 0.753, 25th percentile 0.664, and 75th percentile 0.829 (based on a triangular 43%, 75%, 100%). For lack of data, we assumed the same contact rate for residues and soil.

Fraction of unclothed body (non-hand) skin surface area contacting residues per time ($F_{contact, res, body}$) [rate per 20 min]

Kissel et al. (1998) Figure 1 indicates that for legs wearing shorts: mean=20%, 95% CI=10-30%; for arms wearing short sleeves: mean=7%, 95% CI= 0-14%; for face mean=1%, 95% CI=0-2%. For lack of data, we assumed the same contact rate for residues and soil. We weighted these means and standard deviations (based on a sample size of 12) by the amount of surface area for each body part.

Thus, we used a beta(3.1,16.5), which has a mean 0.158, standard deviation 0.0805, median 0.146, 25th percentile 0.0979, and 75th percentile 0.206 (based on a triangular(0%, 12%, 36%)).

Fraction of hand skin surface area contacting soil per time ($F_{contact, soil, hand}$) [rate per 20 min]

Kissel et al. (1998) used a fluorescent tracer to study the soil loading on 12 children, wearing short pants and short sleeves, playing in soil for 20 minutes. Figure 1 from this paper indicates a mean of 75% and a 95% confidence interval of 65%-85%. Based on the mean and standard deviation, and a sample size of 12, we fit a beta(9.4,3.3) with mean 0.740, standard deviation 0.118, median 0.753, 25th percentile 0.664, and 75th percentile 0.829.

Fraction of unclothed body (non-hand) skin surface area contacting soil per time ($F_{contact, soil, body}$) [rate per 20 min]

Figure 1 in Kissel et al. (1998) indicates that for legs wearing shorts the mean for this variable (based on 20 minutes) is 20% and the 95% confidence interval is10%-30%. For arms wearing short sleeves, the mean is 7% and the 95% confidence interval is 0%-14%. For face the mean is 1% and the 95% confidence interval is 0%-2%. These means and standard deviations were weighted (based on a sample size of 12) by the amount of surface area for each body part. Thus, a beta(3.1,16.5) was used, which has a mean 0.158, standard deviation 0.0805, median 0.146, 25th percentile 0.0979, and 75th percentile 0.206.

Daily soil ingestion rate (IR_{soil}) [mg/day]

Soil ingestion rate estimates that were used in the first version SHEDS-Wood model were derived by Buck et al. (2001) using soil ingestion rates that were reported in Thompson and Burmaster (1991), Calabrese et al. (1989) and Davis et al. (1990). The statistical distributions generated by Buck et al. (2001) for variability and uncertainty distributions relied upon two tracers only, Al and Si, in estimating the parameters of the lognormal variability distributions (geometric mean, x_g, and geometric standard deviation, σ_g) as well as producing the uncertainty distributions associated with the estimated x_g and σ_g. The values reported in these publications for Al and Si were combined in generating the variability distribution but were used separately to generate a mixed normal uncertainty distribution with equal likelihood of values being assigned to the soil ingestion amount for either Al or Si. The median or the geometric mean value used for the variability distribution was 41 with a geometric standard deviation of 3.6. With these parameters the arithmetic mean is estimated to be 93mg/day with the 95th % tile value of 531mg/day. All of these estimates are quite consistent with the existing literature values and the recommended mean soil ingestion rate of 100mg/day by EPA with an upper percent value of 400mg/day. However, the SHEDS-Wood 2002 SAP suggested incorporation of more recent publications into the derivation of soil ingestion rates in the development of the variability and uncertainty distributions. The SAP also requested that EPA separate the high-end pica children's soil exposures from those seen for the typical or non-pica population of children.

A review of recent literature revealed additional analysis of earlier studies recently conducted using the study results from Amherst, MA and Anaconda, MT by Stanek and Calabrese (2000) and Stanek et al. (2001). In addition, the Child Specific Exposure Factors Handbook (US EPA 2002) and a workshop report by ATSDR on soil pica workshop (ATSDR, 2001) were identified as pertinent new information sources. Information presented in Table II of Stanek and Calabrese (2000) was used to develop a robust median estimate for the data from the Amherst and Anaconda studies. Specifically, the two mean estimates for the observed median ingestion rates (i.e., 17 and 45 mg/day) over each of the 7 day studies were averaged to estimate a representative median value of 31 mg/day for the general population of children, including potential pica and non-pica children. Coincidentally, these same two median and mean values are selected for long term soil ingestion analysis shown by Stanek et al. (2001) in Table 3. The geometric standard deviation (σ_g) values for the soil ingestion rates reported by each of these two studies were estimated assuming an underlying lognormal distribution with the corresponding arithmetic means (i.e., 31 and 179 mg/day) and geometric means (i.e., 17 and 45 mg/day) also given in Table II. The estimated σ_g values for these studies are thus 3 and 5.3, with an approximate average value of 4.

Thus, the new soil ingestion rate variability distribution developed for the current SHEDS-Wood model is: lognormal(31, 4). The arithmetic mean for this lognormal distribution is 81mg/day and the 95^{th} % tile value is 303 mg/day. These values are also consistent with the recommended values in EPA's Children's exposure factors Handbook (US EPA 2002). The definition of pica children is somewhat uncertain but assumed to be descriptive of recurrent ingestion of unusually high amounts of soil i.e., on the order of 1,000-5,000 mg/day (ATSDR, 2001). Given the long-term ingestion aspect of pica behavior, it is reasonable to select values exceeding 500 mg/day over many days or months for this particular exposure modeling scenario as representative of pica type (high) soil ingestion rate estimates. Since the revised soil ingestion distribution includes the potential pica children at the upper tail of the distribution (assumed to be above the 95^{th} %tile value), the soil ingestion rates for the typical or non-pica children are simulated by the SHEDS-Wood model using only the results generated below 500 mg/day. Therefore, the SHEDS-Wood simulations for soil ingestion rates are sorted under two categories: those below the 500 mg/day considered as typical population, and those greater than 500 mg/day corresponding to pica children. The soil ingestion rate distribution for non-pica behavior children has a mean of 60.6, standard deviation 80.5, median 29.8, 25^{th} percentile 11.9, 75^{th} percentile 73.4, 95^{th} percentile 236., and 99^{th} percentile 402. (mg/day). For children exhibiting pica behavior the summary statistics are: mean 962 mg/day, standard deviation 758, median 735, 25^{th} percentile 590, 75^{th} percentile 1046, 95^{th} percentile 2130, 99^{th} %ile 3852 mg/day.

Soil-skin adherence factor ($Adh_{soil\text{-}skin}$) [mg/cm2]

Based on their reference in the Child-Specific Exposure Factors Handbook (US EPA 2002), we used Holmes et al. (1999) and Kissel et al. (1996) studies to fit soil-skin adherence distributions. Only summary statistics were reported; no raw data were available. The Kissel mud studies were not used because of the different adhesive characteristics of mud as opposed to soil (the geometric means reported for the mud studies were more than two orders of magnitude greater than those from the other studies). Only the reported statistics for the hands were used because the arms, legs, or feet were not necessarily bare. Thus, by restricting consideration to the hand data, all studies could be placed on the same foundation.

Summary statistics for central tendency in these studies were reported in the form of geometric means; variability was reported by Holmes et al. (1999) by a geometric standard deviation and a confidence interval about the geometric mean. This suggested utilizing the lognormal distribution for the soil-skin adherence factor. It was decided to accept the lognormal as the distributional shape of choice for the soil-skin adherence factor. Given this selection, it remained to provide parameters for the lognormal distribution in the form of geometric mean and geometric standard deviation. Each of the five data sets from the two studies was given equal consideration. The following geometric means (GM) and geometric standard deviations (GSD) based on soil-skin adherence for the hands were available: Holmes 1a (GM 0.11, GSD 1.9); Holmes 1b (GM 0.15, GSD 2.1); Holmes 2 (GM 0.073, GSD 1.6); Holmes 3 (GM 0.036, 1.3); and Kissel soccer (GM 0.11, GSD 2.1).

These values appear reasonably consistent from study to study and were used to generate the desired estimates for the geometric mean and standard deviation. Under the lognormality assumption, the reported values from each study were used to calculate arithmetic means and variances for each study; these means and variances were then averaged and a standard deviation computed from this average variance. From these numbers, the estimated geometric mean and geometric standard deviation were then algebraically determined. The result is that the variability distribution for the soil-skin adherence factor is given by a lognormal distribution with a geometric mean of 0.11 mg/cm^2 and a geometric standard deviation of 2.0.

Fraction of hand surface area mouthed per mouthing event ($F_{hand\text{-}mouth}$) [-]

Distributions for the "fraction of hand with residue mouthed per mouthing event" and "frequency of hand-to-mouth activity per hour" were based on a small data set in Leckie et al. (2000) for 20 suburban children videotaped outdoors (Tables 3.5b1-3.5b20 for frequency of mouthing events for different number of fingers mouthed and surface area categories used in the study: partial fingers, full fingers, palm with fingers, palm without fingers). We assumed that each finger is 10% of the hand, and that the surface area of palm that can be mouthed is 25% of the hand. For 1 “partial finger” inserted into the mouth we assumed 5% of the hand, 2 partial fingers 10%, et cetera. This yielded a beta(3.7, 25) with mean 0.129, standard deviation 0.0615, median 0.120, 25th percentile 0.0834, and 75th percentile 0.165. Assuming 200 cm^2 for the total hand surface area of a 3-year-old child (US EPA, 2002) yields an average of 25 cm^2 mouthed per mouthing event. This is consistent with the EPA 2000 draft SOPs: 20 cm^2 (central value) as the surface area of 3 fingers for oral hand-mouth contact, based on a 3 year-old child.

Frequency of hand-mouth activity per hour (N_{hm}) [-]

Several studies containing raw data (Leckie et al., 2000; Zartarian et al. 1998; Reed, 1998; Reed et al., 1999; Tulve et al. 2002) were used to fit a Weibull(0.73, 6.93) with mean 8.45, standard deviation 11.75, median 4.21, 25th percentile 1.27, and 75th percentile 10.86. Leckie et al. (2000) obtained frequency of hands actually inserted into mouth based on videography analyses for 20 children outdoors. Reed (1998) and Reed et al. (1999) reported hourly frequency counts of hand mouthing behaviors for 30 daycare and residential NJ children ages 2-5 years. Zartarian et al. (1998) reported skin-mouth contacts for each hour of the study day for 4 children in the Salinas Valley of California. Reed et al. 1999 provided the basis for EPA OPP Draft SOP 2000 values of: 9.5/hr (central); 20/hr (high end). Tulve et al. 2002 reported indoor hourly mouthing frequencies for 69 children <=24 months and 117 children >24 months.

Two other studies with summary statistics were used for the uncertainty distributions. Freeman et al. (2001) reported hand-to-mouth contacts/hr (mean +/-std) based on 4 hrs observation per child for 19 children in MN. Black et al., (2003) reported data for 4 hrs of videotaping for 6 children ages 7-12 months, 10 children 13-24 months, 13 children 25-36 months, and 7 children >36 months.

Hand washing events per day [-]

Data from Wong et al. 2000; Tsang and Klepeis 1996; Freeman et al., 2001; and Kissel (2003, personal communication; raw SCS-II data for warm and cold weather) were used to obtain a lognormal(3.74,2.63) distribution.

Hand washing removal efficiency (F_{hw})[-]

The first wash removal efficiency data from Wester et al. (1993) reported a mean of 60% and a standard deviation of 8%. To obtain a minimum and a maximum for a triangular distribution, we used the mean ± 2 standard deviations, which yielded 44% and 76%. The best fitting beta distribution to this triangle was beta(32, 22) with mean 0.593, standard deviation 0.0662, median 0.594, 25th percentile 0.548, and 75th percentile 0.638.

Bathing removal efficiency (F_{bath}) [-]

The total removal efficiency data from Wester et al. (1993) reported a mean of 77% and a standard deviation of 10%. To obtain a minimum and a maximum for a triangular distribution, we used the mean ± 2 standard deviations, which yielded 57% and 97%. The best fitting beta distribution to this triangle was beta(17.1,5.1) with mean 0.770, standard deviation 0.0874, median 0.778, 25th percentile 0.715, and 75th percentile 0.834.

Typical number of days between baths [-]

A multinomial distribution was fit using raw data from the bathing frequency Soil Contact Survey (SCS)-II study provided by Kissel (2003, personal communication) and assumed equally spaced baths throughout the week. This was converted to a multinomial set of probabilities for the allowable number of days between baths, ranging from 1 to 7. While the data would theoretically allow fractional days between baths, an integral number of days was preferable, else the model would dictate multiple baths per day and at odd hours of the day. Examination of the data by individual ages did not suggest a need for parceling this parameter very finely by age. The most common number of baths per week was 7. This value dominated by at least a factor of 10 for warm climate and at least a factor of 3 in cold climate. To generate the days between baths, the number of baths per week was divided into 7 and the result (if not equal to 1.0) rounded up to the next highest integer. (Rounding to the nearest integer could have been done but would have generated zero days between baths and even further increased the dominance of 1 day between baths.) This method cannot generate either 5 or 6 days between baths; this is not realistic from a modeling point of view, so the tails of the observed probabilities were "smeared". The probabilities in Table 13 were used in the model.

Table 13. Model Input Probabilities (%) of Number of Days between Baths

Days between baths	1	2	3	4	5	6	7
Warm climate	75	14	7	1	1	1	1
Cold climate	59	24	9	5	1	1	1

Hand-to-mouth dermal transfer fraction ($F_{hm\text{-}remov}$) [-]

We first fit a triangular distribution using lower bound 0.5 from Camann et al. (1995) which reported 50% efficiency by human saliva for chlorpyrifos on freshly spiked human hands (consistent with OPP standard operating procedures and SAP comments, recommending 0.5). For the mode we used 75% (Lewis, personal communication), and for the upper bound we assumed 100%. We then fit a beta distribution to this triangular, to yield beta(14.5,4.1) with mean 0.780, standard deviation 0.0935, median 0.790, 25th percentile 0.721, and 75th percentile 0.849. Although metals were the focus here, Camann (1995) data for organophosphate pesticides were used because there is uncertainty in whether the As and Cr wood residues are particle-bound or water-soluble.

Dermal absorption fraction per day for Arsenic in residues ($AbsR_{dermal, res'}$) [1/day]

Wester et al. (1993) *in vivo* results with monkeys ranged from 2.0% to 6.4%. In their 2001 deterministic assessment, OPP used 6.4%. The 2001 SAP recommended a value in the range of 2%-3%. Thus, we fit a triangular distribution with minimum 0.02, peak 0.03, maximum 0.04, and then a beta(50, 1611) with mean 0.0301, standard deviation 0.0042, median 0.0299, 25th percentile 0.0272, and 75th percentile 0.0328.

It is important to note that because of dermal removal processes (hand washing, bathing, and hand mouthing), the modeled daily dermal absorption rate is lower than the user-specified value. For a 3%/day input, the actual amount absorbed is predicted at about 1%/day. This is consistent with the SAP 2001 (FIFRA SAP, 2001) comment that the 2%-3% from the monkey studies may be too high because of real-world removal processes from skin noted above.

In a recent study conducted by Wester et al. (2003), a patch containing CCA-treated wood residues was applied to monkeys, resulting in an observed 0.01% dermal absorption. This value was used for the daily dermal absorption rate in a special SHEDS-Wood analysis (discussed below) to assess the impact of the different values for this variable. Nico et al. (2003), using X-ray absorption spectroscopy to determine the chemical structure of the CCA-treated wood residue matrix, found that As and Cr form an insoluble cluster with a lower dermal absorption than that of soluble As.

Dermal absorption fraction per day for Arsenic in soil ($AbsR_{dermal, soil}$) [1/day]

Per Wester et al. (1993), the same distribution was specified as for dermal absorption fraction per day for As in residues.

Dermal absorption fraction per day for Chromium residues ($AbsR_{dermal, res}$) [1/day]

Per the FIFRA (2001) recommendations, 0.01/day was used as a point estimate for this variable.

Dermal absorption fraction per day for Chromium in soil ($AbsR_{dermal, soil}$) [1/day]

Per the FIFRA (2001) recommendations, 0.01/day was used as a point estimate for this variable.

GI absorption fraction per day for Arsenic residues ($AbsR_{ingest, res}$) [1/day]

Using new pig study data (ACC, 2003c) we fit a beta(4.7,12.5) with mean 0.273, standard deviation 0.105, median 0.264, 25th percentile 0.197, and 75th percentile 0.341. A special SHEDS-Wood simulation was conducted (see below) setting this variable to 100% per day as a bounding scenario. However, Nico et al. (2003), using X-ray absorption spectroscopy to determine the chemical structure of the CCA-treated wood residue matrix, found that As and Cr form an insoluble cluster with a lower relative bioavailability than that of soluble As (assumed to be 100% per day).

GI absorption fraction per day for Chromium residues ($AbsR_{ingest, res}$) [1/day]

Per the FIFRA (2001) recommendations, 1/day was used as a point estimate, assuming both the relative bioavailability (residues vs. water) and absolute bioavailability are 100%.

GI absorption fraction per day for Arsenic in soil (BF) ($AbsR_{ingest, soil}$) [1/day]

ACC (2003d) pig study data were fit to yield a beta(11.4,13) with mean 0.467, standard deviation 0.0989, median 0.466, 25th percentile 0.398, and 75th percentile 0.535.

GI absorption fraction per day for Chromium in soil (BF) ($AbsR_{ingest, soil}$) [1/day]

Per the FIFRA (2001) recommendations, 1/day was used as a point estimate, assuming both the relative bioavailability (soil vs. water) and absolute bioavailability are 100%.

SHEDS-Wood Approach for Generating Variability, Sensitivity, and Uncertainty Results

SHEDS-Wood considers both variability and uncertainty in model inputs and outputs. Variability is defined as the heterogeneity of values over time (e.g., hand-to-mouth frequency by age), space (e.g., soil concentrations by location), or different members of a population (e.g., body weight) (Cullen and Frey, 1999). Uncertainty, a property of the analyst, is defined as the lack of knowledge about the "true" value of a quantity, lack of knowledge about which of several alternative model representations best describes a biological/chemical/physical/other mechanism of interest, or lack of knowledge about which of several alternative probability density functions should represent a quantity of interest (Cullen and Frey, 1999). Sensitivity and uncertainty analyses involve examining which variables contribute the most to variability and uncertainty, respectively, in model results. The following sections describe how variability, sensitivity, and uncertainty analyses were conducted in the SHEDS-Wood CCA assessment.

Variability Analyses

Population

For a single-stage Monte Carlo analysis run (variability only), the process for obtaining information from individual absorbed dose profiles (described above) was repeated 1500 times to construct a distribution over the simulated population for each selected variable. Analyses were conducted to support this variability sample size above which results are fairly stable (Figure 13).

The variability distributions are characterized by the standard statistical parameters such as mean, standard deviation, minimum, maximum, median, and various percentiles. Results can be reported for various averaging time periods and for separate or aggregated pathways. The SHEDS-Wood output options for viewing variability results for a population are summary tables, cumulative density functions (CDFs), box and whiskers plots, and pie charts. For each of these output types, except pie charts, the user can select variable(s) of interest:

- absorbed dose from dermal hand contact with playset surfaces
- absorbed dose from dermal body contact with playset surfaces
- absorbed dose from dermal hand contact with soil around playsets
- absorbed dose from dermal body contact with soil around playsets
- absorbed dose from ingested playset surface residues from hand-in-mouth events
- absorbed dose from ingested soil around playsets
- absorbed dose from hand and body dermal contact with playset surfaces
- absorbed dose from hand and body dermal contact with soil around playsets
- total absorbed dose from playsets
- absorbed dose from dermal hand contact with deck surfaces
- absorbed dose from dermal body contact with deck surfaces
- absorbed dose from dermal hand contact with soil around decks
- absorbed dose from dermal body contact with soil around decks

- absorbed dose from ingested deck surface residues from hand-in-mouth events
- absorbed dose from ingested soil around decks
- absorbed dose from hand and body dermal contact with deck surfaces
- absorbed dose from hand and body dermal contact with soil around decks
- total absorbed dose from decks
- absorbed dose from dermal hand contact with playset and deck surfaces
- absorbed dose from dermal body contact with playset and deck surfaces
- absorbed dose from dermal hand contact with soil around playsets and decks
- absorbed dose from dermal body contact with soil around playsets and decks
- absorbed dose from ingested playset and deck surface residues from hand-in-mouth events
- absorbed dose from ingested soil around playsets and decks
- absorbed dose from hand and body dermal contact with playset and deck surfaces
- absorbed dose from hand and body dermal contact with soil around playsets and decks
- total absorbed dose from playsets and decks

SHEDS-Wood pie charts show percent contribution to total dose (based on population means) for the following variables:

- absorbed dose from hand and body dermal contact with playset and deck surfaces
- absorbed dose from hand and body dermal contact with soil around playsets and decks
- absorbed dose from ingested playset and deck surface residues from hand-in-mouth events
- absorbed dose from ingested soil around playsets and decks

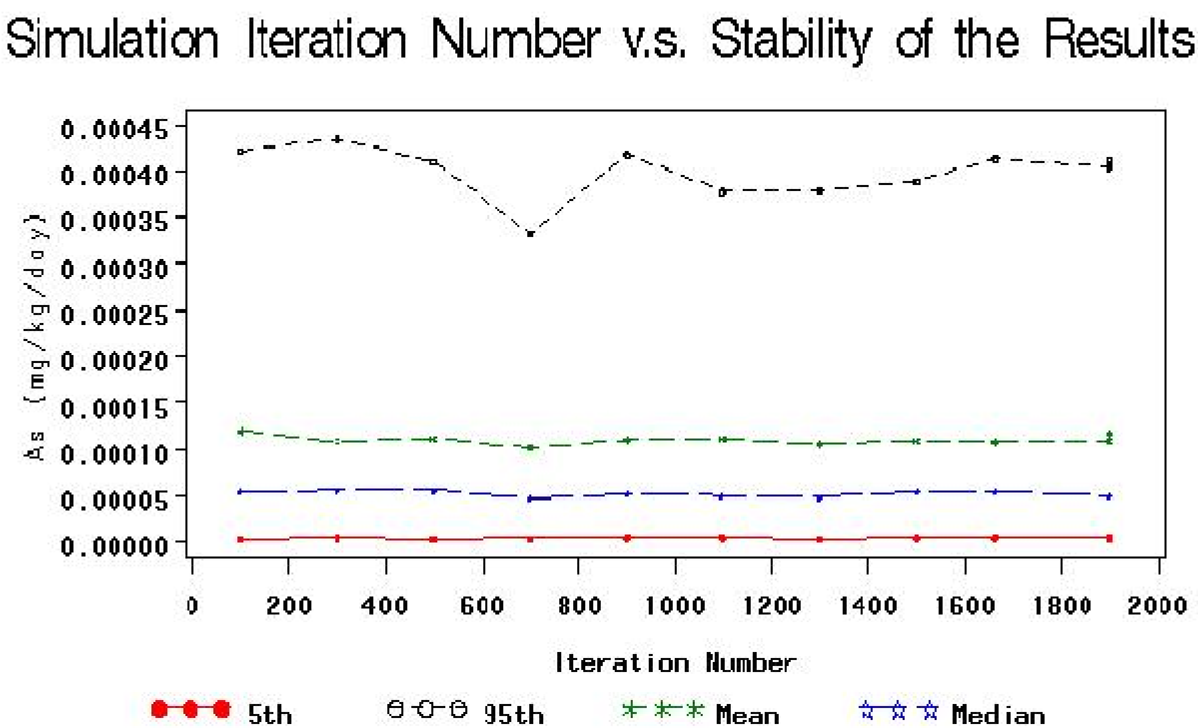


Figure 13. Analysis supporting selection of 1500 for variability analysis sample size (based on Arsenic Warm Climate LADD scenario).

Individual

SHEDS-Wood outputs for individuals include detailed tabular information for the selected individual and simulated days. This information includes the date, day number, gender, age, body weight (in kilograms), child identification number, and the daily dose averages (in mg/kg/day) for the selected variables. An absorbed dose time profile with absorbed dose plotted on the y-axis and day on the x-axis is plotted for the selected variables. Pie charts can be produced showing a selected individual's percent contribution to total dose for the combined pathways listed in the previous paragraph.

Sensitivity Analyses

Two primary approaches were used to conduct sensitivity analyses for this assessment with fixed diaries. In the first approach (the "scaling" method), all independent variables were fixed as point estimates ("medium values"). For Weibull and lognormal distributions, the means were used for medium values. Absorbed dose estimates were obtained with SHEDS-Wood by first increasing and then decreasing the medium values of model inputs by one standard deviation (for "high" and "low" input values, respectively). For each child, the activity diary was fixed while varying each exposure variable. This approach was specifically suggested by the 2002 SAP. We also used the approach of increasing and decreasing by a factor of two, as presented to the 2002 SAP, for comparison. For both scaling methods, a total of 32 independent variables set to low, medium, and high values, and using 480 simulations per run, the total data size was 46,080 (32 variables * 3 values per variable * 480 simulations). The number of 480 simulations was used because of the computer-intensive nature of conducting sensitivity simulations and because 40 children per each age-gender cohort (6 age groups * 2 genders = 12 cohorts) achieved stability of the average value. The difference in predicted results between the low, medium, and high inputs was assessed by computing the ratio of medium to low, high to medium, and high to low absorbed doses. This provided information on the magnitude of sensitivity of each input on the predicted ADD.

The second method of sensitivity analyses was to apply multiple stepwise regression to all of the data generated with the first deterministic sensitivity analysis methodology (using all of the 46,080 data points discussed above). Using the multiple stepwise regression results, the independent variables were ranked by their partial R^2 correlation coefficients to assess the relative importance of input variables based on contribution to population variance. Results from these complementary approaches were analyzed to rank importance of inputs as a function of the sensitivity of predicted dose results on corresponding input variables.

Special Analyses

In addition to sensitivity analyses to examine the impact of each variable on the absorbed dose result, several "special" analyses were conducted. To examine the difference between 1-6 year olds and 1-13 year olds as the age group selection, LADD calculations were made assuming that 7-13 year-olds have 100%, 75%, 50%, 25% of 1-6 year-olds' doses. This approach was taken because a number of SHEDS-Wood variable values are likely to differ for 7-13 year-olds than 1-6 year-olds, such as time spent on playsets and decks, frequency of hand washing and bathing, and frequency of hand-to-mouth contact. Analyses for children exposed to public playgrounds only were conducted by setting the average fraction residential outdoor time a child plays on/around CCA-treated residential playset and average fraction residential outdoor time a child* plays on/around CCA-treated residential deck to zero in the SHEDS-Wood input files. To examine children with pica behavior, one soil ingestion distribution was used, but non-pica and pica behavior children were separated based on 500 mg/day as the minimum ingestion for pica behavior. (Similarly, one could examine other subgroups having particular behavior patterns; such as infrequent washing.) Because the ACC pig study for bioavailability (ACC 2003c) involved feeding pigs residues mixed with feed, we conducted a simulation assuming 100%/day GI absorption rate for As residues (rather than beta(4.7,12.5) with mean 0.27). Wester et al. (2003) also provided new As residue dermal absorption data which were several orders of magnitude lower than in Wester et al. (1993), so a separate simulation was conducted using a mean As residue dermal absorption rate of 0.01% rather than 3%. In addition, extreme high and low dose profiles were examined to understand the extremes and assess whether they are reasonable. Finally, several exposure mitigation simulations were conducted by reducing wood residues by 90% (e.g., using sealants), washing children's hands after playing on treated decks or playsets, and a combination of the two. Results for these analyses are given in the results section below.

Uncertainty Analyses

To conduct uncertainty analyses, SHEDS-Wood was run for a one year simulation period using the two stage Monte Carlo option, with 189 uncertainty runs each consisting of 480 simulated individuals. Two stage Monte Carlo sampling is described earlier, in the section on the Overview of the SHEDS Model. The number of 480 simulated individuals was chosen because of the computer-intensive nature of conducting lifetime scenario uncertainty simulations and because 40 children per each age-gender cohort were desired (6 age groups * 2 genders = 12 cohorts). The number of 189 uncertainty runs was selected because of the computation time and because it appeared to produce stable results.

For the two stage Monte Carlo model runs (uncertainty runs), the SHEDS-Wood results for specific individuals are not retained. Instead, on each iteration of the uncertainty loop, the results for each exposure or dose variable are summarized by selected statistical parameters before proceeding to the next iteration. Additionally, the specific values for each of the input parameters subject to uncertainty are noted. At the end of the model run, the relationship between input parameters and the output statistics can be examined using either regression or correlation methods.

Modifications to the bootstrap approach

The SHEDS-Wood uncertainty analysis approach presented to the 2002 SAP involved the parametric bootstrap approach. A 2002 SAP Panel member suggested that using the parametric bootstrap procedure to define uncertainty distributions is unnecessary and gives a false sense of objectivity. The process was considered to be complicated and somewhat arbitrary in the choice of sample size, making the results of the model difficult to justify. The 2002 SAP Panel was also concerned about a lack of correlation in the outputs of that bootstrap procedure; assuming independent marginal distributions and not accounting for correlations, a fair fraction of the mean and variance combinations generated in the uncertainty analysis could be unrealistic. To address the SAP comments, the bootstrap method described in Frey et al. (2002) (Figure 14) was modified to include the following steps:

(1) Fit a variability distribution (the "parent distribution"), estimating parameters v1 and v2 (e.g., geometric mean and geometric standard deviation), to all data from the original N studies using the method of moments.

(2) Fit a variability distribution (using the shape of the parent distribution) to data in each of the original N studies using the method of moments, and examine the scatter plot of the N v1 and v2 values, to get a sense of the scale of uncertainty.

(3) Sample B data points from the parent distribution K different times (B is the bootstrap sample size; K is the number of samples of parameter pairs to be saved for uncertainty runs, typically 150).

(4) For each of those K sets of B data points, fit the parent distribution and compute the parameter values of interest. This gives K (v1,v2) pairs.

(5) Overlay the scatter plot of the K (v1,v2) pairs with the N (v1,v2) pairs obtained in step (2).

(6) Repeat steps 3-5 with different values of B, until the scatter plot from step (4) satisfactorily matches the spread seen in the scatter plot from step (2).

At the start of each uncertainty iteration, one of the K parameter pairs is randomly selected for each input variable. The selected (v1,v2) pairs define the variability distributions to be used for this iteration. All of the simulated individuals within one uncertainty iteration randomly draw values from these variability distributions.

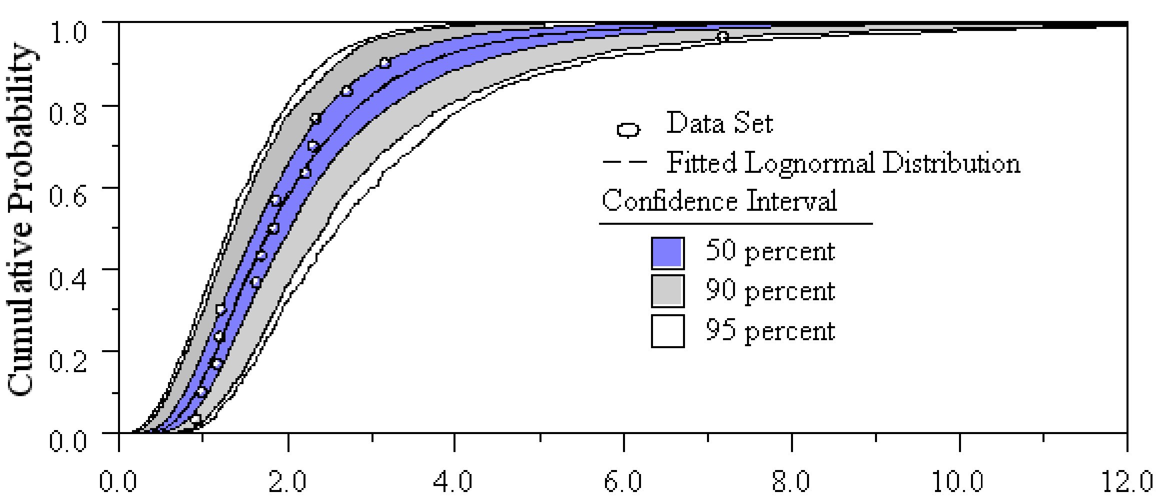


Figure 14. Illustration of bootstrap approach to compute uncertainty distributions (lognormal distributed fitted using MLE. Confidence intervals estimated based upon Bootstrap simulation.)

This approach avoids the potential problems associated with independently determining v1 and v2 parameter values. The resultant sample size "B" is less arbitrary than before, in that it requires one to assess the agreement of the uncertainty with that seen in the original N studies. Typically, it was found that a sample size of 5 was suitable for very small or highly uncertain datasets; 10 for slightly larger datasets; and 15 or 20 for even larger or less uncertain datasets. Appendix 3 illustrates graphically the uncertainty (and variability) distributions for each SHEDS-Wood variable for which uncertainty was considered (all variables except for point estimates).

Treatment of Output

The two stage Monte Carlo runs produced 189 population variability distributions, along with 189 sets of input variable distributions. Collectively, these may be used to address two related issues. The first is the extent of spread among the variability distributions. This is often expressed as a range for given percentiles of the variability distribution. The second issue is to ascertain the relative influence of the various model inputs.subject to uncertainty.

To determine which model inputs contributed the most to uncertainty for the As scenario, the mean (of 480 realizations) for each input variable is computed, along with the mean absorbed dose, for each of the 189 uncertainty runs. Spearman and Pearson correlation coefficients were computed between the absorbed dose and each input variable; these were then ranked to identify the most important contributors to uncertainty. The correlations of selected input variables to the total dose aggregated over all pathways for both playsets and decks are reported Stepwise regression was also applied, using the 189 mean numbers for each input and absorbed dose estimates, to rank the inputs in order of relative importance by their partial R^2 correlation coefficients. The partial R^2 correlation coefficient, model R^2 correlation coefficient, and significance probability (Pr>F) are reported for selected independent variables.

The graphical analysis of uncertainty takes two forms. One involves displaying three complete variability distributions (CDFs), namely the variability distributions corresponding to the 5^{th}, 50^{th}, and 95^{th} percentile as ranked by their medians (that is, those that have the 9^{th}, 95^{th}, and 180^{th} highest medians, for 189 runs). The horizontal axis represents percentiles of the population variability. The vertical distances between the three curves represent uncertainty in each percentile of the variability distribution.

The other type of graph displays three selected variability percentiles (the 5^{th}, 50^{th}, and 95^{th}) from each of the 189 uncertainty runs. Here the horizontal axis represents percentiles of the uncertainty distribution, while the vertical separation between the curves measures variability.

RESULTS

The sections below summarize results for variability analyses, sensitivity analyses, special analyses, and uncertainty analyses. Also presented here is a model evaluation that compares and contrasts the SHEDS model structure, the inputs, and results to other approaches. All of the tables presented below (except for Table 33) are summaries for non-pica children only.

Tables containing a "Deck" column refer to model simulations separated by children without decks who contact treated playsets (Deck=NO) and children with decks who contact treated playsets (Deck=YES). Tables with population summary statistics that do not include this column refer to all children in the specified population (with and without decks who contact treated playsets). It is important to note that while the 95th percentile is one of the statistics presented, this is not necessarily the high end value that will be used for regulatory decisions pertaining to CCA. Note that the cumulative density functions (CDFs) presented here display the percentile on the horizontal axis.

Variability Analyses

Lifetime Arsenic Scenario for 1-6 Year-Old Children

Tables 14 and 15 present probabilistic estimates of lifetime average daily dose for children exposed to As dislodgeable residues and contaminated soil from CCA-treated wood (on public playsets, home playsets, and decks) in warm and cold scenarios, respectively. These tables show: (1) children with decks have higher absorbed doses than children without decks (by a factor of about 2); (2) there are several orders of magnitude between lower and upper percentiles due primarily to variability in activity patterns, residues and concentrations contacted, and exposure factors; (3) predicted total absorbed doses for probabilistic analyses are greater in the warm climate bounding scenario than in cold climate bounding scenario by a factor of about 2; and (4) residue pathways are more important than soil pathways, with residue ingestion the most important pathway.

For children who contact playsets and decks, the LADD of As in the cold climate bounding scenario was 2.9 E-6 mg/kg/day (median); 6.0 E-6 mg/kg/day (mean); and 2.1 E-5 mg/kg/day (95%ile). The LADD of As in warm climate was: 6.1 E-6 mg/kg/day (median); 1.1 E-5 mg/kg/day (mean); and 3.9 E-5 mg/kg/day (95%ile).

Figure 15 presents CDFs of arsenic LADD in cold and warm climates, for the entire simulated population (corresponding to values in Tables 14 and 15). Figure 16 illustrates the relative contribution by exposure route over the entire population for the Arsenic LADD in warm climate.

Table 14. Percentiles of Population LADD (mg/kg/day) for Children Exposed to Arsenic Dislodgeable Residues and Contaminated Soil from Treated Wood Playsets and Residential Decks in Warm Climate (separated by children with and without decks)

Pathway	Deck	n	mean	std	p50	min	p05	p25	p75	p95	p99	max
Total Playset	NO	728	6.4E-06	1.2E-05	3.0E-06	2.9E-08	4.6E-07	1.3E-06	6.8E-06	2.3E-05	6.5E-05	1.3E-04
Residue Ingestion from Playset	NO	728	3.8E-06	8.8E-06	1.4E-06	2.8E-09	1.1E-07	5.2E-07	3.6E-06	1.5E-05	4.7E-05	1.0E-04
Soil Ingestion from Playset	NO	728	6.3E-07	1.1E-06	2.1E-07	2.6E-10	1.2E-08	6.1E-08	6.4E-07	2.9E-06	5.3E-06	1.1E-05
Residue Dermal Contact from Playset	NO	728	1.8E-06	3.2E-06	8.0E-07	4.6E-09	9.0E-08	3.5E-07	1.8E-06	6.2E-06	1.9E-05	3.0E-05
Soil Dermal Contact from Playset	NO	728	1.2E-07	1.4E-07	7.1E-08	1.1E-09	8.8E-09	3.5E-08	1.4E-07	3.9E-07	6.3E-07	1.6E-06
Total (Playset + Deck)	YES	738	1.1E-05	1.6E-05	6.1E-06	2.5E-07	1.0E-06	3.0E-06	1.3E-05	3.9E-05	8.4E-05	1.7E-04
Total Playset	YES	738	5.4E-06	8.2E-06	3.0E-06	1.2E-08	4.1E-07	1.3E-06	5.9E-06	1.8E-05	3.8E-05	1.0E-04
Residue Ingestion from Playset	YES	738	3.1E-06	5.9E-06	1.2E-06	3.8E-09	8.5E-08	4.9E-07	3.3E-06	1.2E-05	2.6E-05	7.4E-05
Soil Ingestion from Playset	YES	738	6.5E-07	1.2E-06	2.1E-07	1.5E-10	1.8E-08	7.8E-08	6.8E-07	2.8E-06	6.7E-06	1.1E-05
Residue Dermal Contact from Playset	YES	738	1.5E-06	2.4E-06	7.1E-07	2.0E-09	6.7E-08	2.8E-07	1.8E-06	6.0E-06	1.3E-05	2.7E-05
Soil Dermal Contact from Playset	YES	738	1.3E-07	2.1E-07	8.1E-08	4.2E-10	1.2E-08	3.8E-08	1.6E-07	3.9E-07	8.1E-07	4.3E-06
Total Deck	YES	738	5.9E-06	9.6E-06	2.8E-06	2.8E-09	3.2E-07	1.2E-06	6.6E-06	2.1E-05	4.8E-05	1.4E-04
Residue Ingestion from Deck	YES	738	3.6E-06	5.9E-06	1.5E-06	7.3E-10	1.4E-07	6.6E-07	3.9E-06	1.3E-05	3.3E-05	5.5E-05
Soil Ingestion from Deck	YES	738	9.2E-08	2.3E-07	2.3E-08	8.6E-13	8.2E-10	6.1E-09	7.2E-08	3.6E-07	1.3E-06	2.9E-06
Residue Dermal Contact from Deck	YES	738	2.2E-06	4.3E-06	1.0E-06	2.0E-09	1.0E-07	4.1E-07	2.4E-06	8.0E-06	1.8E-05	8.4E-05
Soil Dermal Contact from Deck	YES	738	2.1E-08	3.3E-08	9.6E-09	1.3E-13	5.5E-10	3.5E-09	2.6E-08	7.3E-08	1.6E-07	3.2E-07

Table 15. Percentiles of Population LADD (mg/kg/day) for Children Exposed to Arsenic Dislodgeable Residues and Contaminated Soil from Treated Wood Playsets and Residential Decks in Cold Climate (separated by children with and without decks)

Pathway	Deck	n	Mean	Stdev	p50	Min	p05	p25	p75	p95	p99	Max
Total playset	No	744	3.2E-06	4.9E-06	1.5E-06	5.1E-09	1.7E-07	6.4E-07	3.5E-06	1.2E-05	2.4E-05	5.4E-05
Residue ingestion from playset	No	744	2.7E-06	4.4E-06	1.2E-06	4.8E-09	1.2E-07	4.8E-07	2.8E-06	1.1E-05	2.1E-05	5.1E-05
Soil ingestion from playset	No	744	2.8E-08	9.2E-08	4.9E-09	2.8E-13	1.8E-10	1.2E-09	1.8E-08	1.1E-07	3.9E-07	1.3E-06
Residue dermal contact from playset	No	744	4.0E-07	5.5E-07	2.1E-07	3.6E-10	2.5E-08	9.4E-08	4.8E-07	1.5E-06	2.6E-06	5.4E-06
Soil dermal contact from playset	No	744	2.1E-09	4.9E-09	6.5E-10	1.5E-13	3.1E-11	2.4E-10	1.8E-09	8.3E-09	2.4E-08	7.1E-08
Total (playset + deck)	Yes	718	6.0E-06	9.3E-06	2.9E-06	7.5E-08	4.1E-07	1.4E-06	7.0E-06	2.1E-05	4.4E-05	1.0E-04
Total playset	Yes	718	2.8E-06	4.4E-06	1.3E-06	3.7E-08	1.5E-07	5.5E-07	3.4E-06	1.0E-05	1.9E-05	5.4E-05
Residue ingestion from playset	Yes	718	2.4E-06	4.0E-06	1.0E-06	2.4E-08	9.5E-08	4.3E-07	2.7E-06	9.4E-06	1.7E-05	5.1E-05
Soil ingestion from playset	Yes	718	3.3E-08	1.7E-07	6.1E-09	3.1E-12	2.0E-10	1.6E-09	2.1E-08	1.1E-07	4.1E-07	4.0E-06
Residue dermal contact from playset	Yes	718	3.8E-07	5.0E-07	2.0E-07	2.7E-09	2.1E-08	8.3E-08	4.6E-07	1.4E-06	2.4E-06	5.3E-06
Soil dermal contact from playset	Yes	718	2.8E-09	8.5E-09	8.4E-10	9.5E-13	4.8E-11	2.7E-10	2.1E-09	1.2E-08	3.3E-08	1.6E-07
Total deck	Yes	718	3.2E-06	5.7E-06	1.5E-06	5.2E-09	1.8E-07	7.0E-07	3.6E-06	1.2E-05	2.3E-05	8.9E-05
Residue ingestion from deck	Yes	718	2.6E-06	4.9E-06	1.1E-06	4.1E-09	1.0E-07	4.6E-07	3.0E-06	1.0E-05	2.0E-05	7.3E-05
Soil ingestion from deck	Yes	718	8.7E-08	2.4E-07	2.5E-08	1.4E-11	1.2E-09	6.5E-09	7.1E-08	3.7E-07	1.0E-06	4.6E-06
Residue dermal contact from deck	Yes	718	4.8E-07	8.6E-07	2.4E-07	8.5E-10	2.3E-08	1.0E-07	5.4E-07	1.8E-06	3.2E-06	1.6E-05
Soil dermal contact from deck	Yes	718	6.3E-09	8.3E-09	3.6E-09	5.3E-12	2.6E-10	1.4E-09	7.6E-09	2.2E-08	4.5E-08	7.8E-08

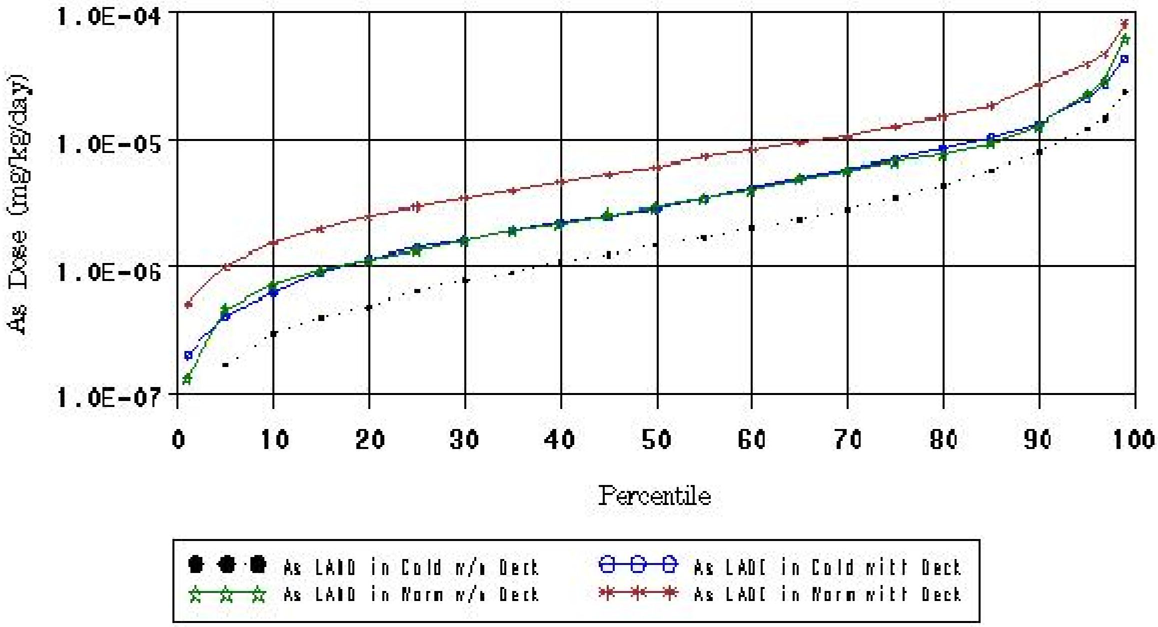


Figure 15. Population LADD for children exposed to As treated wood playsets and decks.

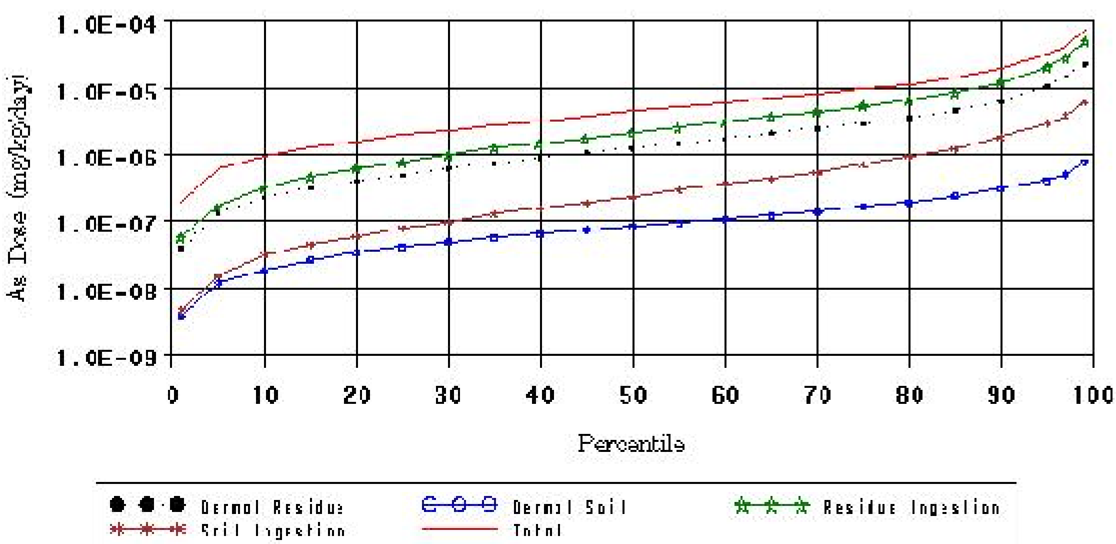


Figure 16. Relative contribution by exposure route: population LADD for children exposed to As treated wood playsets and decks in warm climates.

Intermediate-Term Arsenic Scenarios

Tables 16 and 17 present percentiles of population intermediate-term ADD for children exposed to arsenic dislodgeable residues and contaminated soil from CCA-Treated wood playsets (home and public) and residential decks (separated by children with and without decks) in warm climate and cold climate, respectively. These results are higher than the lifetime values reported above. The mean, median, and 95th percentiles for total intermediate-term As ADD in the cold climate bounding scenario for children exposed to both playsets and decks were 7.0 E-5 mg/kg/day, 3.1 E-5 mg/kg/day, and 2.4 E-4 mg/kg/day, respectively. The mean, median, and 95th percentiles for total intermediate-term As ADD in the warm climate bounding scenario for children exposed to both playsets and decks were 1.3 E-4 mg/kg/day, 6.8 E-5 mg/kg/day, and 4.5 E-4 mg/kg/day, respectively.

These tables also show: (1) for children with decks, the intermediate-term contribution to absorbed dose from decks is almost the same as from playsets; (2) there were several orders of magnitude between lower and upper percentiles due to variability in activity patterns, residues and concentrations contacted, and exposure factors; (3) predicted total absorbed doses for probabilistic analyses were greater in the intermediate-term warm climate bounding scenario than in the intermediate-term cold climate bounding scenario by a factor of about 2; and (4) residue pathways are more important than soil pathways, with residue ingestion the most important pathway.

Figure 17 illustrates CDFs of intermediate-term As ADD in cold and warm climates.

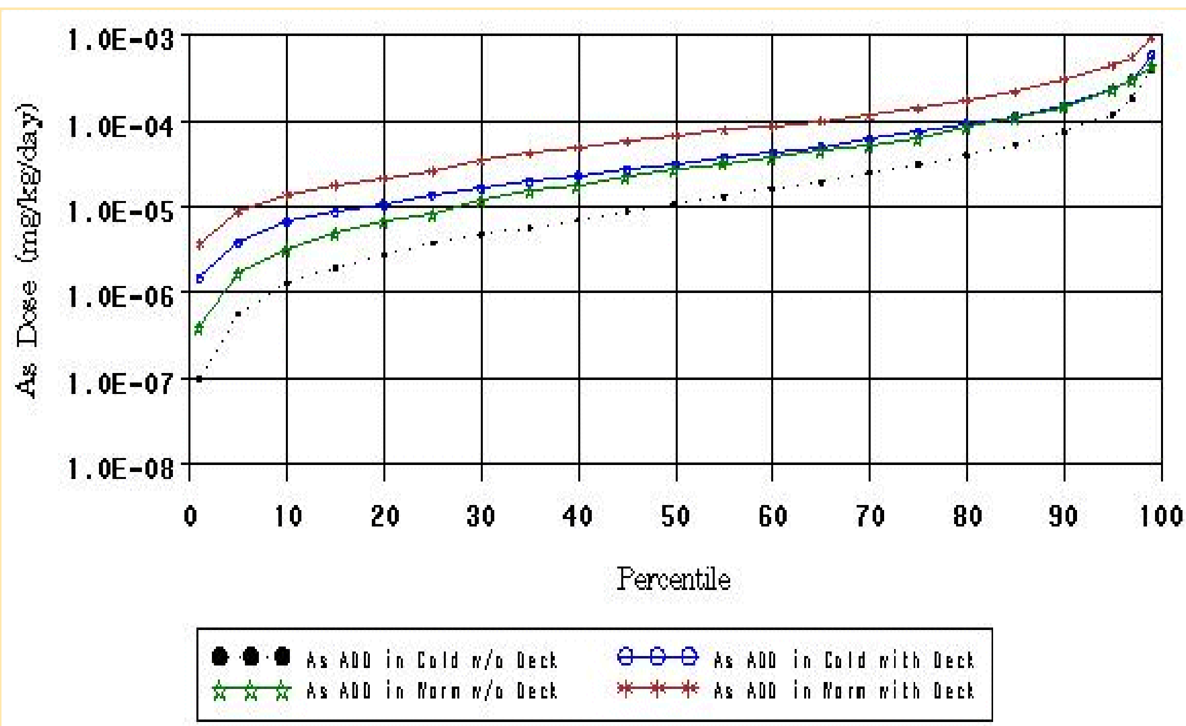


Figure 17. Population intermediate-term ADD for children exposed to As from treated wood playsets and decks.

Table 16. Probabilistic Estimates of Intermediate-Term ADD (mg/kg/day) for Children Exposed to Arsenic Dislodgeable Residues and Contaminated Soil from Treated Wood Playsets and Residential Decks in Warm Climate (separated by children with and without decks)

Pathway	Deck	n	Mean	Stdev	p50	Min	p05	p25	p75	p95	p99	Max
Total playset	No	715	5.9E-05	9.4E-05	2.8E-05	4.9E-08	1.7E-06	8.2E-06	6.4E-05	2.3E-04	4.3E-04	8.6E-04
Residue ingestion from playset	No	715	3.5E-05	7.0E-05	1.2E-05	8.4E-09	5.6E-07	4.1E-06	3.5E-05	1.6E-04	3.4E-04	7.1E-04
Soil ingestion from playset	No	715	6.8E-06	1.7E-05	1.3E-06	2.7E-09	4.7E-08	3.3E-07	5.3E-06	3.3E-05	8.4E-05	1.7E-04
Residue dermal contact from playset	No	715	1.5E-05	2.4E-05	6.5E-06	6.0E-09	2.6E-07	2.2E-06	1.8E-05	6.2E-05	1.3E-04	1.9E-04
Soil dermal contact from playset	No	715	1.5E-06	2.4E-06	6.2E-07	3.6E-09	3.6E-08	2.1E-07	1.6E-06	6.2E-06	1.2E-05	2.0E-05
Total (playset + deck)	Yes	752	1.3E-04	1.9E-04	6.8E-05	7.0E-07	8.8E-06	2.6E-05	1.4E-04	4.5E-04	9.6E-04	2.0E-03
Total playset	Yes	752	6.4E-05	1.2E-04	2.5E-05	2.4E-08	1.9E-06	9.5E-06	6.2E-05	2.6E-04	6.4E-04	1.1E-03
Residue ingestion from playset	Yes	752	3.6E-05	7.7E-05	1.1E-05	1.4E-08	6.7E-07	3.0E-06	3.4E-05	1.7E-04	4.1E-04	8.3E-04
Soil ingestion from playset	Yes	752	8.6E-06	2.8E-05	1.6E-06	3.1E-10	4.5E-08	3.8E-07	6.3E-06	3.4E-05	1.2E-04	5.4E-04
Residue dermal contact from playset	Yes	752	1.8E-05	4.0E-05	6.2E-06	1.0E-08	3.7E-07	2.1E-06	1.7E-05	7.0E-05	1.9E-04	6.1E-04
Soil dermal contact from playset	Yes	752	1.7E-06	3.1E-06	7.0E-07	1.6E-10	3.9E-08	2.3E-07	1.8E-06	6.5E-06	1.5E-05	3.1E-05
Total deck	Yes	752	6.3E-05	1.1E-04	2.6E-05	0.0E+00	1.8E-06	8.9E-06	7.1E-05	2.2E-04	5.9E-04	1.1E-03
Residue ingestion from deck	Yes	752	3.9E-05	6.7E-05	1.5E-05	0.0E+00	7.4E-07	4.4E-06	4.3E-05	1.5E-04	3.7E-04	6.6E-04
Soil ingestion from deck	Yes	752	1.0E-06	2.5E-06	2.2E-07	0.0E+00	3.6E-09	5.2E-08	7.8E-07	4.5E-06	1.2E-05	4.1E-05
Residue dermal contact from deck	Yes	752	2.3E-05	4.7E-05	9.6E-06	0.0E+00	5.3E-07	2.9E-06	2.4E-05	8.0E-05	2.0E-04	7.0E-04
Soil dermal contact from deck	Yes	752	2.4E-07	4.7E-07	8.3E-08	0.0E+00	2.2E-09	2.8E-08	2.5E-07	9.5E-07	2.3E-06	5.1E-06

Table 17. Probabilistic Estimates of Intermediate-Term ADD (mg/kg/day) for Children Exposed to Arsenic Dislodgeable Residues and Contaminated Soil from Treated Wood Playsets and Residential Decks in Cold Climate (separated by children with and without decks)

Pathway	Deck	n	Mean	Stdev	p50	Min	p05	p25	p75	p95	p99	Max
Total playset	No	721	3.7E-05	1.4E-04	1.1E-05	0.0E+00	5.7E-07	3.8E-06	3.1E-05	1.2E-04	3.9E-04	3.1E-03
Residue ingestion from playset	No	721	3.2E-05	1.2E-04	8.5E-06	0.0E+00	4.3E-07	2.8E-06	2.7E-05	1.0E-04	3.7E-04	2.6E-03
Soil ingestion from playset	No	721	3.0E-07	1.4E-06	3.5E-08	0.0E+00	4.2E-10	6.0E-09	1.5E-07	1.1E-06	3.9E-06	2.7E-05
Residue dermal contact from playset	No	721	4.7E-06	2.3E-05	1.5E-06	0.0E+00	6.5E-08	4.7E-07	3.9E-06	1.5E-05	3.8E-05	5.4E-04
Soil dermal contact from playset	No	721	2.6E-08	9.3E-08	4.3E-09	0.0E+00	1.4E-10	1.1E-09	1.5E-08	9.6E-08	4.1E-07	1.4E-06
Total (playset + deck)	Yes	742	7.0E-05	1.4E-04	3.1E-05	7.2E-07	3.9E-06	1.4E-05	7.4E-05	2.4E-04	5.9E-04	2.4E-03
Total playset	Yes	742	3.3E-05	7.5E-05	1.1E-05	0.0E+00	6.3E-07	3.5E-06	3.2E-05	1.2E-04	3.1E-04	1.3E-03
Residue ingestion from playset	Yes	742	2.8E-05	6.8E-05	9.1E-06	0.0E+00	4.8E-07	2.9E-06	2.7E-05	1.0E-04	2.6E-04	1.1E-03
Soil ingestion from playset	Yes	742	4.0E-07	1.6E-06	3.8E-08	0.0E+00	7.6E-10	7.4E-09	1.8E-07	1.8E-06	5.1E-06	2.5E-05
Residue dermal contact from playset	Yes	742	4.1E-06	8.7E-06	1.5E-06	0.0E+00	7.2E-08	4.2E-07	4.4E-06	1.6E-05	4.5E-05	1.2E-04
Soil dermal contact from playset	Yes	742	3.2E-08	1.1E-07	5.9E-09	0.0E+00	1.8E-10	1.5E-09	2.0E-08	1.2E-07	5.1E-07	1.5E-06
Total deck	Yes	742	3.7E-05	1.1E-04	1.4E-05	0.0E+00	1.2E-06	5.1E-06	3.4E-05	1.4E-04	3.1E-04	2.3E-03
Residue ingestion from deck	Yes	742	3.1E-05	9.9E-05	1.1E-05	0.0E+00	6.8E-07	3.7E-06	2.8E-05	1.2E-04	2.8E-04	2.2E-03
Soil ingestion from deck	Yes	742	8.3E-07	2.0E-06	2.1E-07	0.0E+00	5.6E-09	5.0E-08	7.4E-07	3.3E-06	9.4E-06	2.3E-05
Residue dermal contact from deck	Yes	742	4.8E-06	9.5E-06	1.9E-06	0.0E+00	1.1E-07	7.0E-07	5.2E-06	1.9E-05	3.4E-05	1.4E-04
Soil dermal contact from deck	Yes	742	6.5E-08	1.2E-07	2.9E-08	0.0E+00	1.6E-09	1.1E-08	6.9E-08	2.3E-07	6.2E-07	1.4E-06

Short- Term Arsenic Scenarios

Tables 18 and 19 present percentiles of population short-term ADD for children exposed to arsenic dislodgeable residues and contaminated soil from CCA-treated wood playsets (home and public) and residential decks (separated by children with and without decks) in warm climate and cold climate, respectively. The results are very similar to the intermediate-term results: (1) for children with decks, the contribution to absorbed dose from decks is almost the same as from playsets; (2) there were several orders of magnitude between lower and upper percentiles due to variability in activity patterns, residues and concentrations contacted, and exposure factors; (3) predicted total absorbed doses for probabilistic analyses were greater in the warm climate bounding scenario than in cold climate bounding scenario by a factor of 2 to 3; and (4) residue pathways are more important than soil pathways, with residue ingestion the most important pathway.

For children contacting playsets and decks, the mean, median, and 95th percentiles for total short-term As ADD in cold climate were 6.7 E-5 mg/kg/day, 2.5 E-5 mg/kg/day, and 2.2 E-4 mg/kg/day, respectively. The mean, median, and 95th percentiles for total short-term ADD in warm climate were 1.3 E-4 mg/kg/day, 6.5 E-5 mg/kg/day, and 4.7 E-4 mg/kg/day, respectively. Figure 18 illustrates the CDFs of arsenic short-term ADD in cold and warm climates.

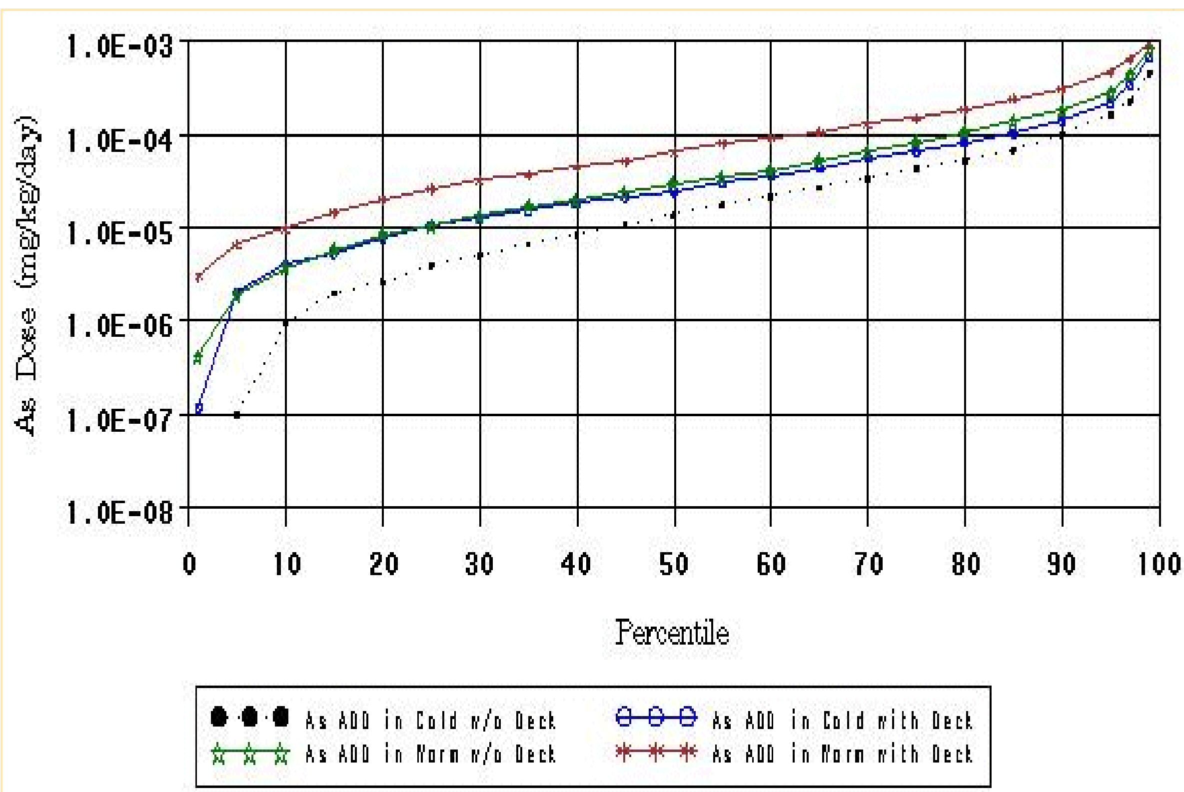


Figure 18. Population short-term ADD for children exposed to As from treated wood playsets and decks.

Absorbed dose values equal to zero may appear in the short- and intermediate-term summary statistics tables for both As and Cr (Tables 16 to 19) because children have a chance of not being exposed to treated wood from playsets or decks in the simulated 15 or 90 day time period (due to assumed input values for parameters that determine whether a child contacts treated playsets or treated decks when they are outdoors - see Table 12). The basis for the SHEDS-Wood calculations is the construction of a year-long activity diary that will have some suitable time for contact to occur; however, suitable time does not necessarily exist on shorter periods within the year. The short and intermediate periods are modeled by examining only a section of each year-long diary. In order to plot absorbed dose CDFs on a log scale, zero values were assigned a value of 1/20 of the minimum non-zero value in the population.

Table 18. Probabilistic Estimates of Short-Term ADD (mg/kg/day) for Children Exposed to Arsenic Dislodgeable Residues and Contaminated Soil from Treated Wood Playsets and Residential Decks in Warm Climate (separated by children with and without decks)

Pathway	Deck	n	Mean	Stdev	p50	Min	p05	p25	p75	p95	p99	Max
Total playset	No	755	8.4E-05	2.2E-04	3.0E-05	0.0E+00	1.9E-06	1.1E-05	8.3E-05	2.9E-04	8.2E-04	4.1E-03
Residue ingestion from playset	No	755	5.3E-05	1.6E-04	1.5E-05	0.0E+00	6.6E-07	4.6E-06	4.4E-05	1.9E-04	5.6E-04	3.2E-03
Soil ingestion from playset	No	755	8.3E-06	2.5E-05	1.7E-06	0.0E+00	6.0E-08	4.1E-07	6.4E-06	4.0E-05	1.1E-04	4.6E-04
Residue dermal contact from playset	No	755	2.2E-05	5.5E-05	7.0E-06	0.0E+00	3.2E-07	2.1E-06	2.0E-05	7.4E-05	2.6E-04	8.3E-04
Soil dermal contact from playset	No	755	1.5E-06	3.1E-06	6.5E-07	0.0E+00	4.4E-08	2.0E-07	1.6E-06	5.8E-06	1.6E-05	3.7E-05
Total (playset + deck)	Yes	710	1.3E-04	1.9E-04	6.5E-05	8.2E-07	6.6E-06	2.6E-05	1.5E-04	4.7E-04	9.5E-04	1.5E-03
Total playset	Yes	710	7.3E-05	1.2E-04	2.9E-05	0.0E+00	2.0E-06	9.7E-06	8.2E-05	2.9E-04	5.4E-04	1.1E-03
Residue ingestion from playset	Yes	710	4.5E-05	8.9E-05	1.5E-05	0.0E+00	6.7E-07	3.9E-06	4.5E-05	1.8E-04	4.2E-04	7.8E-04
Soil ingestion from playset	Yes	710	7.8E-06	2.5E-05	1.6E-06	0.0E+00	6.1E-08	4.0E-07	6.1E-06	3.1E-05	1.2E-04	3.7E-04
Residue dermal contact from playset	Yes	710	1.8E-05	3.4E-05	6.2E-06	0.0E+00	3.4E-07	1.9E-06	2.0E-05	7.5E-05	1.5E-04	3.4E-04
Soil dermal contact from playset	Yes	710	1.8E-06	4.0E-06	6.6E-07	0.0E+00	4.2E-08	2.3E-07	1.9E-06	7.3E-06	1.7E-05	7.2E-05
Total deck	Yes	710	5.8E-05	1.1E-04	2.1E-05	0.0E+00	0.0E+00	5.7E-06	5.9E-05	2.5E-04	6.6E-04	1.0E-03
Residue ingestion from deck	Yes	710	3.7E-05	7.8E-05	1.1E-05	0.0E+00	0.0E+00	2.9E-06	3.8E-05	1.6E-04	3.6E-04	8.4E-04
Soil ingestion from deck	Yes	710	7.7E-07	2.2E-06	1.3E-07	0.0E+00	0.0E+00	2.1E-08	4.9E-07	3.8E-06	1.0E-05	2.3E-05
Residue dermal contact from deck	Yes	710	1.9E-05	4.4E-05	6.0E-06	0.0E+00	0.0E+00	1.5E-06	1.7E-05	7.8E-05	2.0E-04	5.0E-04
Soil dermal contact from deck	Yes	710	1.8E-07	3.4E-07	5.8E-08	0.0E+00	0.0E+00	1.3E-08	1.9E-07	7.2E-07	1.5E-06	3.7E-06

Table 19. Probabilistic Estimates of Short-Term ADD (mg/kg/day) for Children Exposed to Arsenic Dislodgeable Residues and Contaminated Soil from Treated Wood Playsets and Residential Decks in Cold Climate (separated by children with and without decks)

Pathway	Deck	n	Mean	Stdev	p50	Min	p05	p25	p75	p95	p99	Max
Total playset	No	742	4.3E-05	1.0E-04	1.4E-05	0.0E+00	1.0E-07	4.0E-06	4.3E-05	1.6E-04	4.6E-04	1.3E-03
Residue ingestion from playset	No	742	3.8E-05	9.4E-05	1.1E-05	0.0E+00	9.0E-08	3.2E-06	3.7E-05	1.4E-04	4.5E-04	1.2E-03
Soil ingestion from playset	No	742	4.2E-07	1.9E-06	3.7E-08	0.0E+00	5.7E-11	7.3E-09	1.7E-07	1.7E-06	9.8E-06	3.0E-05
Residue dermal contact from playset	No	742	5.0E-06	1.3E-05	1.5E-06	0.0E+00	9.4E-09	5.0E-07	4.7E-06	1.9E-05	5.1E-05	2.8E-04
Soil dermal contact from playset	No	742	2.7E-08	1.0E-07	4.8E-09	0.0E+00	4.3E-11	1.0E-09	1.8E-08	1.1E-07	3.4E-07	2.2E-06
Total (playset + deck)	Yes	720	6.7E-05	1.6E-04	2.5E-05	0.0E+00	2.1E-06	1.0E-05	6.8E-05	2.2E-04	7.0E-04	2.3E-03
Total playset	Yes	720	4.0E-05	1.1E-04	1.1E-05	0.0E+00	0.0E+00	3.4E-06	3.5E-05	1.5E-04	4.2E-04	1.9E-03
Residue ingestion from playset	Yes	720	3.5E-05	1.0E-04	9.2E-06	0.0E+00	0.0E+00	2.7E-06	3.0E-05	1.4E-04	4.0E-04	1.8E-03
Soil ingestion from playset	Yes	720	4.8E-07	2.6E-06	3.1E-08	0.0E+00	0.0E+00	7.6E-09	1.5E-07	1.8E-06	7.3E-06	4.8E-05
Residue dermal contact from playset	Yes	720	4.2E-06	9.4E-06	1.3E-06	0.0E+00	0.0E+00	4.1E-07	4.1E-06	1.7E-05	4.5E-05	1.2E-04
Soil dermal contact from playset	Yes	720	2.8E-08	7.4E-08	4.9E-09	0.0E+00	0.0E+00	1.1E-09	2.0E-08	1.3E-07	3.4E-07	8.1E-07
Total deck	Yes	720	2.7E-05	8.9E-05	7.3E-06	0.0E+00	0.0E+00	3.0E-07	2.3E-05	1.0E-04	2.9E-04	1.7E-03
Residue ingestion from deck	Yes	720	2.3E-05	8.0E-05	5.4E-06	0.0E+00	0.0E+00	4.9E-08	1.9E-05	9.0E-05	2.3E-04	1.5E-03
Soil ingestion from deck	Yes	720	7.7E-07	2.3E-06	8.3E-08	0.0E+00	0.0E+00	3.8E-10	4.9E-07	3.9E-06	1.0E-05	3.7E-05
Residue dermal contact from deck	Yes	720	3.2E-06	8.9E-06	8.6E-07	0.0E+00	0.0E+00	1.2E-08	3.0E-06	1.4E-05	3.4E-05	1.4E-04
Soil dermal contact from deck	Yes	720	5.5E-08	1.4E-07	1.4E-08	0.0E+00	0.0E+00	5.5E-11	4.9E-08	2.6E-07	5.5E-07	2.4E-06

Intermediate-Term Chromium Scenarios

Tables 20 and 21 show percentiles of population intermediate-term ADD for children exposed to chromium dislodgeable residues and contaminated soil from CCA-treated wood playground structures (home and public) and residential decks (separated by children with and without decks) in warm and cold climates, respectively. For children who contact both playsets and decks, the mean, median, and 95th percentiles for total intermediate-term Cr ADD in cold climate were 7.4 E-5 mg/kg/day, 3.4 E-5 mg/kg/day, and 2.6 E-4 mg/kg/day, respectively. The mean, median, and 95th percentiles for total intermediate-term Cr ADD in warm climate were 1.2 E-4 mg/kg/day, 5.9 E-5 mg/kg/day, and 4.4 E-4 mg/kg/day, respectively.

The results are very similar to the intermediate-term As results because the As and Cr residue concentrations and residue values were similar: (1) children with decks have higher short-term absorbed doses than children without decks (by a factor of about 2 to 3); (2) there were several orders of magnitude between lower and upper percentiles due to variability in activity patterns, residues and concentrations contacted, and exposure factors; (3) predicted total absorbed doses for probabilistic analyses were greater in the warm climate bounding scenario than in cold climate bounding scenario by a factor of 1.5 to 2; and (4) residue pathways are more important than soil pathways, with residue ingestion the most important pathway.

Figure 19 illustrates the CDFs of intermediate-term Cr ADD in cold and warm climates.

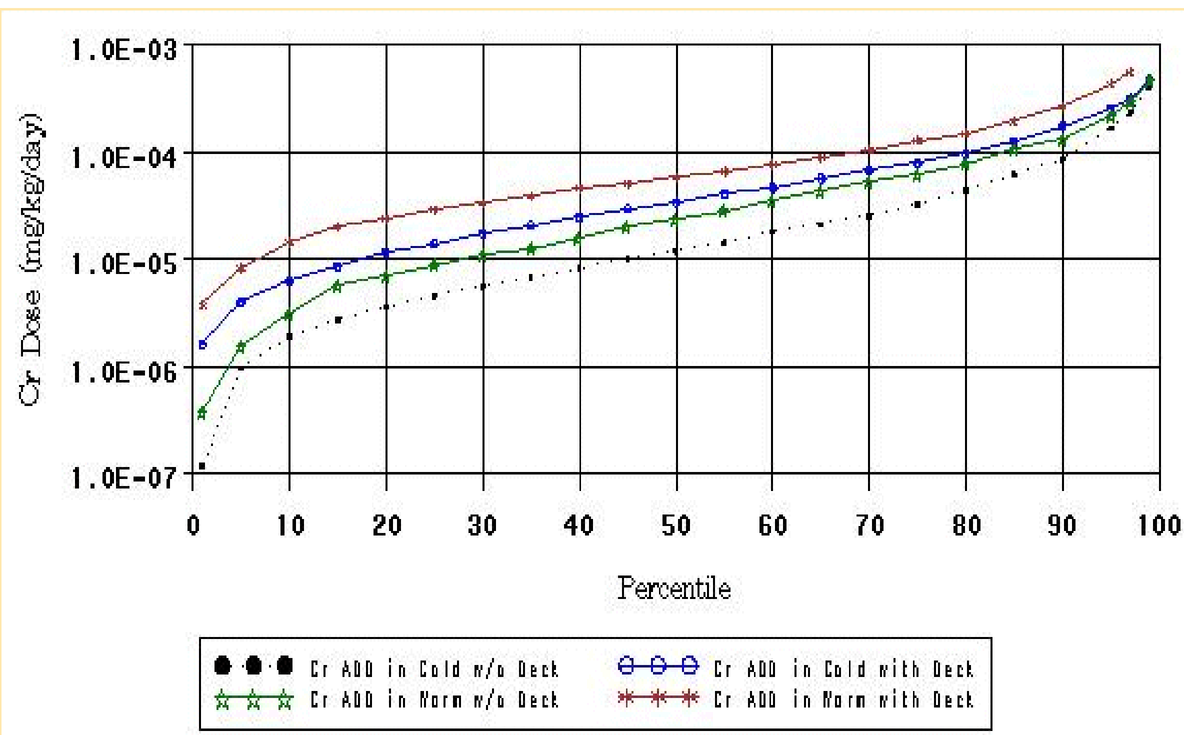


Figure 19. Population intermediate-term ADD for children exposed to Cr from treated wood playsets and decks.

Table 20. Probabilistic Estimates of Intermediate-Term ADD (mg/kg/day) for Children Exposed to Chromium Dislodgeable Residues and Contaminated Soil from Treated Wood Playsets and Residential Decks in Warm Climate (separated by children with and without decks)

Pathway	Deck	n	Mean	Stdev	p50	Min	p05	p25	p75	p95	p99	Max
Total playset	No	727	5.6E-05	9.1E-05	2.3E-05	2.9E-08	1.5E-06	8.8E-06	6.2E-05	2.2E-04	4.6E-04	8.2E-04
Residue ingestion from playset	No	727	3.0E-05	6.0E-05	1.0E-05	1.2E-08	5.5E-07	3.7E-06	3.1E-05	1.2E-04	3.2E-04	6.7E-04
Soil ingestion from playset	No	727	8.9E-06	2.8E-05	1.6E-06	1.0E-10	5.0E-08	4.1E-07	6.0E-06	3.5E-05	1.6E-04	3.6E-04
Residue dermal contact from playset	No	727	1.5E-05	2.9E-05	5.4E-06	1.2E-08	3.3E-07	1.8E-06	1.7E-05	6.4E-05	1.5E-04	3.2E-04
Soil dermal contact from playset	No	727	1.8E-06	3.0E-06	6.9E-07	5.4E-10	4.1E-08	2.4E-07	2.0E-06	6.8E-06	1.6E-05	3.2E-05
Total (playset + deck)	Yes	734	1.2E-04	1.9E-04	5.9E-05	2.0E-06	8.4E-06	2.9E-05	1.3E-04	4.4E-04	1.0E-03	1.9E-03
Total playset	Yes	734	5.6E-05	1.0E-04	2.4E-05	2.7E-08	1.3E-06	8.2E-06	6.0E-05	2.2E-04	5.2E-04	1.2E-03
Residue ingestion from playset	Yes	734	3.0E-05	6.7E-05	1.1E-05	1.8E-08	4.2E-07	3.1E-06	2.9E-05	1.4E-04	3.0E-04	9.3E-04
Soil ingestion from playset	Yes	734	8.2E-06	3.1E-05	1.6E-06	5.0E-10	4.0E-08	4.1E-07	5.4E-06	3.3E-05	9.9E-05	6.6E-04
Residue dermal contact from playset	Yes	734	1.5E-05	3.2E-05	5.3E-06	4.1E-09	2.3E-07	1.6E-06	1.5E-05	6.2E-05	1.6E-04	4.0E-04
Soil dermal contact from playset	Yes	734	1.7E-06	3.0E-06	6.7E-07	3.9E-10	2.9E-08	2.4E-07	1.8E-06	7.0E-06	1.5E-05	3.8E-05
Total deck	Yes	734	6.3E-05	1.3E-04	2.5E-05	0.0E+00	2.1E-06	9.7E-06	6.6E-05	2.2E-04	6.6E-04	1.7E-03
Residue ingestion from deck	Yes	734	4.0E-05	9.4E-05	1.5E-05	0.0E+00	9.7E-07	5.0E-06	3.7E-05	1.4E-04	4.3E-04	1.3E-03
Soil ingestion from deck	Yes	734	9.4E-07	3.1E-06	1.8E-07	0.0E+00	5.5E-09	5.3E-08	6.5E-07	3.6E-06	1.4E-05	4.7E-05
Residue dermal contact from deck	Yes	734	2.1E-05	4.5E-05	7.5E-06	0.0E+00	5.2E-07	3.0E-06	2.2E-05	7.7E-05	1.8E-04	5.0E-04
Soil dermal contact from deck	Yes	734	2.1E-07	4.1E-07	8.3E-08	0.0E+00	4.5E-09	2.3E-08	2.1E-07	8.4E-07	2.5E-06	3.9E-06

Table 21. Probabilistic Estimates of Intermediate-Term ADD (mg/kg/day) for Children Exposed to Chromium Dislodgeable Residues and Contaminated Soil from Treated Wood Playsets and Residential Decks in Cold Climate (separated by children with and without decks)

Pathway	Deck	n	Mean	Stdev	p50	Min	p05	p25	p75	p95	p99	Max
Total playset	No	721	3.9E-05	9.7E-05	1.2E-05	0.0E+00	9.7E-07	4.6E-06	3.3E-05	1.7E-04	4.1E-04	1.7E-03
Residue ingestion from playset	No	721	3.3E-05	8.6E-05	9.4E-06	0.0E+00	6.4E-07	3.3E-06	2.6E-05	1.6E-04	3.8E-04	1.5E-03
Soil ingestion from playset	No	721	1.3E-06	4.6E-06	1.4E-07	0.0E+00	3.4E-09	3.3E-08	7.0E-07	6.0E-06	1.8E-05	8.4E-05
Residue dermal contact from playset	No	721	4.6E-06	1.1E-05	1.4E-06	0.0E+00	9.6E-08	5.0E-07	4.3E-06	1.9E-05	4.0E-05	2.1E-04
Soil dermal contact from playset	No	721	7.9E-08	1.9E-07	2.1E-08	0.0E+00	7.5E-10	5.6E-09	8.1E-08	3.3E-07	7.0E-07	3.0E-06
Total (playset + deck)	Yes	733	7.4E-05	1.6E-04	3.4E-05	5.7E-07	4.0E-06	1.4E-05	8.0E-05	2.6E-04	4.8E-04	2.6E-03
Total playset	Yes	733	3.7E-05	8.5E-05	1.4E-05	0.0E+00	8.5E-07	4.9E-06	3.7E-05	1.5E-04	2.8E-04	1.4E-03
Residue ingestion from playset	Yes	733	3.1E-05	7.9E-05	1.1E-05	0.0E+00	5.4E-07	3.4E-06	3.0E-05	1.3E-04	2.5E-04	1.4E-03
Soil ingestion from playset	Yes	733	1.7E-06	7.4E-06	1.6E-07	0.0E+00	3.4E-09	3.0E-08	7.4E-07	6.5E-06	3.3E-05	1.2E-04
Residue dermal contact from playset	Yes	733	4.0E-06	6.6E-06	1.8E-06	0.0E+00	9.5E-08	5.3E-07	4.5E-06	1.5E-05	3.4E-05	5.6E-05
Soil dermal contact from playset	Yes	733	1.2E-07	3.3E-07	2.8E-08	0.0E+00	8.3E-10	7.5E-09	9.0E-08	5.9E-07	1.8E-06	4.4E-06
Total deck	Yes	733	3.7E-05	9.0E-05	1.4E-05	0.0E+00	6.8E-07	4.9E-06	3.5E-05	1.5E-04	2.6E-04	1.5E-03
Residue ingestion from deck	Yes	733	3.2E-05	8.2E-05	1.1E-05	0.0E+00	4.3E-07	3.6E-06	3.0E-05	1.2E-04	2.0E-04	1.4E-03
Soil ingestion from deck	Yes	733	5.6E-07	3.8E-06	6.7E-08	0.0E+00	1.0E-09	1.3E-08	2.6E-07	2.1E-06	8.3E-06	9.6E-05
Residue dermal contact from deck	Yes	733	5.1E-06	1.1E-05	1.9E-06	0.0E+00	1.1E-07	6.5E-07	4.9E-06	2.1E-05	5.1E-05	1.2E-04
Soil dermal contact from deck	Yes	733	4.4E-08	2.6E-07	8.6E-09	0.0E+00	2.7E-10	2.5E-09	2.8E-08	1.7E-07	4.3E-07	6.5E-06

Short-Term Chromium Scenarios

Tables 22 and 23 show percentiles of population short-term ADD for children exposed to chromium dislodgeable residues and contaminated soil from CCA-treated wood playground structures (home and public) and residential decks (separated by children with and without decks) in warm climate and cold climates, respectively. For children who contact both playsets and decks, the mean, median, and 95th percentiles for total short-term Cr ADD in cold climate were 6.9 E-5 mg/kg/day, 3.0E-5 mg/kg/day, and 2.5 E-4 mg/kg/day, respectively. The mean, median, and 95th percentiles for total short-term Cr ADD in warm climate were 1.2 E-4 mg/kg/day, 5.6 E-5 mg/kg/day, and 4.3 E-4 mg/kg/day, respectively.

The short-term results are very similar to the intermediate-term results: (1) children with decks have higher short-term absorbed doses than children without decks (by a factor of 2 to 3); (2) there were several orders of magnitude between lower and upper percentiles due to variability in activity patterns, residues and concentrations contacted, and exposure factors; (3) predicted total absorbed doses for probabilistic analyses were greater in the warm climate bounding scenario than in cold climate bounding scenario by a factor of about 2; and (4) residue pathways are more important than soil pathways, with residue ingestion the most important pathway.

Figure 20 illustrates the CDFs of short-term Cr ADD in cold and warm climates.

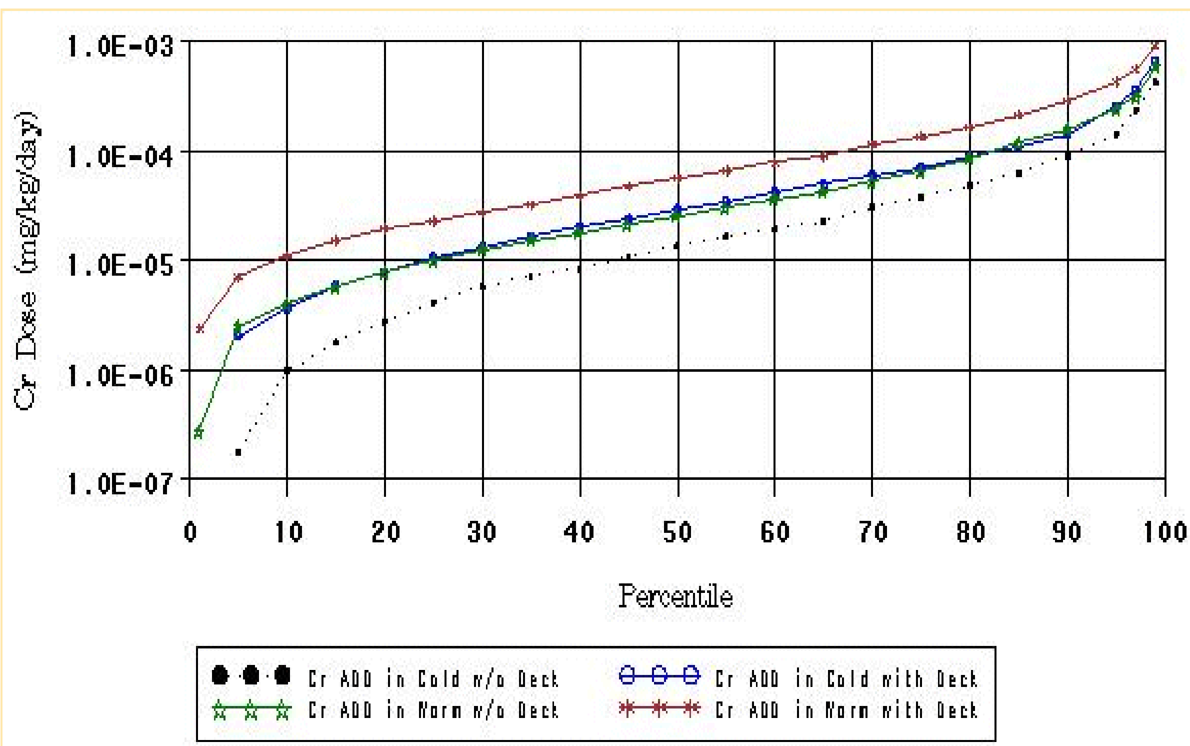


Figure 20. Population short-term ADD for children exposed to Cr from treated wood playsets and decks.

Table 22. Probabilistic Estimates of Short-Term ADD (mg/kg/day) for Children Exposed to Chromium Dislodgeable Residues and Contaminated Soil from Treated Wood Playsets and Residential Decks in Warm Climate (separated by children with and without decks)

Pathway	Deck	n	Mean	Stdev	p50	Min	p05	p25	p75	p95	p99	Max
Total playset	No	726	6.5E-05	1.3E-04	2.6E-05	0.0E+00	2.5E-06	1.0E-05	6.6E-05	2.4E-04	5.9E-04	2.1E-03
Residue ingestion from playset	No	726	3.7E-05	9.0E-05	1.3E-05	0.0E+00	6.9E-07	4.3E-06	3.3E-05	1.3E-04	4.0E-04	1.6E-03
Soil ingestion from playset	No	726	9.7E-06	3.0E-05	1.8E-06	0.0E+00	5.6E-08	4.8E-07	5.9E-06	4.3E-05	1.5E-04	3.4E-04
Residue dermal contact from playset	No	726	1.7E-05	4.1E-05	6.1E-06	0.0E+00	3.1E-07	1.9E-06	1.5E-05	7.1E-05	1.8E-04	5.1E-04
Soil dermal contact from playset	No	726	1.6E-06	2.7E-06	6.3E-07	0.0E+00	3.3E-08	2.1E-07	1.9E-06	6.5E-06	1.4E-05	2.3E-05
Total (playset + deck)	Yes	734	1.2E-04	2.1E-04	5.6E-05	7.4E-07	7.0E-06	2.3E-05	1.4E-04	4.3E-04	9.4E-04	2.7E-03
Total playset	Yes	734	7.0E-05	1.3E-04	2.6E-05	0.0E+00	1.7E-06	9.7E-06	6.9E-05	2.9E-04	6.0E-04	1.7E-03
Residue ingestion from playset	Yes	734	4.2E-05	9.4E-05	1.2E-05	0.0E+00	5.5E-07	3.5E-06	3.8E-05	2.1E-04	4.6E-04	1.2E-03
Soil ingestion from playset	Yes	734	9.3E-06	2.9E-05	1.9E-06	0.0E+00	6.1E-08	4.8E-07	7.5E-06	3.2E-05	1.3E-04	4.2E-04
Residue dermal contact from playset	Yes	734	1.7E-05	3.8E-05	5.5E-06	0.0E+00	2.6E-07	1.7E-06	1.6E-05	6.7E-05	1.7E-04	4.8E-04
Soil dermal contact from playset	Yes	734	1.7E-06	2.9E-06	6.5E-07	0.0E+00	4.7E-08	2.1E-07	1.8E-06	8.1E-06	1.3E-05	2.4E-05
Total deck	Yes	734	5.2E-05	1.4E-04	1.6E-05	0.0E+00	0.0E+00	4.2E-06	5.1E-05	2.1E-04	5.2E-04	2.7E-03
Residue ingestion from deck	Yes	734	3.5E-05	1.2E-04	9.3E-06	0.0E+00	0.0E+00	2.1E-06	3.0E-05	1.5E-04	3.3E-04	2.4E-03
Soil ingestion from deck	Yes	734	8.0E-07	3.3E-06	1.2E-07	0.0E+00	0.0E+00	2.1E-08	5.4E-07	2.8E-06	1.1E-05	6.1E-05
Residue dermal contact from deck	Yes	734	1.6E-05	3.6E-05	4.4E-06	0.0E+00	0.0E+00	1.2E-06	1.5E-05	6.7E-05	1.6E-04	5.3E-04
Soil dermal contact from deck	Yes	734	1.5E-07	3.5E-07	4.3E-08	0.0E+00	0.0E+00	9.9E-09	1.4E-07	6.2E-07	1.9E-06	4.7E-06

Table 23. Probabilistic Estimates of Short-Term ADD (mg/kg/day) for Children Exposed to Chromium Dislodgeable Residues and Contaminated Soil from Treated Wood Playsets and Residential Decks in Cold Climate (separated by children with and without decks)

Pathway	Deck	n	Mean	Stdev	p50	Min	p05	p25	p75	p95	p99	Max
Total playset	No	739	3.9E-05	8.6E-05	1.4E-05	0.0E+00	1.8E-07	4.1E-06	3.8E-05	1.4E-04	4.3E-04	9.5E-04
Residue ingestion from playset	No	739	3.3E-05	7.7E-05	1.0E-05	0.0E+00	1.1E-07	2.8E-06	3.0E-05	1.3E-04	4.0E-04	8.7E-04
Soil ingestion from playset	No	739	1.8E-06	8.9E-06	1.5E-07	0.0E+00	6.4E-10	2.8E-08	7.7E-07	6.9E-06	3.0E-05	1.9E-04
Residue dermal contact from playset	No	739	4.4E-06	8.9E-06	1.4E-06	0.0E+00	2.2E-08	3.8E-07	4.4E-06	1.8E-05	4.6E-05	9.7E-05
Soil dermal contact from playset	No	739	1.0E-07	2.4E-07	2.0E-08	0.0E+00	1.1E-10	4.7E-09	8.3E-08	4.6E-07	1.3E-06	2.4E-06
Total (playset + deck)	Yes	728	6.9E-05	1.4E-04	3.0E-05	0.0E+00	2.0E-06	1.1E-05	7.0E-05	2.5E-04	6.7E-04	1.9E-03
Total playset	Yes	728	3.9E-05	8.3E-05	1.3E-05	0.0E+00	0.0E+00	3.9E-06	3.8E-05	1.5E-04	3.9E-04	9.8E-04
Residue ingestion from playset	Yes	728	3.2E-05	7.5E-05	1.0E-05	0.0E+00	0.0E+00	2.7E-06	2.9E-05	1.3E-04	3.5E-04	9.4E-04
Soil ingestion from playset	Yes	728	1.9E-06	8.1E-06	1.5E-07	0.0E+00	0.0E+00	2.8E-08	8.3E-07	7.8E-06	3.2E-05	1.5E-04
Residue dermal contact from playset	Yes	728	4.2E-06	8.5E-06	1.6E-06	0.0E+00	0.0E+00	4.3E-07	4.0E-06	1.8E-05	4.4E-05	9.0E-05
Soil dermal contact from playset	Yes	728	1.3E-07	4.1E-07	2.1E-08	0.0E+00	0.0E+00	4.7E-09	8.7E-08	5.1E-07	2.0E-06	6.4E-06
Total deck	Yes	728	3.0E-05	7.7E-05	7.7E-06	0.0E+00	0.0E+00	5.7E-07	3.0E-05	1.2E-04	3.0E-04	1.1E-03
Residue ingestion from deck	Yes	728	2.5E-05	6.9E-05	5.5E-06	0.0E+00	0.0E+00	3.5E-07	2.4E-05	1.1E-04	2.6E-04	9.8E-04
Soil ingestion from deck	Yes	728	5.9E-07	3.5E-06	2.5E-08	0.0E+00	0.0E+00	7.1E-10	1.8E-07	2.4E-06	7.6E-06	6.8E-05
Residue dermal contact from deck	Yes	728	4.1E-06	1.1E-05	1.0E-06	0.0E+00	0.0E+00	7.9E-08	3.5E-06	1.5E-05	4.5E-05	1.3E-04
Soil dermal contact from deck	Yes	728	2.9E-08	8.9E-08	3.9E-09	0.0E+00	0.0E+00	1.8E-10	1.9E-08	1.2E-07	3.9E-07	1.1E-06

Comparison of Arsenic and Chromium Results

Tables 24 and 25 present a summary of the mean and 95th percentiles, respectively, for As and Cr population absorbed dose values by exposure pathway for the short-term, intermediate-term, and lifetime scenarios (for children exposed to home playsets, public playsets, and decks). The total mean short-term and intermediate-term playset and deck ADD values were on the order of 10^{-5} mg/kg/day, except for As warm short-term ADD which was 1.1E-4 mg/kg/day. As warm climate LADD was on the order of 10^{-6} mg/kg/day for warm and cold climate. Mean values in warm climate were 1.5 to 2 times higher than in cold climate for both As and Cr, both time frames. Total mean dose from home and public playsets was 2 to 3 times higher than total dose from decks. The most important pathways, in order of importance based on means, were consistently residue ingestion, dermal residue contact, soil ingestion, and soil dermal contact.

Total 95th percentile ADD and LADD values were 3 to 4 times higher than corresponding mean values. The total dose playset and deck 95th percentile values were on the order of 10^{-4} mg/kg/day, with the highest value being As warm short-term ADD which was 4.0E-4. As LADD was on the order of 10^{-5} mg/kg/day for warm and cold climate. 95th percentile values in warm climate were 1 to 2 times higher than in cold climate for both As and Cr, for both short-term and intermediate-term time frames. Total 95th percentile dose from home and public playsets were 1 to 3 times higher than total dose from decks. As with the means, the most important pathways, in order of importance based on 95th percentiles, were consistently residue ingestion, dermal residue contact, soil ingestion, and soil dermal contact.

Tables 26 and 27 separate the results in Tables 24 and 25 for the children with and without residential decks. The total mean and 95th percentile dose for children with decks were 1.5 to 2 times higher than for children without decks.

Table 24. Summary of Mean Arsenic and Chromium Population Absorbed Dose Values (mg/kg/day) by Exposure Pathway for the Short-Term, Intermediate-Term, and Lifetime Scenarios (for children exposed to home playsets, public playsets, and decks)

Pathway	As Warm Short-Term	As Cold Short-Term	Cr Warm Short-Term	Cr Cold Short-Term	As Warm Int.-Term	As Cold Int.-Term	Cr Warm Int.-Term	Cr Cold Int.-Term	As Warm LADD	As Cold LADD
Total (playset+deck)	1.1E-04	5.5E-05	9.4E-05	5.4E-05	9.4E-05	5.4E-05	8.7E-05	5.7E-05	8.9E-06	4.6E-06
Total playset	7.9E-05	4.2E-05	6.8E-05	3.9E-05	6.2E-05	3.5E-05	5.6E-05	3.8E-05	5.9E-06	3.0E-06
Residue ingestion from playset	4.9E-05	3.7E-05	3.9E-05	3.3E-05	3.6E-05	3.0E-05	3.0E-05	3.2E-05	3.5E-06	2.6E-06
Soil ingestion from playset	8.0E-06	4.5E-07	9.5E-06	1.8E-06	7.7E-06	3.5E-07	8.5E-06	1.5E-06	6.4E-07	3.1E-08
Residue dermal contact from playset	2.0E-05	4.6E-06	1.7E-05	4.3E-06	1.6E-05	4.4E-06	1.5E-05	4.3E-06	1.7E-06	3.9E-07
Soil dermal contact from playset	1.7E-06	2.8E-08	1.7E-06	1.1E-07	1.6E-06	2.9E-08	1.7E-06	1.0E-07	1.2E-07	2.4E-09
Total deck	2.8E-05	1.4E-05	2.6E-05	1.5E-05	3.2E-05	1.9E-05	3.2E-05	1.9E-05	3.0E-06	1.6E-06
Residue ingestion from deck	1.8E-05	1.2E-05	1.8E-05	1.3E-05	2.0E-05	1.6E-05	2.0E-05	1.6E-05	1.8E-06	1.3E-06
Soil ingestion from deck	3.7E-07	3.8E-07	4.0E-07	2.9E-07	5.2E-07	4.2E-07	4.7E-07	2.8E-07	4.6E-08	4.3E-08
Residue dermal contact from deck	9.3E-06	1.6E-06	7.9E-06	2.0E-06	1.2E-05	2.4E-06	1.1E-05	2.6E-06	1.1E-06	2.3E-07
Soil dermal contact from deck	8.5E-08	2.7E-08	7.6E-08	1.4E-08	1.3E-07	3.3E-08	1.1E-07	2.2E-08	1.1E-08	3.1E-09

Table 25. Summary of 95th Percentile Arsenic and Chromium Population Absorbed Dose Values (mg/kg/day) by Exposure Pathway for the Short-Term, Intermediate-Term, and Lifetime Scenarios (for children exposed to home playsets, public playsets, and decks)

Pathway	As Warm Short-Term	As Cold Short-Term	Cr Warm Short-Term	Cr Cold Short-Term	As Warm Int.-Term	As Cold Int.-Term	Cr Warm Int.-Term	Cr Cold Int.-Term	As Warm LADD	As Cold LADD
Total (playset+deck)	4.0E-04	1.9E-04	3.5E-04	2.0E-04	3.6E-04	2.0E-04	3.2E-04	2.2E-04	3.3E-05	1.6E-05
Total playset	2.9E-04	1.6E-04	2.7E-04	1.4E-04	2.6E-04	1.2E-04	2.2E-04	1.5E-04	2.0E-05	1.1E-05
Residue ingestion from playset	1.9E-04	1.4E-04	1.7E-04	1.3E-04	1.6E-04	1.0E-04	1.2E-04	1.3E-04	1.3E-05	1.0E-05
Soil ingestion from playset	3.5E-05	1.8E-06	3.9E-05	7.1E-06	3.3E-05	1.5E-06	3.4E-05	6.1E-06	2.9E-06	1.1E-07
Residue dermal contact from playset	7.4E-05	1.8E-05	6.9E-05	1.8E-05	6.4E-05	1.5E-05	6.2E-05	1.7E-05	6.1E-06	1.4E-06
Soil dermal contact from playset	6.1E-06	1.3E-07	6.7E-06	4.8E-07	6.4E-06	1.1E-07	6.9E-06	4.2E-07	3.9E-07	9.6E-09
Total deck	1.3E-04	5.9E-05	1.3E-04	7.3E-05	1.6E-04	7.8E-05	1.3E-04	9.4E-05	1.5E-05	6.9E-06
Residue ingestion from deck	9.2E-05	4.9E-05	8.0E-05	6.2E-05	9.2E-05	6.7E-05	8.7E-05	8.1E-05	9.1E-06	5.9E-06
Soil ingestion from deck	1.7E-06	1.9E-06	1.7E-06	8.3E-07	3.0E-06	2.0E-06	2.1E-06	1.0E-06	2.2E-07	1.9E-07
Residue dermal contact from deck	4.8E-05	7.5E-06	3.9E-05	9.0E-06	5.4E-05	1.2E-05	5.1E-05	1.2E-05	5.2E-06	1.1E-06
Soil dermal contact from deck	3.8E-07	1.5E-07	3.8E-07	7.0E-08	6.2E-07	1.5E-07	4.7E-07	8.9E-08	5.2E-08	1.5E-08

Table 26. Summary of Mean Arsenic and Chromium Population Absorbed Dose Values (mg/kg/day) by Exposure Pathway for the Short-Term, Intermediate-Term, and Lifetime Scenarios (for children exposed to home playsets, public playsets, and decks, separated by children with and without decks)

Pathway	Deck	As Warm Short-Term	As Cold Short-Term	Cr Warm Short-Term	Cr Cold Short-Term	As Warm Int.-Term	As Cold Int.-Term	Cr Warm Int.-Term	Cr Cold Int.-Term	As Warm LADD	As Cold LADD
Total playset	No	8.4E-05	4.3E-05	6.5E-05	3.9E-05	5.9E-05	3.7E-05	5.6E-05	3.9E-05	6.4E-06	3.2E-06
Residue ingestion from playset	No	5.3E-05	3.8E-05	3.7E-05	3.3E-05	3.5E-05	3.2E-05	3.0E-05	3.3E-05	3.8E-06	2.7E-06
Soil ingestion from playset	No	8.3E-06	4.2E-07	9.7E-06	1.8E-06	6.8E-06	3.0E-07	8.9E-06	1.3E-06	6.3E-07	2.8E-08
Residue dermal contact from playset	No	2.2E-05	5.0E-06	1.7E-05	4.4E-06	1.5E-05	4.7E-06	1.5E-05	4.6E-06	1.8E-06	4.0E-07
Soil dermal contact from playset	No	1.5E-06	2.7E-08	1.6E-06	1.0E-07	1.5E-06	2.6E-08	1.8E-06	7.9E-08	1.2E-07	2.1E-09
Total (playset + deck)	Yes	1.3E-04	6.7E-05	1.2E-04	6.9E-05	1.3E-04	7.0E-05	1.2E-04	7.4E-05	1.1E-05	6.0E-06
Total playset	Yes	7.3E-05	4.0E-05	7.0E-05	3.9E-05	6.4E-05	3.3E-05	5.6E-05	3.7E-05	5.4E-06	2.8E-06
Residue ingestion from playset	Yes	4.5E-05	3.5E-05	4.2E-05	3.2E-05	3.6E-05	2.8E-05	3.0E-05	3.1E-05	3.1E-06	2.4E-06
Soil ingestion from playset	Yes	7.8E-06	4.8E-07	9.3E-06	1.9E-06	8.6E-06	4.0E-07	8.2E-06	1.7E-06	6.5E-07	3.3E-08
Residue dermal contact from playset	Yes	1.8E-05	4.2E-06	1.7E-05	4.2E-06	1.8E-05	4.1E-06	1.5E-05	4.0E-06	1.5E-06	3.8E-07
Soil dermal contact from playset	Yes	1.8E-06	2.8E-08	1.7E-06	1.3E-07	1.7E-06	3.2E-08	1.7E-06	1.2E-07	1.3E-07	2.8E-09
Total deck	Yes	5.8E-05	2.7E-05	5.2E-05	3.0E-05	6.3E-05	3.7E-05	6.3E-05	3.7E-05	5.9E-06	3.2E-06
Residue ingestion from deck	Yes	3.7E-05	2.3E-05	3.5E-05	2.5E-05	3.9E-05	3.1E-05	4.0E-05	3.2E-05	3.6E-06	2.6E-06
Soil ingestion from deck	Yes	7.7E-07	7.7E-07	8.0E-07	5.9E-07	1.0E-06	8.3E-07	9.4E-07	5.6E-07	9.2E-08	8.7E-08
Residue dermal contact from deck	Yes	1.9E-05	3.2E-06	1.6E-05	4.1E-06	2.3E-05	4.8E-06	2.1E-05	5.1E-06	2.2E-06	4.8E-07
Soil dermal contact from deck	Yes	1.8E-07	5.5E-08	1.5E-07	2.9E-08	2.4E-07	6.5E-08	2.1E-07	4.4E-08	2.1E-08	6.3E-09

Table 27. Summary of 95th Percentile Arsenic and Chromium Population Absorbed Dose Values (mg/kg/day) by Exposure Pathway for the Short-Term, Intermediate-Term, and Lifetime Scenarios (for children exposed to home playsets, public playsets, and decks, separated by children with and without decks)

Pathway	Deck	As Warm Short-Term	As Cold Short-Term	Cr Warm Short-Term	Cr Cold Short-Term	As Warm Int.-Term	As Cold Int.-Term	Cr Warm Int.-Term	Cr Cold Int.-Term	As Warm LADD	As Cold LADD
Total playset	No	2.9E-04	1.6E-04	2.4E-04	1.4E-04	2.3E-04	1.2E-04	2.2E-04	1.7E-04	2.3E-05	1.2E-05
Residue ingestion from playset	No	1.9E-04	1.4E-04	1.3E-04	1.3E-04	1.6E-04	1.0E-04	1.2E-04	1.6E-04	1.5E-05	1.1E-05
Soil ingestion from playset	No	4.0E-05	1.7E-06	4.3E-05	6.9E-06	3.3E-05	1.1E-06	3.5E-05	6.0E-06	2.9E-06	1.1E-07
Residue dermal contact from playset	No	7.4E-05	1.9E-05	7.1E-05	1.8E-05	6.2E-05	1.5E-05	6.4E-05	1.9E-05	6.2E-06	1.5E-06
Soil dermal contact from playset	No	5.8E-06	1.1E-07	6.5E-06	4.6E-07	6.2E-06	9.6E-08	6.8E-06	3.3E-07	3.9E-07	8.3E-09
Total (playset + deck)	Yes	4.7E-04	2.2E-04	4.3E-04	2.5E-04	4.5E-04	2.4E-04	4.4E-04	2.6E-04	3.9E-05	2.1E-05
Total playset	Yes	2.9E-04	1.5E-04	2.9E-04	1.5E-04	2.6E-04	1.2E-04	2.2E-04	1.5E-04	1.8E-05	1.0E-05
Residue ingestion from playset	Yes	1.8E-04	1.4E-04	2.1E-04	1.3E-04	1.7E-04	1.0E-04	1.4E-04	1.3E-04	1.2E-05	9.4E-06
Soil ingestion from playset	Yes	3.1E-05	1.8E-06	3.2E-05	7.8E-06	3.4E-05	1.8E-06	3.3E-05	6.5E-06	2.8E-06	1.1E-07
Residue dermal contact from playset	Yes	7.5E-05	1.7E-05	6.7E-05	1.8E-05	7.0E-05	1.6E-05	6.2E-05	1.5E-05	6.0E-06	1.4E-06
Soil dermal contact from playset	Yes	7.3E-06	1.3E-07	8.1E-06	5.1E-07	6.5E-06	1.2E-07	7.0E-06	5.9E-07	3.9E-07	1.2E-08
Total deck	Yes	2.5E-04	1.0E-04	2.1E-04	1.2E-04	2.2E-04	1.4E-04	2.2E-04	1.5E-04	2.1E-05	1.2E-05
Residue ingestion from deck	Yes	1.6E-04	9.0E-05	1.5E-04	1.1E-04	1.5E-04	1.2E-04	1.4E-04	1.2E-04	1.3E-05	1.0E-05
Soil ingestion from deck	Yes	3.8E-06	3.9E-06	2.8E-06	2.4E-06	4.5E-06	3.3E-06	3.6E-06	2.1E-06	3.6E-07	3.7E-07
Residue dermal contact from deck	Yes	7.8E-05	1.4E-05	6.7E-05	1.5E-05	8.0E-05	1.9E-05	7.7E-05	2.1E-05	8.0E-06	1.8E-06
Soil dermal contact from deck	Yes	7.2E-07	2.6E-07	6.2E-07	1.2E-07	9.5E-07	2.3E-07	8.4E-07	1.7E-07	7.3E-08	2.2E-08

Sensitivity Analyses

As described in the Methods section, sensitivity analyses were conducted by systematically re-running the model with the inputs set to deterministic (point) values. The first type of analysis involved multiplying and dividing the value of each input in turn by a factor of 2, while the second type involved adding and subtracting one standard deviation (from the original variability distribution) to the mean of each input in turn. The sensitivity analyses were conducted for short-term As exposure under the warm climate scenario. The results are presented in Tables 28 and 29. The "Stepwise" column shows stepwise regression results (the ranking of each input variable in the final stepwise regression model). The three columns labeled 'Input Value' indicate the settings (point values) assigned to each input variable. The three "Ratios of Dose" columns show the effect of increasing and decreasing each input by the scaling factor or standard deviation. "Med:low" is the ratio of doses obtained when running the given variable at its medium and its low settings, with all other inputs held fixed at their medium values. Similarly, "high:med" is the ratio of doses obtained when the given input assumes its high and medium input values, while all other inputs are held at their medium values. Finally, "high:low" is the ratio of doses obtained when the given input is set to its high and low values, with other inputs at their medium values. Note that in some cases the low value (mean minus one standard deviation) resulted in a negative value for a given input; such cases were not run and the results are therefore left blank. Results are ordered by the "high:low" column, considered to be the most reliable indicator of sensitivity of the two approaches. Results of the two methods are very similar: both reveal that the four most critical input variables are wood surface residue-to-skin transfer efficiency; wood surface residue on CCA-treated decks; fraction of hand surface area mouthed per mouthing event; and hand washing events per day. Also, the two methods displayed a similar pattern in results: 22 input variables were statistically significant with the scaling method and 14 with the stepwise regression method. The difference may be due to missing values (where mean minus the standard deviation was negative) for some input variables in the scaling method.

Increasing and decreasing the most sensitive inputs either by a factor of 2 or by 1 standard deviation resulted in an increase or decrease of ADD by a factor of 1.2 to 2. Note in Table 29 that the ADD results corresponding to several variables with a standard deviation of zero indicate that there is 1%-9% variability in ADD due to internal model randomness (from the code's algorithms to assign contact days and contact events within a day), even though activity diaries and input values were fixed. This variability, however, is much less than that resulting from changing the most sensitive variables. This variability is more pronounced in short-term model runs (as used here) than in longer term or lifetime runs. Short term runs were used to reduce the computational burden of conducting a large number of model runs.

Table 28. Sensitivity Analysis Comparison of Mean Total Arsenic Short-Term ADD (mg/kg/day) in Warm Climate (scaling by factor 1/2 or 2)

			Input Value			Ratio		
Variable	**Unit**	**Stepwise Rank**	**Low**	**Med**	**High**	**Med:Low**	**High:Med**	**High:Low**
Residue-skin transfer efficiency	[-]	1	0.11	0.21	0.42	1.89	1.83	3.47
Wood surface residues on CCA-treated deck	μg/cm^2	2	0.16	0.31	0.62	1.62	1.46	2.35
Fraction of hand surface area mouthed per mouthing event	[-]	3	0.06	0.13	0.25	1.39	1.50	2.09
GI absorption fraction per day for residues	1/day	5	0.14	0.27	0.54	1.47	1.42	2.08
Maximum dermal loading	mg/cm^2	6	0.02	0.04	0.09	1.51	1.36	2.05
Avg #days/yr a child* plays on/around treated CCA-treated public playset	Days/yr	7	63.00	126.00	252.00	1.45	1.30	1.89
Fraction children* who have a CCA-treated residential deck	[-]	8	0.25	0.50	1.00	1.16	1.33	1.54
Avg fraction non-residential outdoor time a child* plays on/around CCA-treated public playset	[-]	12	0.37	0.74	1.00	1.40	1.10	1.53
Wood surface residues on CCA-treated playset	μg/cm^2	14	0.17	0.33	0.66	1.34	1.14	1.53
Avg #days/yr a child* plays on/around CCA-treated residential deck	Days/yr	9	63.00	126.00	252.00	1.18	1.29	1.52
Dermal absorption fraction per day for residues	1/day	10	0.01	0.03	0.06	1.15	1.28	1.47
Fraction of total body (non-hand) skin S.A. that is unclothed	[-]	13	0.15	0.31	0.62	1.11	1.22	1.36
Fraction of bare skin on hands contacting residues per time	[1/min]	15	0.02	0.04	0.07	1.25	1.05	1.32
Fraction time a child* on/around treated playset is on playset itself vs on ground near playset	[-]	18	0.25	0.51	1.00	1.18	1.04	1.24
Fraction of bare skin on body (non-hands) contacting residues per time	[1/min]	20	0.00	0.01	0.02	1.11	1.07	1.19
Avg fraction residential outdoor time a child* plays on/around CCA-treated residential deck	[-]	19	0.37	0.74	1.00	1.10	1.07	1.18
Hand-mouth dermal transfer fraction	[-]	22	0.39	0.77	1.00	1.11	1.02	1.14
Daily soil ingestion rate	mg/day	21	50.87	101.74	203.48	1.06	1.07	1.13

Variable	Unit	Stepwise Rank	Input Value			Ratio		
			Low	Med	High	Med:Low	High:Med	High:Low
Soil concentrations near CCA-treated playset	mg/kg	23	17.36	34.72	69.44	1.06	1.05	1.11
Frequency of hand-mouth activity per hour	Events/hr	16	4.01	8.02	16.04	1.03	1.07	1.10
Fraction time a child* on/around CCA-treated home deck is on the deck vs on the ground near the deck	[-]		0.45	0.90	1.00	1.05	1.04	1.09
Soil-skin adherence factor	mg/cm^2		0.07	0.14	0.29	1.02	1.02	1.04
GI absorption fraction per day for soil	1/day		0.24	0.47	0.94	1.03	1.01	1.04
Dermal absorption fraction per day for soil	1/day		0.02	0.03	0.06	1.01	1.02	1.04
Soil concentrations near CCA-treated deck	mg/kg		20.05	40.11	80.22	1.00	1.00	1.01
Avg fraction residential outdoor time a child* plays on/around CCA-treated residential playset	[-]		0.39	0.77	1.00	0.99	1.00	0.99
Avg #days/yr a child* plays on/around residential CCA-treated playset	Days/yr		63.00	126.00	252.00	0.97	1.01	0.99
Fraction of bare skin on hands contacting soil per time	[1/min]		0.02	0.04	0.07	1.00	0.97	0.97
Fraction children* with CCA-treated home playset	[-]		0.04	0.08	0.16	1.00	0.96	0.96
Fraction of bare skin on body (non-hands) contacting soil per time	[1/min]		0.00	0.01	0.02	1.00	0.96	0.96
Hand-washing removal efficiency	[-]	17	0.30	0.59	1.00	0.91	0.91	0.83
Hand-washing events per day	Events/day	4	2.79	5.58	11.15	0.86	0.84	0.72
Bathing removal efficiency	[-]	11	0.39	0.77	1.00	0.79	0.88	0.70

Table 29. Sensitivity Analysis Comparison of Mean Total Arsenic Short-Term ADD in Warm Climate (scaling ± 1 standard deviation)

Variable	Unit	Stepwise Rank	Input Value			Ratio		
			Low	Med	High	Med:Low	High:Med	High:Low
Residue-skin transfer efficiency	[-]	1	-0.01	0.21	0.43		1.95	
Wood surface residues on CCA-treated deck	$\mu g/cm^2$	2	-0.02	0.31	0.65		1.49	
GI absorption fraction per day for residues	1/day	6	0.17	0.27	0.37	0.57	1.21	0.69
Fraction of hand surface area mouthed per mouthing event	[-]	4	0.07	0.13	0.18	1.42	1.20	1.71
Daily soil ingestion rate	mg/day	11	-72.51	101.74	275.99		1.13	
Wood surface residues on CCA-treated playset	$\mu g/cm^2$	10	-0.01	0.33	0.67		1.13	
Avg fraction non-residential outdoor time a child* plays on/around CCA-treated public playset	[-]	5	0.46	0.74	1.00	1.22	1.12	1.37
Fraction of total body (non-hand) skin S.A. that is unclothed	[-]	8	0.16	0.31	0.46	1.14	1.11	1.27
Fraction of bare skin on hands contacting residues per time	[1/min]		0.03	0.04	0.04	1.00	1.09	1.09
Avg fraction residential outdoor time a child* plays on/around CCA-treated residential playset	[-]		0.51	0.77	1.00	1.00	1.09	1.09
Dermal absorption fraction per day for residues	1/day		0.03	0.03	0.03	1.06	1.05	1.11
Avg #days/yr a child* plays on/around residential CCA-treated playset	Days/yr		126.00	126.00	126.00	1.04	1.05	1.09
Frequency of hand-mouth activity per hour	Events/hr	7	-2.65	8.02	18.69		1.04	
Hand-mouth dermal transfer fraction	[-]		0.68	0.77	0.87	1.03	1.03	1.05
Fraction of bare skin on body (non-hands) contacting residues per time	[1/min]	12	0.00	0.01	0.01	1.16	1.02	1.18
Avg fraction residential outdoor time a child* plays on/around CCA-treated residential deck	[-]	13	0.47	0.74	1.00	1.10	1.02	1.13
Fraction children* with CCA-treated home playset	[-]		0.08	0.08	0.08	1.05	1.02	1.07
Fraction time a child* on/around treated playset is on playset itself vs on ground near playset	[-]		0.40	0.51	0.62	1.03	1.02	1.06
Avg #days/yr a child* plays on/around CCA-treated residential deck	Days/yr		126.00	126.00	126.00	1.03	1.02	1.06
Soil concentrations near CCA-treated playset	mg/kg		17.24	34.72	52.20	1.03	1.02	1.05
Soil-skin adherence factor	mg/cm^2		0.02	0.14	0.27	0.98	1.01	1.00

Variable	Unit	Stepwise Rank	Input Value			Ratio		
			Low	Med	High	Med:Low	High:Med	High:Low
GI absorption fraction per day for soil	1/day		0.37	0.47	0.58	1.04	1.01	1.05
Dermal absorption fraction per day for soil	1/day		0.03	0.03	0.03	1.00	1.01	1.01
Fraction of bare skin on body (non-hands) contacting soil per time	[1/min]		0.00	0.01	0.01	1.02	0.99	1.01
Fraction time a child* on/around CCA-treated home deck is on the deck vs on the ground near the deck	[-]		0.85	0.90	0.94	0.97	0.99	0.97
Avg #days/yr a child* plays on/around treated CCA-treated public playset	Days/yr		126.00	126.00	126.00	1.01	0.98	0.99
Fraction of bare skin on hands contacting soil per time	[1/min]		0.03	0.04	0.04	1.02	0.97	0.99
Fraction children* who have a CCA-treated residential deck	[-]		0.50	0.50	0.50	1.02	0.97	0.99
Soil concentrations near CCA-treated deck	mg/kg		-0.25	40.11	80.47		0.97	
Hand-washing removal efficiency	[-]	14	0.53	0.59	0.66	0.93	0.96	0.89
Bathing removal efficiency	[-]	9	0.68	0.77	0.86	0.93	0.89	0.83
Hand-washing events per day	Events/day	3	-1.20	5.58	12.35		0.86	

Note: Results were not calculated for cases where the low value for the input was negative.

Special Analyses

Children Exposed to Public Playsets Only

Table 30 summarizes the mean and 95th %ile Arsenic and Chromium population absorbed dose values, warm and cold scenarios, different time periods, for children exposed to public playsets only. These results can be compared to those in Tables 24 and 25, which look at all children exposed to home playsets, public playsets, and decks (i.e., children with and without decks, combined), and to Tables 26 and 27 which separate children exposed to both public and home playsets only (no decks). As and Cr dose values were very similar for children exposed to public playsets only and for playset total in the entire population studied, indicating that public playsets contribute the majority of playset exposures.

Table 31 presents summary statistics for probabilistic estimates of LADD for children exposed to As dislodgeable residues and contaminated soil from CCA-treated wood in warm climate from public playsets only. These results can be compared to Table 14, the corresponding results for children exposed to public playsets, home playsets, and decks. The values are 10% to 20% higher for children exposed to both public and home playsets, as opposed to public playsets only.

Table 30. Summary of Mean Arsenic and Chromium Population Absorbed Dose Values (mg/kg/day) by Exposure Pathway for the Short-Term, Intermediate-Term, and Lifetime Scenarios (for children exposed to public playsets only)

Route	Statistics	As Warm Short-Term	As Cold Short-Term	Cr Warm Short-Term	Cr Cold Short-Term	As Warm Int.-Term	As Cold Int.-Term	Cr Warm Int.-Term	Cr Cold Int.-Term	As Warm LADD	As Cold LADD
Total playset	Mean	7.8E-05	4.0E-05	7.1E-05	3.9E-05	6.0E-05	3.5E-05	5.4E-05	3.5E-05	5.3E-06	2.6E-06
Residue ingestion from playset	Mean	4.6E-05	3.5E-05	4.1E-05	3.3E-05	3.5E-05	3.0E-05	3.1E-05	2.9E-05	3.1E-06	2.3E-06
Soil ingestion from playset	Mean	9.5E-06	4.6E-07	1.1E-05	1.8E-06	7.4E-06	3.1E-07	7.6E-06	1.6E-06	5.8E-07	3.8E-08
Residue dermal contact from playset	Mean	2.0E-05	4.6E-06	1.7E-05	4.3E-06	1.6E-05	4.5E-06	1.4E-05	4.0E-06	1.5E-06	3.5E-07
Soil dermal contact from playset	Mean	1.8E-06	2.7E-08	1.7E-06	1.0E-07	1.4E-06	2.3E-08	1.6E-06	1.1E-07	1.3E-07	2.0E-09
Total playset	95^{th}	3.1E-04	1.6E-04	2.8E-04	1.6E-04	2.4E-04	1.4E-04	2.0E-04	1.4E-04	1.8E-05	9.6E-06
Residue ingestion from playset	95^{th}	1.9E-04	1.3E-04	1.7E-04	1.4E-04	1.4E-04	1.3E-04	1.2E-04	1.2E-04	1.1E-05	8.3E-06
Soil ingestion from playset	95^{th}	4.3E-05	1.8E-06	5.0E-05	7.9E-06	2.9E-05	1.1E-06	3.4E-05	6.9E-06	2.3E-06	1.4E-07
Residue dermal contact from playset	95^{th}	8.4E-05	2.1E-05	6.8E-05	1.7E-05	6.7E-05	1.9E-05	5.7E-05	1.5E-05	5.5E-06	1.3E-06
Soil dermal contact from playset	95^{th}	6.6E-06	1.2E-07	6.2E-06	5.1E-07	5.5E-06	9.0E-08	6.1E-06	4.5E-07	4.3E-07	8.6E-09

Table 31. Percentiles of Population LADD (mg/kg/day) for Children Exposed to Arsenic Dislodgeable Residues and Contaminated Soil from Treated Public Playsets in Warm Climate

Pathway	n	Mean	Stdev	p50	Min	p05	p25	p75	p95	p99	Max
Total playset	976	5.3E-06	8.0E-06	2.7E-06	1.1E-08	4.1E-07	1.4E-06	6.1E-06	1.8E-05	4.3E-05	1.0E-04
Residue ingestion from playset	976	3.1E-06	5.7E-06	1.3E-06	6.5E-09	1.1E-07	5.1E-07	3.3E-06	1.1E-05	3.1E-05	7.1E-05
Soil ingestion from playset	976	5.8E-07	1.1E-06	1.9E-07	4.3E-10	1.2E-08	6.5E-08	6.0E-07	2.3E-06	5.8E-06	1.2E-05
Residue dermal contact from playset	976	1.5E-06	2.4E-06	7.5E-07	1.2E-09	7.4E-08	3.0E-07	1.7E-06	5.5E-06	1.2E-05	2.7E-05
Soil dermal contact from playset	976	1.3E-07	1.8E-07	7.4E-08	1.8E-10	9.4E-09	3.2E-08	1.6E-07	4.3E-07	1.0E-06	1.5E-06

Age group selection

A number of SHEDS-Wood variable values are likely to differ for 7-13 year-olds than 1-6 year-olds, such as time spent on playsets and decks, frequency of hand washing and bathing, and frequency of hand-to-mouth contact. Because of limited data, rather than conduct a simulation with guesses for these different values, LADD calculations were projected assuming that 7-13 year-olds have 25%, 50%, 75%, 100% of the absolute absorbed dose (before adjusting for body weight) of 1-6 year-old doses (Table 32). For children both with and without decks, the total As LADD (warm climate bounding scenario) in mg/kg/day is 1.1, 1.2, 1.3, and 1.4 times higher for 1-13 year-olds assuming the 4 scenarios above, respectively (based on means).

Table 32. Percentiles of Population LADD (mg/kg/day) for Children Exposed to Arsenic Dislodgeable Residues and Contaminated Soil from Treated Wood Playsets and Residential Decks in Warm Climate (1-13 year-old dose projected from 1-6 year modeled dose)

Pathway	Deck	n	Mean	p50	Min	p05	p25	p75	p95	p99	Max
Total dose 1-6 year-olds	No	728	6.4E-06	3.0E-06	2.9E-08	4.6E-07	1.3E-06	6.8E-06	2.3E-05	6.5E-05	1.3E-04
Total dose 1-13 year-olds (25% of 1-6 year-old dose for 7-13 year-olds)	No	NA	7.1E-06	3.3E-06	3.2E-08	5.2E-07	1.5E-06	7.5E-06	2.5E-05	7.2E-05	1.5E-04
Total dose 1-13 year-olds (50% of 1-6 year-old dose for 7-13 year-olds)	No	NA	7.8E-06	3.6E-06	3.5E-08	5.7E-07	1.6E-06	8.3E-06	2.8E-05	7.9E-05	1.6E-04
Total dose 1-13 year-olds (75% of 1-6 year-old dose for 7-13 year-olds)	No	NA	8.5E-06	4.0E-06	3.8E-08	6.2E-07	1.8E-06	9.0E-06	3.0E-05	8.6E-05	1.8E-04
Total dose 1-13 year-olds (100% of 1-6 year-old dose for 7-13 year-olds)	No	NA	9.2E-06	4.3E-06	4.1E-08	6.7E-07	1.9E-06	9.8E-06	3.3E-05	9.3E-05	1.9E-04
Total dose 1-6 year-olds	Yes	738	1.1E-05	6.1E-06	2.5E-07	1.0E-06	3.0E-06	1.3E-05	3.9E-05	8.4E-05	1.7E-04
Total dose 1-13 year-olds (25% of 1-6 year-old dose for 7-13 year-olds)	Yes	NA	1.3E-05	6.8E-06	2.7E-07	1.1E-06	3.3E-06	1.4E-05	4.4E-05	9.3E-05	1.9E-04
Total dose 1-13 year-olds (50% of 1-6 year-old dose for 7-13 year-olds)	Yes	NA	1.4E-05	7.5E-06	3.0E-07	1.2E-06	3.6E-06	1.6E-05	4.8E-05	1.0E-04	2.0E-04
Total dose 1-13 year-olds (75% of 1-6 year-old dose for 7-13 year-olds)	Yes	NA	1.5E-05	8.2E-06	3.3E-07	1.3E-06	4.0E-06	1.7E-05	5.2E-05	1.1E-04	2.2E-04
Total dose 1-13 year-olds (100% of 1-6 year-old dose for 7-13 year-olds)	Yes	NA	1.6E-05	8.9E-06	3.6E-07	1.4E-06	4.3E-06	1.9E-05	5.7E-05	1.2E-04	2.4E-04

Pica Behavior

Table 33 shows As warm climate short-term ADD results for children with assumed pica behavior, using the pica soil ingestion rate described above. These can be compared to Table 18. For children without decks, the mean and median values were 2.7 and 3.3 times higher, respectively, for pica children. For children with decks, the mean and median values were both 2.3 times higher, respectively, for pica children.

Table 33. Probabilistic Estimates of Short-Term ADD (mg/kg/day) for Children Exposed to Arsenic Dislodgeable Residues and Contaminated Soil from Treated Wood Playsets and Residential Decks in Warm Climate (for children with assumed pica soil ingestion behavior)

Pathway	Deck	n	Mean	Stdev	p50	Min	p05	p25	p75	p95	p99	Max
Total playset	No	288	2.3E-04	4.0E-04	9.9E-05	2.2E-07	6.4E-06	3.7E-05	2.4E-04	7.7E-04	2.2E-03	3.6E-03
Residue ingestion from playset	No	288	3.9E-05	6.4E-05	1.5E-05	6.3E-08	9.3E-07	5.1E-06	3.6E-05	2.0E-04	2.9E-04	4.1E-04
Soil ingestion from playset	No	288	1.7E-04	3.7E-04	5.2E-05	8.8E-08	2.7E-06	2.2E-05	1.5E-04	7.2E-04	2.1E-03	3.3E-03
Residue dermal contact from playset	No	288	1.9E-05	3.5E-05	7.6E-06	3.5E-08	3.4E-07	2.1E-06	2.1E-05	8.0E-05	1.9E-04	3.5E-04
Soil dermal contact from playset	No	288	2.0E-06	3.7E-06	8.7E-07	1.1E-09	2.3E-08	2.2E-07	1.9E-06	8.0E-06	2.3E-05	3.1E-05
Total (playset + deck)	Yes	318	3.1E-04	5.3E-04	1.5E-04	4.2E-06	3.5E-05	7.7E-05	3.2E-04	1.0E-03	1.6E-03	7.1E-03
Total playset	Yes	318	2.4E-04	4.9E-04	9.1E-05	1.7E-06	1.4E-05	4.1E-05	2.6E-04	8.5E-04	1.6E-03	6.5E-03
Residue ingestion from playset	Yes	318	4.7E-05	1.2E-04	1.4E-05	3.5E-08	1.0E-06	5.6E-06	3.7E-05	2.1E-04	5.4E-04	1.6E-03
Soil ingestion from playset	Yes	318	1.7E-04	4.4E-04	5.2E-05	1.5E-06	7.3E-06	2.2E-05	1.5E-04	7.5E-04	1.5E-03	6.3E-03
Residue dermal contact from playset	Yes	318	1.9E-05	3.7E-05	7.7E-06	5.2E-08	3.8E-07	2.7E-06	1.9E-05	7.2E-05	1.7E-04	3.2E-04
Soil dermal contact from playset	Yes	318	1.9E-06	2.9E-06	8.5E-07	1.1E-08	6.2E-08	3.2E-07	2.1E-06	8.3E-06	1.4E-05	2.2E-05
Total deck	Yes	318	6.4E-05	1.2E-04	2.2E-05	0.0E+00	0.0E+00	6.8E-06	6.0E-05	2.7E-04	7.0E-04	9.6E-04
Residue ingestion from deck	Yes	318	3.5E-05	8.2E-05	8.2E-06	0.0E+00	0.0E+00	2.0E-06	2.5E-05	1.7E-04	4.3E-04	7.4E-04
Soil ingestion from deck	Yes	318	1.4E-05	3.4E-05	3.7E-06	0.0E+00	0.0E+00	4.7E-07	1.3E-05	6.4E-05	1.1E-04	4.8E-04
Residue dermal contact from deck	Yes	318	1.6E-05	4.2E-05	4.2E-06	0.0E+00	0.0E+00	1.1E-06	1.3E-05	6.1E-05	1.6E-04	5.5E-04
Soil dermal contact from deck	Yes	318	1.8E-07	4.3E-07	5.0E-08	0.0E+00	0.0E+00	7.3E-09	1.5E-07	8.0E-07	2.3E-06	4.3E-06

Assuming 100%/day GI Absorption Rate for Arsenic Residues

Table 34 contains probabilistic estimates of short-term ADD for children exposed to As dislodgeable residues and contaminated soil from treated wood playsets and residential decks in warm climate, using a GI absorption rate of 100% rather than 27% (mean) as used to generate Table 18. For children who contact both playsets and decks, the total dose was about a factor of about 1.9 times higher using the 100% GI absorption rate. For children without deck contact, the factor was slightly lower (about 1.6). Figure 21 illustrates CDFs showing the impact of using the increased GI absorption rate.

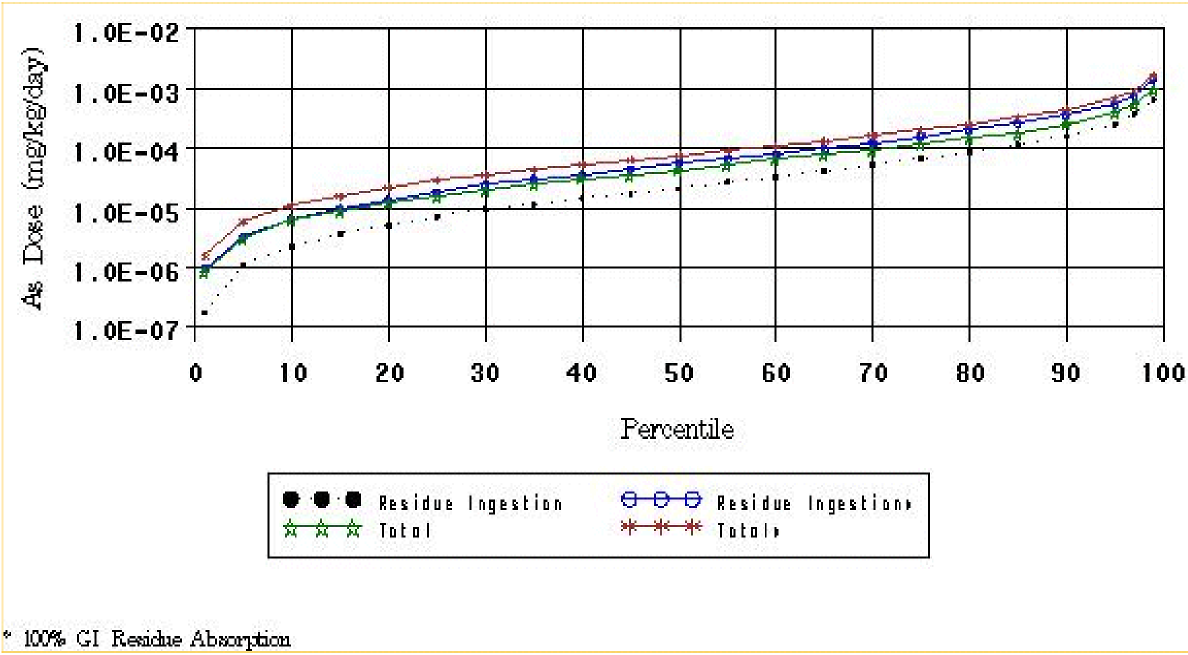


Figure 21. Population short-term ADD for children exposed to As from treated wood playsets and decks, assuming 100% GI absorption.

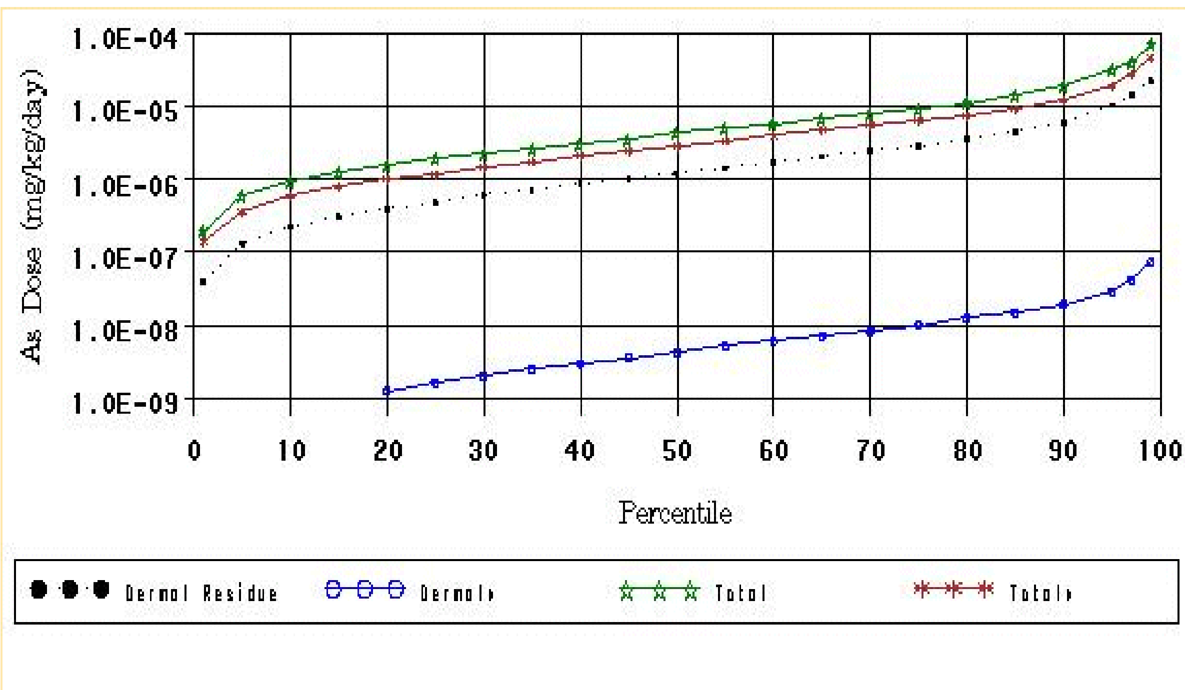
Table 34. Probabilistic Estimates of Short-Term ADD (mg/kg/day) for Children Exposed to Arsenic Dislodgeable Residues and Contaminated Soil from Treated Wood Playsets and Residential Decks in Warm Climate (GI residue absorption 100%)

Pathway	Deck	n	Mean	Stdev	p50	Min	p05	p25	p75	p95	p99	Max
Total playset	No	986	1.4E-04	3.2E-04	5.0E-05	0.0E+00	3.7E-06	1.7E-05	1.4E-04	4.7E-04	1.5E-03	6.4E-03
Residue ingestion from playset	No	986	1.1E-04	2.7E-04	3.4E-05	0.0E+00	1.9E-06	1.1E-05	1.0E-04	3.9E-04	1.3E-03	5.8E-03
Soil ingestion from playset	No	986	8.3E-06	2.8E-05	1.7E-06	0.0E+00	6.4E-08	4.5E-07	6.3E-06	3.6E-05	1.1E-04	5.6E-04
Residue dermal contact from playset	No	986	1.9E-05	4.6E-05	6.8E-06	0.0E+00	3.0E-07	2.0E-06	1.7E-05	7.2E-05	2.9E-04	6.1E-04
Soil dermal contact from playset	No	986	1.8E-06	3.4E-06	7.5E-07	0.0E+00	4.5E-08	2.5E-07	1.9E-06	6.4E-06	1.5E-05	4.4E-05
Total (playset + deck)	Yes	967	2.4E-04	4.3E-04	1.1E-04	7.6E-07	1.1E-05	4.6E-05	2.7E-04	8.7E-04	1.9E-03	6.2E-03
Total playset	Yes	967	1.2E-04	2.1E-04	4.9E-05	0.0E+00	3.6E-06	1.8E-05	1.3E-04	5.2E-04	1.0E-03	2.4E-03
Residue ingestion from playset	Yes	967	9.8E-05	1.8E-04	3.4E-05	0.0E+00	2.3E-06	1.1E-05	9.7E-05	4.1E-04	9.4E-04	2.3E-03
Soil ingestion from playset	Yes	967	8.9E-06	2.9E-05	1.6E-06	0.0E+00	6.0E-08	4.0E-07	5.9E-06	3.7E-05	1.4E-04	4.2E-04
Residue dermal contact from playset	Yes	967	1.6E-05	2.8E-05	6.4E-06	0.0E+00	3.3E-07	1.9E-06	1.9E-05	6.2E-05	1.5E-04	3.2E-04
Soil dermal contact from playset	Yes	967	1.5E-06	3.3E-06	5.8E-07	0.0E+00	3.5E-08	2.0E-07	1.6E-06	5.7E-06	1.5E-05	5.3E-05
Total deck	Yes	967	1.2E-04	3.2E-04	3.5E-05	0.0E+00	0.0E+00	9.5E-06	1.1E-04	4.7E-04	1.2E-03	5.6E-03
Residue ingestion from deck	Yes	967	1.0E-04	2.8E-04	2.8E-05	0.0E+00	0.0E+00	6.9E-06	9.5E-05	4.0E-04	1.1E-03	5.2E-03
Soil ingestion from deck	Yes	967	9.7E-07	3.1E-06	1.3E-07	0.0E+00	0.0E+00	2.0E-08	6.8E-07	4.2E-06	1.2E-05	5.1E-05
Residue dermal contact from deck	Yes	967	1.9E-05	4.9E-05	5.1E-06	0.0E+00	0.0E+00	1.2E-06	1.7E-05	7.9E-05	2.2E-04	7.4E-04
Soil dermal contact from deck	Yes	967	1.9E-07	3.8E-07	4.9E-08	0.0E+00	0.0E+00	8.9E-09	2.0E-07	7.7E-07	1.8E-06	5.3E-06

Assuming 0.01% Dermal Absorption for Arsenic Residues

Tables 35 and 36 show As warm and cold climate LADD results, respectively, for children with assumed average dermal absorption rate of 0.01% rather than 3% (based on new data from Wester et al., 2003). These can be compared to results in Tables 14 and 15. For children without decks in the warm climate scenario, the mean and median LADD were 37% and 33% lower, respectively, for the children with lower assumed dermal absorption rate. For children with decks in the warm climate scenario, the mean and median LADD were 30% and 26% lower, respectively, for the children with lower assumed dermal absorption rate. For children without decks in the cold climate scenario, the mean and median LADD were 8% and 23% lower, respectively, for the children with lower assumed dermal absorption rate. For children with decks in the cold climate scenario, the mean and median LADD were 11% and 7% lower, respectively, for the children with lower assumed dermal absorption rate.

Figure 22 illustrates CDFs showing the impact of using the reduced dermal absorption rate for the warm climate scenario.



* 0.01%/day dermal absorption rate

Figure 22. Population LADD for children exposed to As from treated wood playsets and decks, assuming 0.01% dermal absorption.

Table 35. Percentiles of Population LADD (mg/kg/day) for Children Exposed to Arsenic Dislodgeable Residues and Contaminated Soil from Treated Wood Playsets and Residential Decks in Warm Climate (dermal residue absorption rate = 0.01%/day)

Pathway	Deck	n	Mean	Stdev	p50	Min	p05	p25	p75	p95	p99	Max
Total playset	No	731	4.0E-06	9.0E-06	2.0E-06	3.4E-09	2.8E-07	9.2E-07	4.3E-06	1.2E-05	3.3E-05	1.9E-04
Residue ingestion from playset	No	731	3.1E-06	8.7E-06	1.1E-06	2.1E-09	1.0E-07	4.4E-07	3.0E-06	9.8E-06	3.1E-05	1.9E-04
Soil ingestion from playset	No	731	7.4E-07	1.6E-06	2.6E-07	2.6E-10	1.4E-08	8.4E-08	7.8E-07	2.9E-06	7.6E-06	2.4E-05
Residue dermal contact from playset	No	731	5.0E-09	1.0E-08	2.3E-09	7.2E-12	2.6E-10	9.2E-10	5.7E-09	1.6E-08	3.8E-08	2.1E-07
Soil dermal contact from playset	No	731	1.7E-07	2.1E-07	1.1E-07	1.9E-10	1.3E-08	4.9E-08	2.1E-07	5.0E-07	1.0E-06	2.6E-06
Total (playset + deck)	Yes	740	7.9E-06	1.4E-05	4.5E-06	1.1E-07	6.3E-07	2.0E-06	8.8E-06	2.7E-05	6.4E-05	2.3E-04
Total playset	Yes	740	3.7E-06	5.8E-06	2.1E-06	1.7E-08	2.8E-07	9.1E-07	4.3E-06	1.1E-05	3.1E-05	7.9E-05
Residue ingestion from playset	Yes	740	3.1E-06	5.7E-06	1.5E-06	1.0E-08	1.1E-07	5.1E-07	3.4E-06	1.1E-05	2.9E-05	7.9E-05
Soil ingestion from playset	Yes	740	4.7E-07	8.9E-07	1.5E-07	1.1E-09	9.7E-09	5.8E-08	4.5E-07	2.1E-06	4.2E-06	8.6E-06
Residue dermal contact from playset	Yes	740	5.2E-09	8.5E-09	2.7E-09	1.4E-11	3.1E-10	1.2E-09	5.7E-09	1.7E-08	4.5E-08	1.0E-07
Soil dermal contact from playset	Yes	740	1.0E-07	1.3E-07	6.0E-08	4.7E-10	7.6E-09	2.9E-08	1.2E-07	3.1E-07	7.3E-07	1.4E-06
Total deck	Yes	740	4.2E-06	8.9E-06	1.9E-06	3.4E-08	1.9E-07	7.3E-07	4.7E-06	1.5E-05	3.4E-05	1.6E-04
Residue ingestion from deck	Yes	740	4.1E-06	8.9E-06	1.8E-06	1.6E-08	1.3E-07	6.2E-07	4.6E-06	1.5E-05	3.4E-05	1.6E-04
Soil ingestion from deck	Yes	740	9.0E-08	2.7E-07	2.4E-08	1.4E-11	7.7E-10	6.1E-09	7.0E-08	3.5E-07	1.0E-06	4.4E-06
Residue dermal contact from deck	Yes	740	7.8E-09	1.6E-08	3.8E-09	2.4E-11	3.4E-10	1.5E-09	8.8E-09	2.4E-08	5.3E-08	2.4E-07
Soil dermal contact from deck	Yes	740	2.2E-08	3.0E-08	1.1E-08	4.4E-13	3.7E-10	4.1E-09	2.5E-08	8.1E-08	1.5E-07	2.5E-07

Table 36. Percentiles of Population LADD (mg/kg/day) for Children Exposed to Arsenic Dislodgeable Residues and Contaminated Soil from Treated Wood Playsets and Residential Decks in Cold Climate (dermal residue absorption rate = 0.01%)

Pathway	Deck	n	Mean	Stdev	p50	Min	p05	p25	p75	p95	p99	Max
Total playset	No	761	2.9E-06	6.5E-06	1.1E-06	1.2E-08	1.5E-07	4.9E-07	3.0E-06	1.0E-05	2.7E-05	1.2E-04
Residue ingestion from playset	No	761	2.9E-06	6.5E-06	1.1E-06	1.2E-08	1.1E-07	4.5E-07	2.8E-06	1.0E-05	2.7E-05	1.2E-04
Soil ingestion from playset	No	761	5.1E-08	1.3E-07	1.2E-08	3.6E-11	4.3E-10	3.0E-09	4.2E-08	2.0E-07	7.6E-07	1.8E-06
Residue dermal contact from playset	No	761	1.5E-09	3.1E-09	6.2E-10	1.6E-11	9.2E-11	2.8E-10	1.5E-09	4.8E-09	1.2E-08	5.3E-08
Soil dermal contact from playset	No	761	4.0E-09	7.7E-09	1.5E-09	9.3E-12	1.2E-10	5.4E-10	4.1E-09	1.5E-08	3.9E-08	8.1E-08
Total (playset + deck)	Yes	713	5.4E-06	8.5E-06	2.7E-06	4.7E-08	3.4E-07	1.2E-06	5.5E-06	2.1E-05	4.3E-05	8.2E-05
Total playset	Yes	713	2.6E-06	4.3E-06	1.2E-06	8.0E-09	1.3E-07	5.1E-07	2.7E-06	9.5E-06	2.5E-05	4.4E-05
Residue ingestion from playset	Yes	713	2.5E-06	4.3E-06	1.2E-06	8.0E-09	1.1E-07	5.1E-07	2.6E-06	9.4E-06	2.5E-05	4.4E-05
Soil ingestion from playset	Yes	713	1.2E-08	3.8E-08	2.6E-09	4.0E-13	9.8E-11	7.0E-10	9.7E-09	5.3E-08	1.6E-07	7.3E-07
Residue dermal contact from playset	Yes	713	1.3E-09	2.1E-09	6.4E-10	4.9E-12	8.7E-11	3.2E-10	1.6E-09	4.4E-09	9.4E-09	2.2E-08
Soil dermal contact from playset	Yes	713	9.9E-10	2.1E-09	3.3E-10	2.5E-12	2.8E-11	1.2E-10	9.6E-10	4.2E-09	9.1E-09	3.1E-08
Total deck	Yes	713	2.8E-06	4.7E-06	1.4E-06	9.8E-09	1.6E-07	5.7E-07	3.0E-06	1.0E-05	2.4E-05	4.3E-05
Residue ingestion from deck	Yes	713	2.7E-06	4.7E-06	1.3E-06	5.5E-09	1.0E-07	4.8E-07	2.8E-06	1.0E-05	2.4E-05	4.3E-05
Soil ingestion from deck	Yes	713	7.8E-08	1.9E-07	2.2E-08	6.3E-11	9.0E-10	6.6E-09	6.7E-08	3.3E-07	9.3E-07	2.7E-06
Residue dermal contact from deck	Yes	713	1.6E-09	2.6E-09	8.1E-10	7.6E-12	9.5E-11	3.7E-10	1.9E-09	5.1E-09	1.3E-08	3.4E-08
Soil dermal contact from deck	Yes	713	5.9E-09	8.4E-09	3.3E-09	4.6E-12	2.3E-10	1.2E-09	7.1E-09	2.1E-08	4.3E-08	1.0E-07

Examination of Extreme Low and High Dose Profiles

Per 2002 SAP recommendations, extreme low and high dose profiles generated in the CCA assessment were examined. A sample run of 1000 children from the As warm climate scenario was examined to determine which factors were driving the variability distribution for total absorbed dose, and whether these differences were reasonable. Each child was followed for one calendar year. For all non-constant quantities, statistics were examined for the lowest 5% of all children as measured by total dose in mg/kg/day; by the central 5%; and by the highest 5%, and 'all' is the average over all 1000 children.

The highest 5% of children averaged 185 times as much As dose as the lowest 5% of children. Of the three sources (public playsets, home playsets, and decks), public playsets were the most important, largely because all children were exposed to this, while only a fraction were exposed to the other two sources. The highest 5% of children averaged almost 9 times as much contact time with public playsets as did the lowest 5%. Their transfer coefficients averaged more than 4 times larger as well. They also had 40% fewer hand washings per day. Residues for decks and playsets were also 20% to 80% higher for the top 5% of children. The soil ingestion rate was 3.8 times larger for the top 5% than for the bottom 5%. However, as a fraction of the total dose, the contribution from soil ingestion was actually lower for the top 5% than for the bottom 5% of children (9% of total dose as opposed to 13%). Thus, soil ingestion is not the primary factor in driving high As doses. Note that the hand-mouth transferred As represents a higher fraction of the total dose (63% as compared to 48%) for the top group of children.

The washing and bathing removal efficiencies and the various absorption rate constants had very little effect on the total dose. The only exception may be the GI absorption rate constant for surface residues, which was 14% larger in the top group than in the bottom group. Note that this factor determines the rate at which hand-mouth transferred As is absorbed, and the hand-mouth pathway is the largest single contributor to the total dose.

In this particular run there were two children who had doses noticeably higher than the others. The top two children averaged 21.8 times more As dose than the average of all children. The primary factors driving this were transfer coefficients nearly seven times the average, and only one-third as many hand washing events. The top two children also had somewhat more contact time and somewhat higher residue concentrations than the average child, but these were relatively unimportant factors. Also, both of the top two children in total dose had very low soil ingestion totals.

One somewhat unexpected result is that pica behavior is not confined to the upper tail of the dose distribution. Of the 1000 children, 23 exhibited pica behavior (meaning soil ingestion rates over 500 mg/day). Of these 23, only 3 were found in the top 5% of total dose (the top 50 children).

Taken together, we consider these results to be reasonable, in the sense that the important variables and the modeled patterns of behavior seem plausible. For example, the top two children in total dose only averaged 1.6 contact hours per day. The major drivers of predicted dose for these children were the transfer coefficients and infrequent hand washing.

Impact of Reduction of Wood Residues on Exposure

Table 37 shows probabilistic estimates of LADD for children exposed to As dislodgeable residues and contaminated soil from CCA-treated playsets and residential decks in warm climate, assuming 90% reduction in deck and playset residue concentrations. These can be compared to results in Table 14. For children who contact both playsets and decks, the mean and median LADD were reduced by a factor of 6 when residues were reduced by 90%. For children without decks, the mean LADD was reduced by a factor of 7 and the median by 6 when residues were reduced by 90%.

Table 38 shows probabilistic estimates of LADD for children exposed to As dislodgeable residues and contaminated soil from CCA-treated playsets and residential decks in warm climate, assuming 99.5% reduction in deck and playset residue concentrations. These can also be compared to results in Table 14. For children who contact both playsets and decks, the mean LADD was reduced by a factor of 14 and the median by 17 when residues were reduced by 99.5%. For children without decks, the mean LADD was reduced by a factor of 11 and the median by 13 when residues were reduced by 99.5%.

Table 37. Probabilistic Estimates of LADD (mg/kg/day) for Children Exposed to Arsenic Dislodgeable Residues and Contaminated Soil from Treated Wood Playsets and Residential Decks in Warm Climate (reducing deck and playset residue concentrations by 90%)

Pathway	Deck	n	Mean	Stdev	p50	Min	p05	p25	p75	p95	p99	Max
Total playset	No	700	9.0E-07	1.1E-06	5.4E-07	3.3E-09	7.0E-08	2.6E-07	1.1E-06	2.9E-06	5.6E-06	1.2E-05
Residue ingestion from playset	No	700	2.2E-07	3.9E-07	9.6E-08	2.0E-10	4.8E-09	3.3E-08	2.5E-07	8.2E-07	1.9E-06	4.6E-06
Soil ingestion from playset	No	700	4.8E-07	9.0E-07	1.7E-07	3.2E-10	9.6E-09	5.6E-08	5.1E-07	1.9E-06	4.7E-06	1.1E-05
Residue dermal contact from playset	No	700	1.2E-07	1.8E-07	5.4E-08	4.9E-10	4.5E-09	2.1E-08	1.4E-07	4.4E-07	9.6E-07	1.6E-06
Soil dermal contact from playset	No	700	7.4E-08	8.5E-08	5.0E-08	8.6E-10	8.8E-09	2.6E-08	8.7E-08	2.1E-07	5.1E-07	7.0E-07
Total (playset + deck)	Yes	759	1.8E-06	2.3E-06	1.1E-06	1.9E-08	1.9E-07	5.2E-07	2.4E-06	5.6E-06	1.0E-05	3.3E-05
Total playset	Yes	759	1.1E-06	1.4E-06	6.2E-07	6.9E-10	8.4E-08	2.8E-07	1.3E-06	3.8E-06	7.4E-06	1.1E-05
Residue ingestion from playset	Yes	759	2.4E-07	5.1E-07	7.1E-08	6.3E-11	3.5E-09	2.1E-08	2.2E-07	1.0E-06	2.5E-06	5.8E-06
Soil ingestion from playset	Yes	759	6.6E-07	1.2E-06	2.4E-07	3.2E-11	1.5E-08	8.5E-08	6.7E-07	2.6E-06	6.7E-06	1.1E-05
Residue dermal contact from playset	Yes	759	1.2E-07	2.0E-07	4.6E-08	2.9E-11	3.2E-09	1.7E-08	1.3E-07	4.4E-07	1.0E-06	1.7E-06
Soil dermal contact from playset	Yes	759	8.5E-08	1.0E-07	5.5E-08	2.6E-10	7.9E-09	2.9E-08	1.0E-07	2.7E-07	4.8E-07	1.1E-06
Total deck	Yes	759	6.9E-07	1.3E-06	3.3E-07	1.9E-09	4.2E-08	1.5E-07	7.6E-07	2.3E-06	5.4E-06	2.6E-05
Residue ingestion from deck	Yes	759	3.9E-07	1.0E-06	1.3E-07	1.1E-10	7.4E-09	4.8E-08	3.8E-07	1.5E-06	3.9E-06	2.1E-05
Soil ingestion from deck	Yes	759	7.8E-08	1.5E-07	2.4E-08	2.1E-12	8.7E-10	6.8E-09	7.6E-08	3.9E-07	8.0E-07	1.2E-06
Residue dermal contact from deck	Yes	759	2.0E-07	3.5E-07	8.8E-08	8.6E-11	5.5E-09	3.6E-08	2.2E-07	7.8E-07	1.6E-06	4.9E-06
Soil dermal contact from deck	Yes	759	1.6E-08	1.9E-08	9.4E-09	8.0E-12	5.8E-10	3.7E-09	2.2E-08	5.8E-08	9.2E-08	1.3E-07

Table 38. Probabilistic Estimates of LADD (mg/kg/day) for Children Exposed to Arsenic Dislodgeable Residues and Contaminated Soil from Treated Wood Playsets and Residential Decks in Warm Climate (reducing deck and playset residue concentrations by 99.5%)

Pathway	Deck	n	Mean	Stdev	p50	Min	p05	p25	p75	p95	p99	Max
Total playset	No	743	5.5E-07	9.4E-07	2.2E-07	9.8E-10	2.4E-08	8.5E-08	6.1E-07	2.2E-06	4.6E-06	9.0E-06
Residue ingestion from playset	No	743	5.6E-09	2.2E-08	6.8E-10	5.8E-13	2.1E-11	1.5E-10	2.7E-09	2.2E-08	7.6E-08	4.5E-07
Soil ingestion from playset	No	743	5.3E-07	9.4E-07	1.9E-07	2.7E-10	1.2E-08	6.2E-08	5.5E-07	2.2E-06	4.6E-06	9.0E-06
Residue dermal contact from playset	No	743	3.2E-09	9.0E-09	6.3E-10	1.3E-12	2.2E-11	1.6E-10	2.2E-09	1.5E-08	4.1E-08	1.4E-07
Soil dermal contact from playset	No	743	1.6E-08	2.9E-08	8.9E-09	3.3E-10	1.4E-09	4.1E-09	1.8E-08	5.2E-08	1.2E-07	5.5E-07
Total (playset + deck)	Yes	721	8.0E-07	1.3E-06	3.6E-07	2.8E-09	4.3E-08	1.5E-07	9.3E-07	2.9E-06	7.8E-06	1.0E-05
Total playset	Yes	721	6.9E-07	1.2E-06	2.9E-07	7.4E-10	2.4E-08	1.0E-07	8.0E-07	2.7E-06	6.0E-06	1.0E-05
Residue ingestion from playset	Yes	721	3.2E-09	1.1E-08	5.2E-10	7.7E-13	1.0E-11	1.4E-10	2.2E-09	1.2E-08	5.7E-08	1.7E-07
Soil ingestion from playset	Yes	721	6.7E-07	1.2E-06	2.7E-07	4.0E-10	1.4E-08	7.9E-08	7.6E-07	2.7E-06	6.0E-06	1.0E-05
Residue dermal contact from playset	Yes	721	2.0E-09	5.4E-09	4.4E-10	1.0E-12	1.3E-11	1.3E-10	1.5E-09	7.1E-09	2.9E-08	6.7E-08
Soil dermal contact from playset	Yes	721	1.5E-08	2.0E-08	8.4E-09	1.7E-10	1.2E-09	3.8E-09	1.8E-08	5.1E-08	9.7E-08	2.0E-07
Total deck	Yes	721	1.1E-07	2.1E-07	5.0E-08	4.8E-10	5.0E-09	2.0E-08	1.2E-07	3.8E-07	8.9E-07	3.1E-06
Residue ingestion from deck	Yes	721	1.3E-08	4.3E-08	2.9E-09	1.3E-12	6.3E-11	6.9E-10	1.0E-08	5.0E-08	1.5E-07	6.9E-07
Soil ingestion from deck	Yes	721	8.3E-08	2.0E-07	2.4E-08	1.1E-11	6.4E-10	6.3E-09	8.0E-08	3.2E-07	7.5E-07	3.1E-06
Residue dermal contact from deck	Yes	721	7.7E-09	2.1E-08	2.2E-09	2.4E-12	8.2E-11	5.7E-10	7.2E-09	2.9E-08	7.8E-08	4.2E-07
Soil dermal contact from deck	Yes	721	5.6E-09	6.6E-09	3.4E-09	2.4E-11	3.8E-10	1.6E-09	7.1E-09	1.8E-08	3.4E-08	5.2E-08

Impact of Hand Washing after Play Events on Exposure

Table 39 shows probabilistic estimates of LADD for children exposed to As dislodgeable residues and contaminated soil from CCA-treated playsets and residential decks in warm climate, reducing simulating washing children's hands after playing on a deck or playset. These can be compared to results in Table 14. For children who contact both playsets and decks, the total mean and median LADD were reduced by a factor of 1.4 and 1.3, respectively. For children without decks, the reduction factor was 1.7 for the mean and 1.4 for the median.

Table 39. Probabilistic Estimates of LADD (mg/kg/day) for Children Exposed to Arsenic Dislodgeable Residues and Contaminated Soil from Treated Wood Playsets and Residential Decks in Warm Climate (simulating hand washing after playing on deck or playset)

Pathway	Deck	n	Mean	Stdev	p50	Min	p05	p25	p75	p95	p99	Max
Total playset	No	747	3.7E-06	4.5E-06	2.1E-06	7.0E-09	2.7E-07	9.9E-07	4.5E-06	1.2E-05	2.0E-05	4.6E-05
Residue ingestion from playset	No	747	1.6E-06	2.6E-06	7.3E-07	2.6E-09	5.2E-08	2.6E-07	1.9E-06	5.8E-06	1.1E-05	3.0E-05
Soil ingestion from playset	No	747	5.7E-07	1.2E-06	1.8E-07	3.4E-10	1.0E-08	5.6E-08	5.9E-07	2.2E-06	6.6E-06	1.4E-05
Residue dermal contact from playset	No	747	1.4E-06	1.8E-06	7.2E-07	1.2E-09	6.7E-08	3.1E-07	1.7E-06	5.1E-06	9.1E-06	1.5E-05
Soil dermal contact from playset	No	747	1.1E-07	1.5E-07	6.6E-08	1.1E-09	6.6E-09	2.9E-08	1.2E-07	3.5E-07	7.8E-07	1.7E-06
Total (playset + deck)	Yes	704	8.4E-06	1.3E-05	4.8E-06	1.3E-07	9.0E-07	2.5E-06	9.5E-06	2.7E-05	7.0E-05	1.2E-04
Total playset	Yes	704	3.7E-06	5.3E-06	2.2E-06	6.2E-08	3.3E-07	1.1E-06	4.3E-06	1.2E-05	2.7E-05	5.5E-05
Residue ingestion from playset	Yes	704	1.6E-06	3.2E-06	7.3E-07	3.1E-09	6.6E-08	3.0E-07	1.6E-06	5.5E-06	1.7E-05	4.1E-05
Soil ingestion from playset	Yes	704	6.2E-07	1.1E-06	2.3E-07	3.6E-09	1.7E-08	8.2E-08	7.2E-07	2.4E-06	5.4E-06	1.3E-05
Residue dermal contact from playset	Yes	704	1.4E-06	2.3E-06	7.2E-07	1.1E-08	7.1E-08	3.0E-07	1.6E-06	4.1E-06	1.0E-05	2.7E-05
Soil dermal contact from playset	Yes	704	1.4E-07	1.6E-07	8.3E-08	1.0E-09	1.3E-08	3.8E-08	1.7E-07	4.5E-07	7.6E-07	1.7E-06
Total deck	Yes	704	4.7E-06	8.7E-06	2.0E-06	1.5E-09	2.0E-07	9.1E-07	4.9E-06	1.5E-05	4.5E-05	1.0E-04
Residue ingestion from deck	Yes	704	2.3E-06	4.4E-06	8.9E-07	8.5E-10	6.8E-08	3.5E-07	2.4E-06	7.9E-06	2.5E-05	4.6E-05
Soil ingestion from deck	Yes	704	8.4E-08	1.9E-07	2.2E-08	5.2E-12	6.4E-10	5.6E-09	7.7E-08	3.7E-07	9.8E-07	2.0E-06
Residue dermal contact from deck	Yes	704	2.2E-06	4.8E-06	9.2E-07	6.5E-10	7.6E-08	3.7E-07	2.3E-06	7.9E-06	1.8E-05	6.0E-05
Soil dermal contact from deck	Yes	704	2.1E-08	3.2E-08	9.7E-09	9.0E-12	4.6E-10	3.3E-09	2.4E-08	8.0E-08	1.3E-07	3.4E-07

Impact of Both Hand Washing and Residue Reduction on Dermal Absorbed Dose

Table 40 shows probabilistic estimates of LADD for children exposed to As dislodgeable residues and contaminated soil from CCA-treated playsets and residential decks in warm climate, assuming 90% residue reduction and hand washing following exposure. These can be compared to results in Table 14. For children who contact both playsets and decks, median LADDs were reduced by a factor of 7 when residues with hand washing following exposure. For children without decks, the reduction factors for the mean and median were 7 and 6, respectively.

Table 41 shows probabilistic estimates of LADD for children exposed to As dislodgeable residues and contaminated soil from CCA-treated playsets and residential decks in warm climate, assuming 99.5% residue reduction and hand washing following exposure. These can be compared to results in Table 14. For children who contact both playsets and decks, without decks, the reduction factor for the mean and median was 11 and 15, respectively.

Figure 23 illustrates CDFs showing the impact of the various exposure mitigation scenarios (no mitigation, hand washing only, 90% residue reduction only, hand washing and 90% residue reduction).

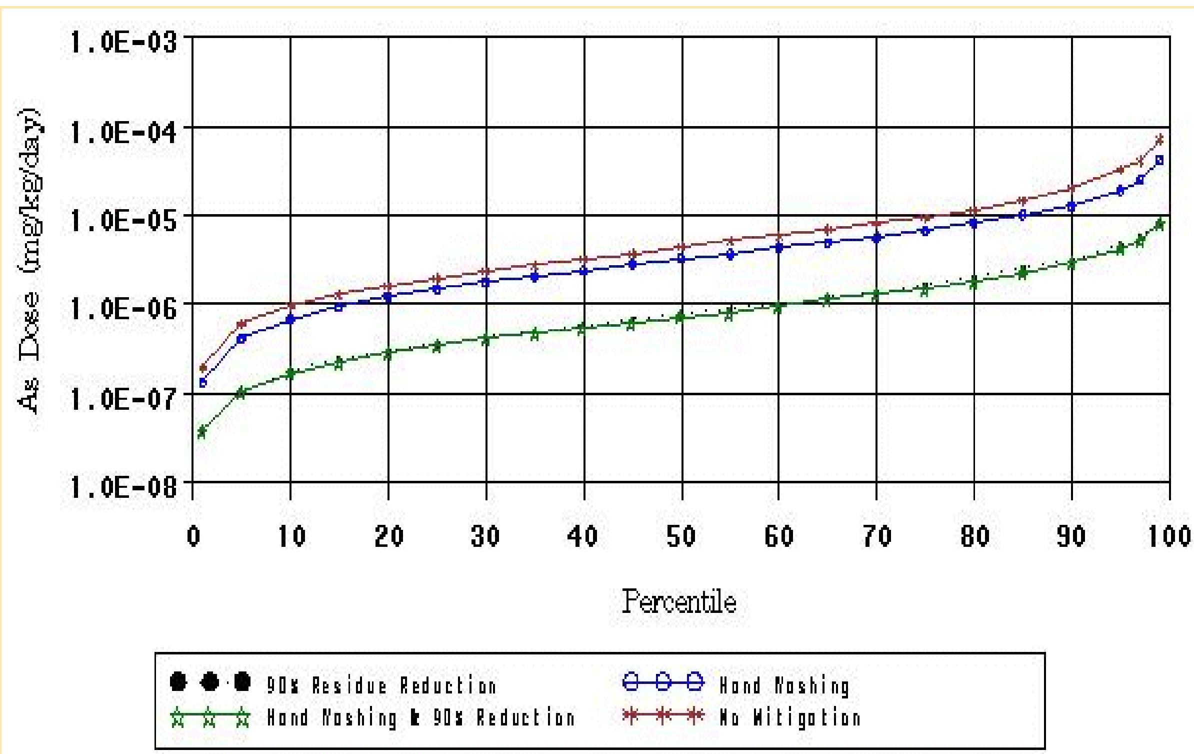


Figure 23. Impact of exposure mitigation scenarios (population LADD for children exposed to As from treated wood playsets and decks.)

Table 40. Probabilistic Estimates of LADD (mg/kg/day) for Children Exposed to Arsenic Dislodgeable Residues and Contaminated Soil from Treated Wood Playsets and Residential Decks in Warm Climate (simulating 90% residue reduction and hand washing)

Pathway	Deck	n	Mean	Stdev	p50	Min	p05	p25	p75	p95	p99	Max
Total playset	No	713	9.8E-07	1.5E-06	5.2E-07	4.4E-09	7.3E-08	2.5E-07	1.2E-06	3.2E-06	6.2E-06	1.9E-05
Residue ingestion from playset	No	713	1.6E-07	3.2E-07	5.8E-08	1.9E-10	2.9E-09	1.9E-08	1.6E-07	6.8E-07	1.8E-06	2.7E-06
Soil ingestion from playset	No	713	5.8E-07	1.2E-06	2.1E-07	3.2E-10	1.2E-08	6.2E-08	5.8E-07	2.5E-06	4.6E-06	1.8E-05
Residue dermal contact from playset	No	713	1.5E-07	4.4E-07	5.9E-08	6.0E-10	3.2E-09	2.3E-08	1.6E-07	4.6E-07	1.3E-06	1.0E-05
Soil dermal contact from playset	No	713	8.3E-08	1.1E-07	4.8E-08	6.4E-10	7.6E-09	2.3E-08	9.6E-08	2.8E-07	5.5E-07	1.2E-06
Total (playset + deck)	Yes	756	1.6E-06	2.5E-06	8.9E-07	3.8E-08	1.8E-07	4.8E-07	1.8E-06	5.2E-06	8.4E-06	5.2E-05
Total playset	Yes	756	9.8E-07	1.2E-06	5.4E-07	1.0E-09	8.2E-08	2.6E-07	1.2E-06	3.7E-06	5.8E-06	8.7E-06
Residue ingestion from playset	Yes	756	1.7E-07	4.0E-07	4.7E-08	7.2E-11	2.4E-09	1.4E-08	1.4E-07	6.6E-07	2.1E-06	5.6E-06
Soil ingestion from playset	Yes	756	6.1E-07	9.5E-07	2.2E-07	1.3E-10	1.5E-08	8.4E-08	7.2E-07	2.5E-06	4.6E-06	7.5E-06
Residue dermal contact from playset	Yes	756	1.2E-07	2.2E-07	5.1E-08	2.8E-10	3.9E-09	1.8E-08	1.2E-07	4.8E-07	1.3E-06	2.1E-06
Soil dermal contact from playset	Yes	756	8.6E-08	1.0E-07	5.5E-08	3.5E-10	9.4E-09	2.6E-08	1.0E-07	2.6E-07	5.3E-07	8.1E-07
Total deck	Yes	756	6.1E-07	1.8E-06	2.7E-07	4.9E-10	3.0E-08	1.3E-07	5.9E-07	2.1E-06	4.7E-06	4.3E-05
Residue ingestion from deck	Yes	756	2.9E-07	1.2E-06	8.0E-08	1.2E-10	4.7E-09	2.8E-08	2.4E-07	1.1E-06	3.0E-06	3.0E-05
Soil ingestion from deck	Yes	756	7.7E-08	1.6E-07	2.0E-08	2.0E-11	5.5E-10	6.0E-09	7.5E-08	3.7E-07	6.8E-07	2.3E-06
Residue dermal contact from deck	Yes	756	2.3E-07	6.1E-07	8.8E-08	2.7E-10	6.5E-09	3.3E-08	2.2E-07	9.2E-07	2.1E-06	1.3E-05
Soil dermal contact from deck	Yes	756	1.6E-08	2.4E-08	8.9E-09	3.6E-12	5.2E-10	3.1E-09	2.0E-08	5.4E-08	1.1E-07	3.4E-07

Table 41. Probabilistic Estimates of LADD (mg/kg/day) for Children Exposed to Arsenic Dislodgeable Residues and Contaminated Soil from Treated Wood Playsets and Residential Decks in Warm Climate (simulating 99.5% residue reduction and hand washing)

Pathway	Deck	n	Mean	Stdev	p50	Min	p05	p25	p75	p95	p99	Max
Total playset	No	729	5.7E-07	9.6E-07	2.0E-07	3.6E-09	2.0E-08	7.1E-08	5.7E-07	2.5E-06	4.7E-06	8.1E-06
Residue ingestion from playset	No	729	2.7E-09	7.5E-09	5.3E-10	8.2E-13	1.7E-11	1.3E-10	2.1E-09	1.2E-08	3.0E-08	1.0E-07
Soil ingestion from playset	No	729	5.5E-07	9.6E-07	1.8E-07	8.7E-10	9.8E-09	5.5E-08	5.4E-07	2.5E-06	4.6E-06	8.1E-06
Residue dermal contact from playset	No	729	2.6E-09	6.1E-09	7.3E-10	1.3E-12	2.9E-11	2.0E-10	2.2E-09	1.1E-08	3.4E-08	6.8E-08
Soil dermal contact from playset	No	729	1.6E-08	2.1E-08	9.2E-09	1.8E-10	1.4E-09	4.1E-09	2.0E-08	5.2E-08	1.0E-07	2.1E-07
Total (playset + deck)	Yes	738	9.2E-07	1.8E-06	3.4E-07	1.1E-08	4.4E-08	1.4E-07	9.2E-07	3.2E-06	1.1E-05	1.9E-05
Total playset	Yes	738	8.1E-07	1.7E-06	2.7E-07	1.5E-09	2.9E-08	1.0E-07	7.5E-07	3.0E-06	1.1E-05	1.7E-05
Residue ingestion from playset	Yes	738	2.4E-09	9.4E-09	2.9E-10	8.6E-13	7.7E-12	6.9E-11	1.1E-09	9.4E-09	4.7E-08	1.3E-07
Soil ingestion from playset	Yes	738	7.9E-07	1.7E-06	2.4E-07	1.1E-09	1.9E-08	8.6E-08	7.2E-07	2.8E-06	1.1E-05	1.7E-05
Residue dermal contact from playset	Yes	738	2.1E-09	7.4E-09	4.0E-10	1.3E-12	1.4E-11	9.7E-11	1.6E-09	7.5E-09	3.1E-08	1.1E-07
Soil dermal contact from playset	Yes	738	1.5E-08	2.0E-08	8.4E-09	2.0E-10	1.2E-09	3.8E-09	1.8E-08	4.5E-08	9.6E-08	2.2E-07
Total deck	Yes	738	1.1E-07	1.8E-07	4.5E-08	2.9E-10	5.1E-09	1.8E-08	1.3E-07	4.0E-07	9.8E-07	1.5E-06
Residue ingestion from deck	Yes	738	8.7E-09	2.7E-08	1.7E-09	2.1E-12	3.9E-11	4.2E-10	6.3E-09	3.7E-08	1.0E-07	3.9E-07
Soil ingestion from deck	Yes	738	9.0E-08	1.8E-07	2.4E-08	2.6E-11	6.1E-10	6.0E-09	9.8E-08	3.5E-07	9.7E-07	1.5E-06
Residue dermal contact from deck	Yes	738	7.6E-09	1.9E-08	2.2E-09	6.2E-12	6.4E-11	5.4E-10	6.7E-09	3.0E-08	7.7E-08	2.1E-07
Soil dermal contact from deck	Yes	738	5.5E-09	8.4E-09	3.3E-09	1.2E-12	3.6E-10	1.5E-09	6.7E-09	1.8E-08	3.0E-08	1.6E-07

Impact of Replacing Deck or Playset Residues with Hand Loading Data

Dermal absorbed dose was computed in part by multiplying ACC (2003b) wood block data by transfer efficiency. The transfer efficiency was determined by dividing ACC (2003b) hand wipe data by ACC (2003b) wood block data. The dermal exposure was compared to maximum dermal loading based on the ACC (2003b) hand wipe data. Table 42 contains probabilistic estimates of short-term ADD for children exposed to As dislodgeable residues and contaminated soil from treated wood playsets and residential decks in warm climate, replacing deck or playset residues (wood block data) with hand loading data (i.e., using dislodgeable residues directly rather than total residues multiplied by transfer efficiency). The results were almost identical (median 6.8E-5 vs 6.5 E-5 for children with playsets and decks; median 3.9 E-5 vs 3.0 E-5 for children without decks).

Table 42. Probabilistic Estimates of Short-Term ADD (mg/kg/day) for Children Exposed to Arsenic Dislodgeable Residues and Contaminated Soil from Treated Wood Playsets and Residential Decks in Warm Climate (replacing deck or playset residue concentration with hand loading)

Pathway	Deck	n	Mean	Stdev	p50	Min	p05	p25	p75	p95	p99	Max
Total playset	No	737	7.4E-05	1.1E-04	3.9E-05	0.0E+00	3.4E-06	1.7E-05	8.8E-05	2.6E-04	4.1E-04	1.9E-03
Residue ingestion from playset	No	737	4.5E-05	9.3E-05	2.0E-05	0.0E+00	1.0E-06	6.4E-06	5.0E-05	1.8E-04	3.1E-04	1.8E-03
Soil ingestion from playset	No	737	1.2E-05	3.2E-05	2.6E-06	0.0E+00	8.6E-08	7.0E-07	7.7E-06	5.4E-05	1.9E-04	3.2E-04
Residue dermal contact from playset	No	737	1.5E-05	2.0E-05	7.8E-06	0.0E+00	5.3E-07	3.2E-06	1.7E-05	5.2E-05	1.0E-04	1.8E-04
Soil dermal contact from playset	No	737	2.1E-06	3.3E-06	9.5E-07	0.0E+00	6.8E-08	3.5E-07	2.4E-06	7.8E-06	1.5E-05	2.9E-05
Total (playset + deck)	Yes	728	1.1E-04	1.4E-04	6.8E-05	3.9E-07	1.2E-05	3.3E-05	1.4E-04	3.1E-04	6.0E-04	1.5E-03
Total playset	Yes	728	6.7E-05	9.7E-05	3.5E-05	0.0E+00	2.5E-06	1.3E-05	8.0E-05	2.3E-04	4.5E-04	1.2E-03
Residue ingestion from playset	Yes	728	4.5E-05	8.3E-05	2.0E-05	0.0E+00	7.6E-07	5.7E-06	5.0E-05	1.7E-04	3.7E-04	1.1E-03
Soil ingestion from playset	Yes	728	6.6E-06	2.4E-05	1.2E-06	0.0E+00	3.8E-08	3.1E-07	4.6E-06	2.7E-05	9.1E-05	4.7E-04
Residue dermal contact from playset	Yes	728	1.4E-05	1.9E-05	7.8E-06	0.0E+00	4.6E-07	2.8E-06	1.7E-05	4.7E-05	1.0E-04	1.7E-04
Soil dermal contact from playset	Yes	728	1.0E-06	1.5E-06	4.4E-07	0.0E+00	2.5E-08	1.7E-07	1.2E-06	4.1E-06	7.2E-06	1.5E-05
Total deck	Yes	728	4.3E-05	6.4E-05	2.2E-05	0.0E+00	0.0E+00	8.2E-06	5.1E-05	1.5E-04	3.1E-04	7.5E-04
Residue ingestion from deck	Yes	728	3.1E-05	5.8E-05	1.2E-05	0.0E+00	0.0E+00	3.4E-06	3.3E-05	1.2E-04	2.9E-04	7.3E-04
Soil ingestion from deck	Yes	728	9.6E-07	2.7E-06	1.5E-07	0.0E+00	0.0E+00	2.0E-08	7.3E-07	4.2E-06	1.6E-05	3.0E-05
Residue dermal contact from deck	Yes	728	1.1E-05	1.5E-05	5.8E-06	0.0E+00	0.0E+00	2.0E-06	1.4E-05	3.8E-05	7.6E-05	1.3E-04
Soil dermal contact from deck	Yes	728	1.7E-07	4.2E-07	4.7E-08	0.0E+00	0.0E+00	7.6E-09	1.5E-07	7.3E-07	2.2E-06	6.1E-06

Relative Contribution to Total Absorbed Dose by Exposure Route

Figures 24-36 and Table 43 present the relative contribution to total absorbed dose by exposure route for As and Cr in the different time periods and climate scenarios. For all of the base As and Cr scenarios (Figures 24-36) it can be seen that the most critical routes, in order of importance, are consistently residue ingestion, dermal residue contact, soil ingestion, and dermal soil contact. As expected, this order holds for the scenarios assuming a higher GI residue absorption rate of 100% and a lower dermal absorption rate of 0.01%, with an even higher contribution by residue ingestion. When a wood residue reduction is considered, the soil ingestion route becomes relatively more important than residue ingestion (Figure 34).

Table 43. Summary of Mean As and Cr Population Absorbed Dose Values (mg/kg/day) and Their Contribution to Total Dose for the Short-Term, Intermediate-Term, and Lifetime Scenarios (for children exposed to home playsets, public playsets, and decks)

Scenario	Mean Dose from Dermal Residue Contact	Mean Dose from Dermal Soil Contact	Mean Dose from Residue Ingestion	Mean Dose from Soil Ingestion	% Contribution of Dermal Residue Contact to Total Dose	% Contribution of Dermal Soil Contact to Total Dose	% Contribution of Residue Ingestion to Total Dose	% Contribution of Soil Ingestion to Total Dose
Population LADD for children exposed to As in warm climate	2.8E-06	1.4E-07	5.3E-06	6.8E-07	31.2	1.5	59.5	7.7
Population LADD for children exposed to As in warm climate (0.01% dermal residue absorption)	9.0E-09	1.4E-07	5.2E-06	6.5E-07	0.2	2.4	86.5	11.0
Population LADD for children exposed to As in warm climate (simulating 90% residue reduction)	2.2E-07	8.9E-08	4.4E-07	6.2E-07	16.3	6.5	32.0	45.1
Population LADD for children exposed to As in warm climate (simulating hand washing after wood contact)	2.5E-06	1.3E-07	2.7E-06	6.4E-07	41.2	2.2	45.9	10.7
Population LADD for children exposed to As in warm climate (simulating 90% residue reduction and hand washing after wood contact)	2.5E-07	9.3E-08	3.1E-07	6.4E-07	19.5	7.2	24.2	49.1
Population LADD for children exposed to As in warm climate (simulating 99.5% residue reduction)	6.4E-09	1.8E-08	1.1E-08	6.4E-07	0.9	2.7	1.6	94.7

Scenario	Mean Dose from Dermal Residue Contact	Mean Dose from Dermal Soil Contact	Mean Dose from Residue Ingestion	Mean Dose from Soil Ingestion	% Contribution of Dermal Residue Contact to Total Dose	% Contribution of Dermal Soil Contact to Total Dose	% Contribution of Residue Ingestion to Total Dose	% Contribution of Soil Ingestion to Total Dose
Population LADD for children exposed to As in warm climate (simulating 99.5% residue reduction and hand washing after wood contacts)	6.2E-09	1.8E-08	6.9E-09	7.2E-07	0.8	2.4	0.9	95.8
Population LADD for children exposed to As in cold climate	6.2E-07	5.5E-09	3.9E-06	7.3E-08	13.6	0.1	84.6	1.6
Population LADD for children exposed to As in cold climate (assuming 0.01% dermal residue absorption)	2.2E-09	5.4E-09	4.0E-06	7.0E-08	0.1	0.1	98.1	1.7
Population short-term ADD for children exposed to As in warm climate	2.9E-05	1.8E-06	6.7E-05	8.4E-06	27.5	1.7	62.9	7.9
Population short-term ADD in warm climate for children exposed to As (assuming 100% GI residue absorption)	2.7E-05	1.8E-06	1.5E-04	9.1E-06	14.1	0.9	80.2	4.8
Population short-term ADD for children exposed to As in cold climate	6.2E-06	5.4E-08	4.8E-05	8.3E-07	11.2	0.1	87.2	1.5
Population intermediate-term ADD for children exposed to As in warm climate	2.8E-05	1.7E-06	5.6E-05	8.2E-06	30.1	1.8	59.2	8.8
Population intermediate-term ADD for children exposed to As in cold climate	6.8E-06	6.2E-08	4.6E-05	7.7E-07	12.7	0.1	85.8	1.4

Scenario	Mean Dose from Dermal Residue Contact	Mean Dose from Dermal Soil Contact	Mean Dose from Residue Ingestion	Mean Dose from Soil Ingestion	% Contribution of Dermal Residue Contact to Total Dose	% Contribution of Dermal Soil Contact to Total Dose	% Contribution of Residue Ingestion to Total Dose	% Contribution of Soil Ingestion to Total Dose
Population intermediate-term ADD for children exposed to Cr in warm climate	2.5E-05	1.7E-06	5.7E-05	9.9E-06	26.7	1.8	60.9	10.5
Population intermediate-term ADD for children exposed to Cr in cold climate	6.3E-06	1.3E-07	4.5E-05	2.1E-06	11.7	0.2	84.2	3.9
Population short-term ADD for children exposed to Cr in warm climate	2.6E-05	1.8E-06	5.0E-05	9.0E-06	29.8	2.1	57.8	10.3
Population short-term ADD for children exposed to Cr in cold climate	6.8E-06	1.2E-07	4.8E-05	1.8E-06	12.0	0.2	84.6	3.1

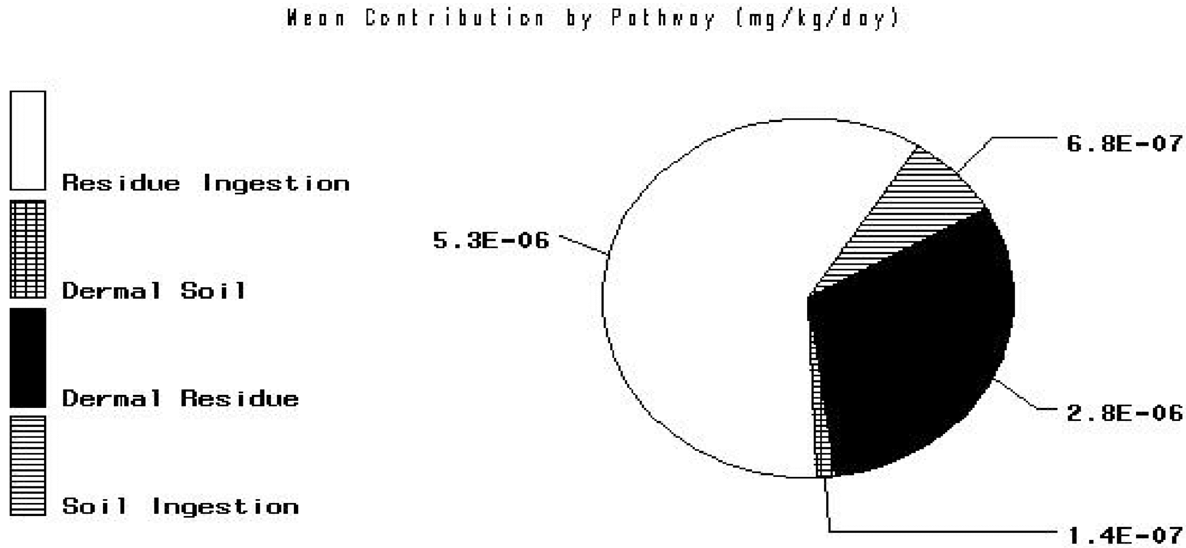


Figure 24. Mean contribution by pathway: population LADD for children exposed to As in warm climate.

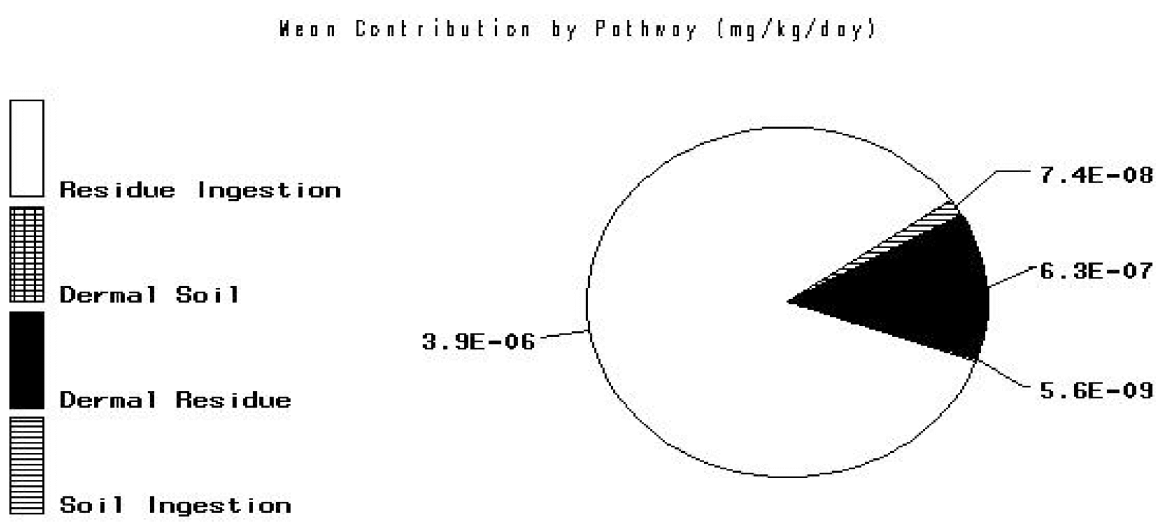


Figure 25. Mean contribution by pathway: population LADD for children exposed to As in cold climate.

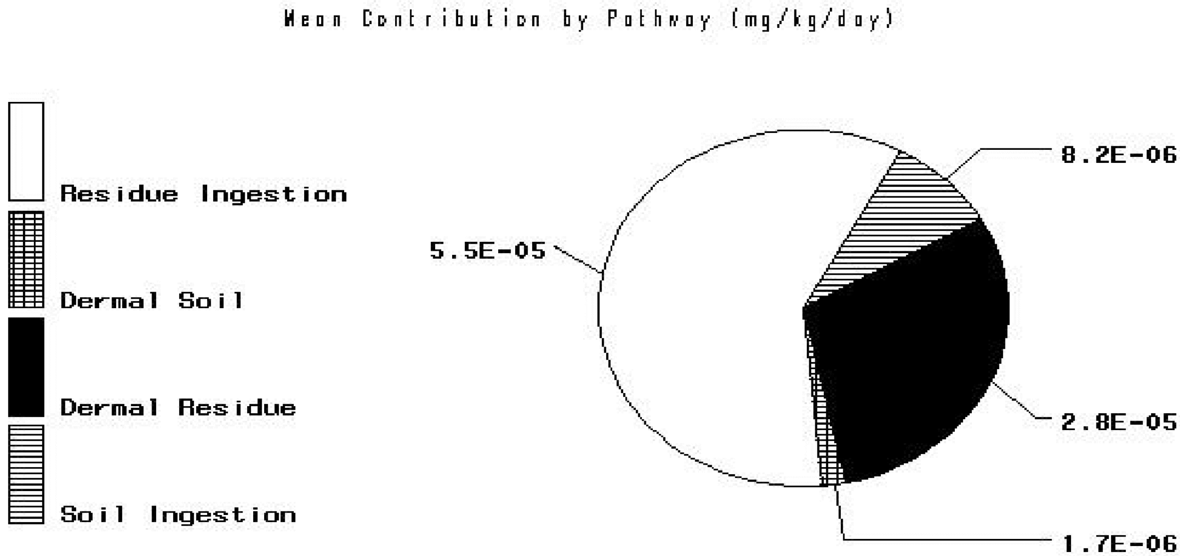


Figure 26. Mean contribution by pathway: population intermediate-term ADD for children exposed to As in warm climate.

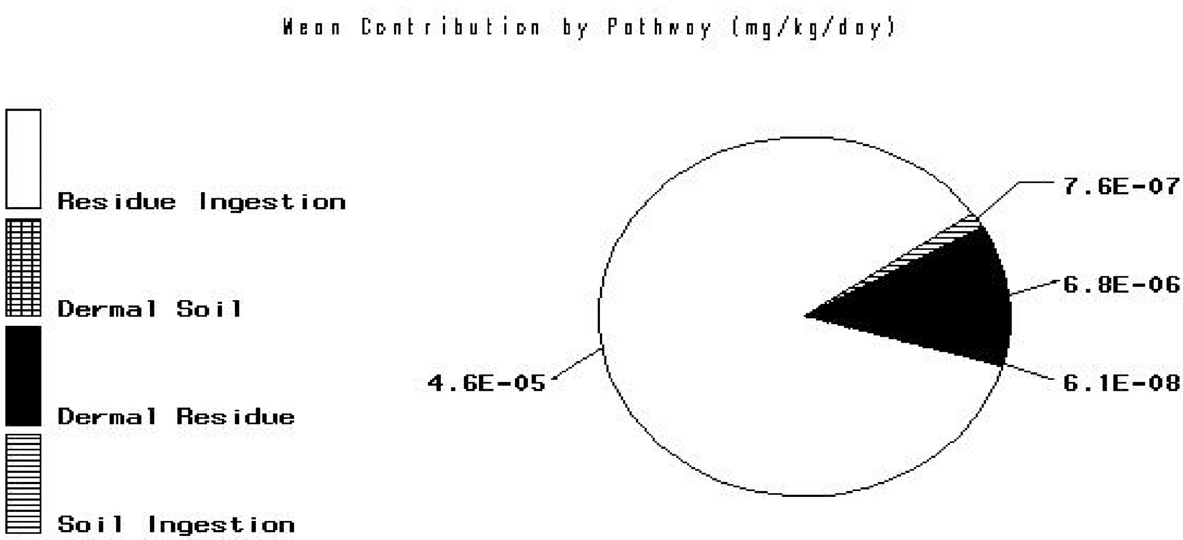


Figure 27. Mean contribution by pathway: population intermediate-term ADD for children exposed to As in cold climate.

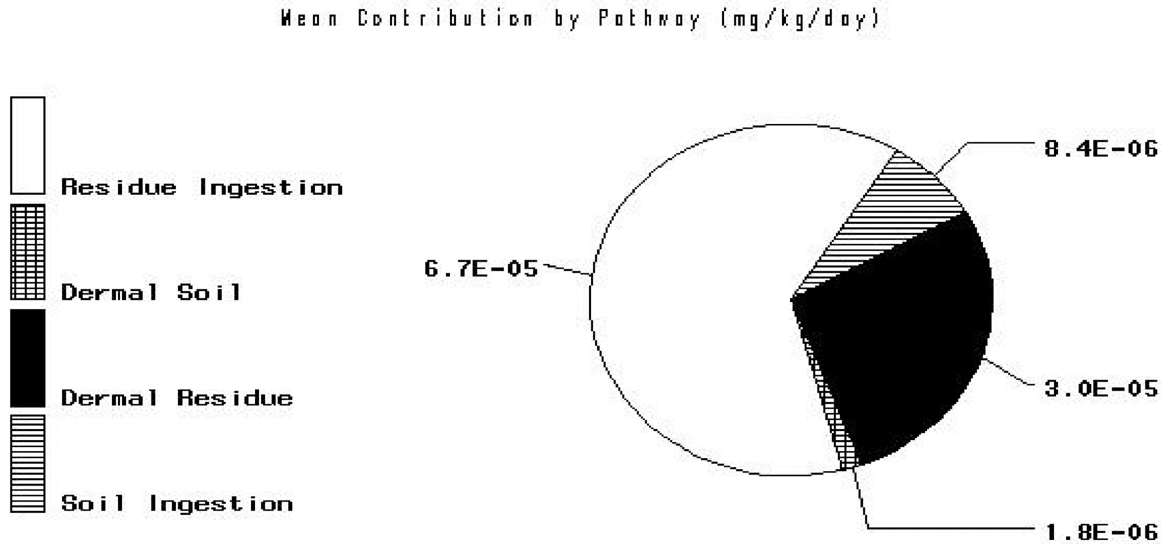


Figure 28. Mean contribution by pathway: population short-term ADD for children exposed to As in warm climate.

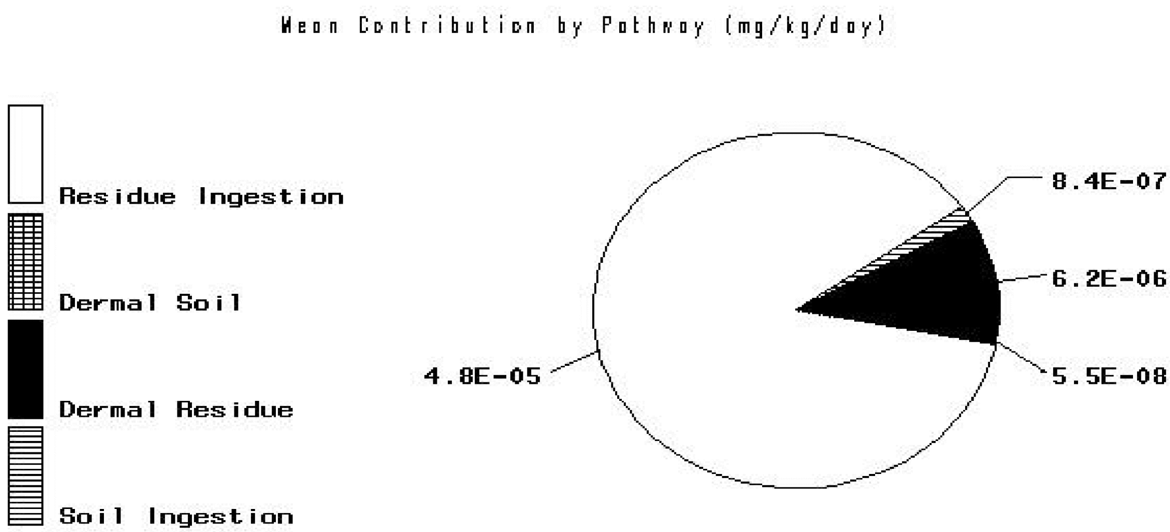


Figure 29. Mean contribution by pathway: population short-term ADD for children exposed to As in cold climate.

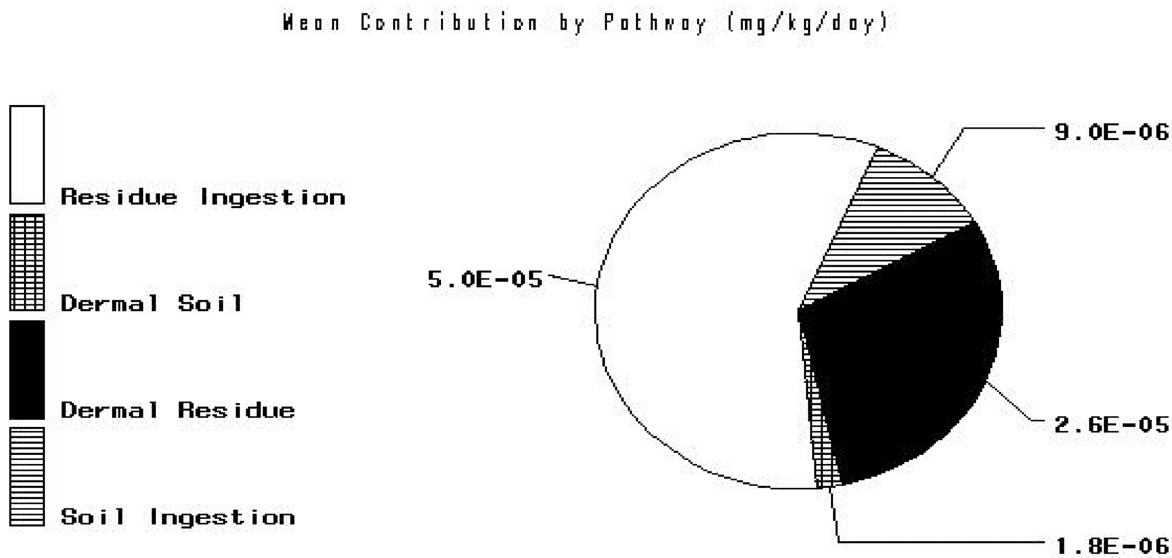


Figure 30. Mean contribution by pathway: population intermediate-term ADD for children exposed to Cr in warm climate.

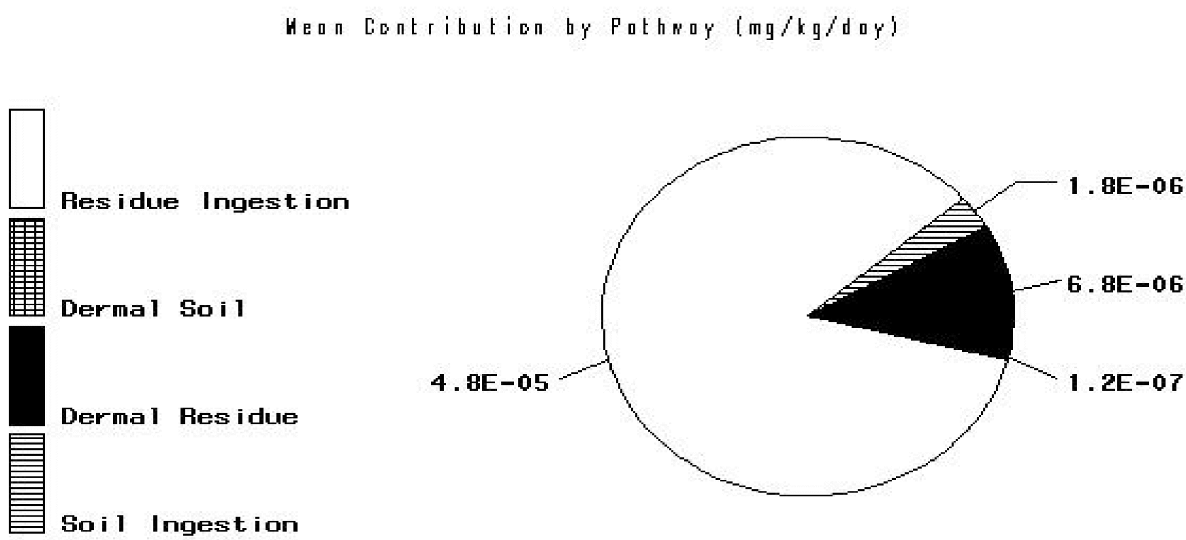


Figure 31. Mean contribution by pathway: population intermediate-term ADD for children exposed to Cr in cold climate.

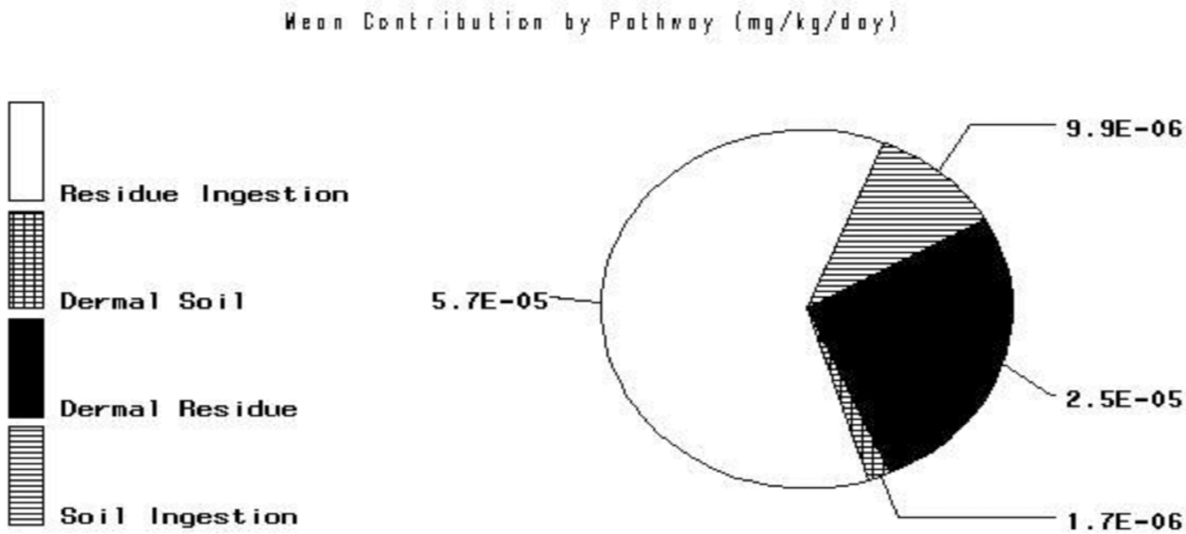


Figure 32. Mean contribution by pathway: population short-term ADD for children exposed to Cr in warm climate.

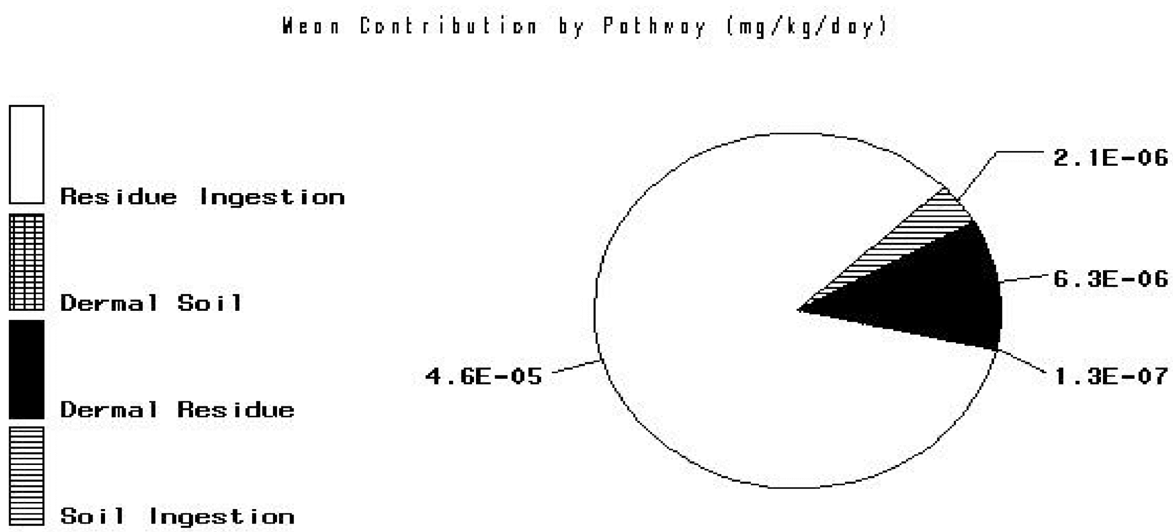


Figure 33. Mean contribution by pathway: population short-term ADD for children exposed to Cr in cold climate.

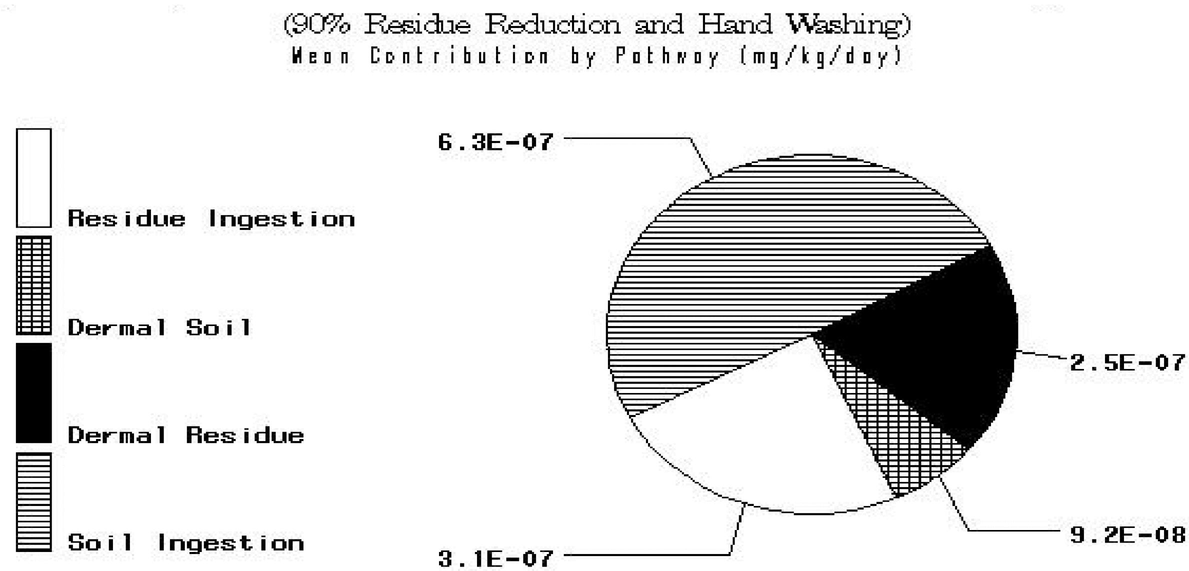


Figure 34. Mean contribution by pathway: population LADD in warm climate for children exposed to As, assuming 90% residue reduction and hand washing.

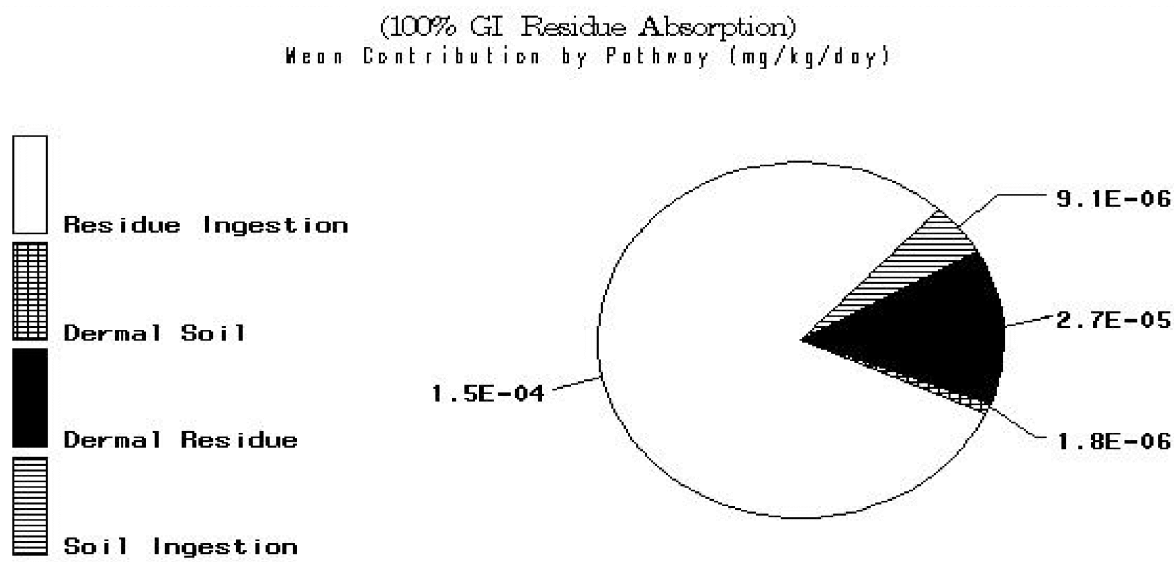


Figure 35. Mean contribution by pathway: population short-term ADD in warm climate for children exposed to As, assuming 100% GI residue absorption.

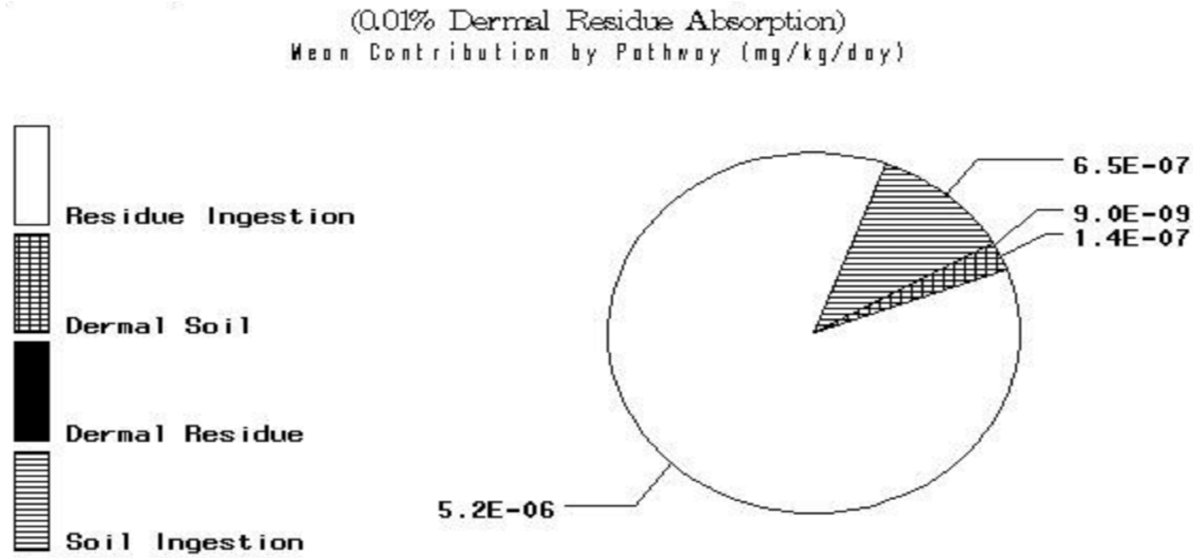


Figure 36. Mean contribution by pathway: population LADD for children exposed to As in warm climate, assuming 0.01% dermal residue absorption.

Summary of Probabilistic Modeling Results for GI Exposure, GI Dose, Dermal Dose, and Total Dose

Table 44 shows summary statistics for total GI exposure for As (separated by children with and without decks). The absorbed dose was also computed for both the ingestion route (in addition to exposure) and the dermal route, so that the relative contribution across all routes and pathways to total absorbed dose could be determined. Summary statistics for GI absorbed dose for As and Cr, all time periods, are shown in Table 45, and the dermal absorbed dose values are shown in Table 46. Table 47 presents summary statistics for total dose (GI + dermal) for As and Cr (separated by children with and without decks), for various scenarios considered in this assessment. Raw data associated with the distributions summarized in Table 47 were used by OPP in conducting the probabilistic CCA cancer risk assessment for the population of interest (Dang, 2003).

Table 44. Summary Statistics for Total GI Exposure (mg/kg/day) for As and Cr (separated by children with and without decks)

Category	Deck	n	Mean	Stdev	p50	Min	p05	p25	p75	p95	p99	Max
Short As in warm climate	0	755	1.9E-04	4.8E-04	6.7E-05	0.0E+00	4.8E-06	2.4E-05	1.9E-04	6.9E-04	2.0E-03	7.0E-03
Short As in warm climate	1	710	3.0E-04	5.1E-04	1.3E-04	1.4E-06	1.4E-05	5.6E-05	3.4E-04	1.2E-03	2.3E-03	7.8E-03
Intermediate As in warm climate	0	715	1.4E-04	2.3E-04	5.8E-05	9.2E-08	3.6E-06	1.8E-05	1.4E-04	5.4E-04	9.9E-04	2.1E-03
Intermediate As in warm climate	1	752	2.9E-04	4.6E-04	1.5E-04	1.3E-06	1.7E-05	5.6E-05	3.2E-04	1.1E-03	2.2E-03	6.1E-03
Lifetime As in warm climate	0	728	1.4E-05	2.8E-05	6.5E-06	6.4E-08	7.8E-07	2.7E-06	1.4E-05	5.1E-05	1.3E-04	4.2E-04
Lifetime As in warm climate	1	738	2.5E-05	3.4E-05	1.3E-05	3.2E-07	2.0E-06	6.2E-06	2.8E-05	9.2E-05	1.8E-04	2.7E-04
Short As in cold climate	0	742	1.3E-04	2.9E-04	4.7E-05	0.0E+00	3.6E-07	1.2E-05	1.3E-04	5.0E-04	1.4E-03	3.6E-03
Short As in cold climate	1	720	2.1E-04	4.3E-04	8.4E-05	0.0E+00	5.5E-06	3.1E-05	2.1E-04	7.2E-04	2.1E-03	5.0E-03
Intermediate As in cold climate	0	721	1.0E-04	3.5E-04	3.4E-05	0.0E+00	1.8E-06	1.1E-05	8.7E-05	3.6E-04	1.1E-03	6.3E-03
Intermediate As in cold climate	1	742	2.0E-04	3.5E-04	9.9E-05	3.2E-06	1.1E-05	4.1E-05	2.3E-04	6.8E-04	1.9E-03	5.3E-03
Lifetime As in cold climate	0	744	9.6E-06	1.5E-05	4.4E-06	1.2E-08	5.1E-07	1.8E-06	1.0E-05	3.5E-05	8.3E-05	1.7E-04
Lifetime As in cold climate	1	718	1.9E-05	3.0E-05	9.2E-06	2.4E-07	1.1E-06	3.9E-06	2.1E-05	6.7E-05	1.2E-04	3.7E-04
Short Cr in warm climate	0	726	1.5E-04	3.3E-04	5.9E-05	0.0E+00	4.9E-06	2.2E-05	1.5E-04	5.8E-04	1.6E-03	4.6E-03
Short Cr in warm climate	1	734	2.9E-04	5.1E-04	1.3E-04	2.4E-06	1.3E-05	4.9E-05	3.0E-04	1.1E-03	2.6E-03	6.5E-03
Intermediate Cr in warm climate	0	727	1.3E-04	2.2E-04	5.0E-05	5.1E-08	2.7E-06	1.9E-05	1.3E-04	5.1E-04	1.1E-03	2.2E-03
Intermediate Cr in warm climate	1	734	2.6E-04	4.2E-04	1.3E-04	3.5E-06	1.6E-05	6.1E-05	2.9E-04	9.0E-04	1.7E-03	5.0E-03
Short Cr in cold climate	0	739	1.2E-04	2.5E-04	4.2E-05	0.0E+00	5.2E-07	1.3E-05	1.2E-04	4.4E-04	1.4E-03	2.4E-03
Short Cr in cold climate	1	728	2.1E-04	4.1E-04	9.5E-05	0.0E+00	5.5E-06	3.4E-05	2.2E-04	8.2E-04	2.1E-03	5.4E-03
Intermediate Cr in cold climate	0	721	1.1E-04	2.5E-04	3.5E-05	0.0E+00	3.2E-06	1.4E-05	9.9E-05	4.8E-04	1.0E-03	3.9E-03
Intermediate Cr in cold climate	1	733	2.3E-04	5.1E-04	1.1E-04	2.0E-06	1.2E-05	4.3E-05	2.4E-04	8.0E-04	1.8E-03	8.5E-03

Table 45. Summary Statistics for Total GI Dose (mg/kg/day) for As and Cr (separated by children with and without decks)

Category	Deck	n	Mean	Stdev	p50	Min	p05	p25	p75	p95	p99	Max
Short As in warm climate	0	755	6.1E-05	1.7E-04	2.0E-05	0.0E+00	1.2E-06	7.0E-06	5.7E-05	2.3E-04	6.0E-04	3.3E-03
Short As in warm climate	1	710	9.1E-05	1.4E-04	4.1E-05	3.7E-07	3.8E-06	1.6E-05	1.1E-04	3.3E-04	7.7E-04	1.1E-03
Intermediate As in warm climate	0	715	4.2E-05	7.3E-05	1.9E-05	3.5E-08	9.1E-07	5.3E-06	4.3E-05	1.8E-04	3.5E-04	7.1E-04
Intermediate As in warm climate	1	752	8.5E-05	1.3E-04	4.1E-05	3.5E-07	4.8E-06	1.6E-05	8.9E-05	3.2E-04	6.5E-04	1.3E-03
Lifetime As in warm climate	0	728	4.5E-06	9.0E-06	2.0E-06	1.7E-08	2.2E-07	8.6E-07	4.5E-06	1.6E-05	4.7E-05	1.0E-04
Lifetime As in warm climate	1	738	7.4E-06	1.1E-05	3.9E-06	1.3E-07	5.4E-07	1.9E-06	8.4E-06	2.4E-05	6.3E-05	1.1E-04
Short As in cold climate	0	742	3.8E-05	9.4E-05	1.2E-05	0.0E+00	9.0E-08	3.3E-06	3.8E-05	1.4E-04	4.5E-04	1.2E-03
Short As in cold climate	1	720	6.0E-05	1.5E-04	2.1E-05	0.0E+00	1.4E-06	8.6E-06	5.9E-05	1.9E-04	6.7E-04	2.2E-03
Intermediate As in cold climate	0	721	3.3E-05	1.2E-04	8.9E-06	0.0E+00	4.7E-07	3.0E-06	2.7E-05	1.1E-04	3.7E-04	2.6E-03
Intermediate As in cold climate	1	742	6.1E-05	1.3E-04	2.6E-05	5.2E-07	3.1E-06	1.1E-05	6.2E-05	2.2E-04	5.5E-04	2.3E-03
Lifetime As in cold climate	0	744	2.8E-06	4.4E-06	1.2E-06	4.8E-09	1.3E-07	5.1E-07	2.9E-06	1.1E-05	2.1E-05	5.1E-05
Lifetime As in cold climate	1	718	5.2E-06	8.2E-06	2.4E-06	5.7E-08	3.1E-07	1.1E-06	5.9E-06	1.9E-05	3.9E-05	9.0E-05
Short Cr in warm climate	0	726	4.6E-05	9.6E-05	1.7E-05	0.0E+00	1.4E-06	6.7E-06	4.6E-05	1.7E-04	4.5E-04	1.6E-03
Short Cr in warm climate	1	734	8.8E-05	1.7E-04	3.8E-05	5.1E-07	3.7E-06	1.4E-05	9.4E-05	3.2E-04	7.0E-04	2.5E-03
Intermediate Cr in warm climate	0	727	3.9E-05	6.8E-05	1.5E-05	1.2E-08	8.8E-07	5.7E-06	4.1E-05	1.6E-04	3.4E-04	6.7E-04
Intermediate Cr in warm climate	1	734	8.0E-05	1.3E-04	3.7E-05	6.7E-07	4.7E-06	1.8E-05	8.3E-05	3.0E-04	7.3E-04	1.5E-03
Short Cr in cold climate	0	739	3.5E-05	7.9E-05	1.1E-05	0.0E+00	1.4E-07	3.6E-06	3.4E-05	1.3E-04	4.2E-04	8.8E-04
Short Cr in cold climate	1	728	6.0E-05	1.3E-04	2.4E-05	0.0E+00	1.4E-06	8.7E-06	6.3E-05	2.2E-04	6.3E-04	1.7E-03
Intermediate Cr in cold climate	0	721	3.4E-05	8.7E-05	1.0E-05	0.0E+00	8.2E-07	3.9E-06	2.9E-05	1.6E-04	3.8E-04	1.5E-03
Intermediate Cr in cold climate	1	733	6.5E-05	1.5E-04	2.9E-05	4.7E-07	3.1E-06	1.2E-05	6.9E-05	2.2E-04	4.4E-04	2.5E-03

Table 46. Summary Statistics for Total Dermal Dose (mg/kg/day) for As and Cr (separated by children with and without decks)

Category	Deck	n	Mean	Stdev	p50	Min	p05	p25	p75	p95	p99	Max
Short As in warm climate	0	755	2.3E-05	5.6E-05	8.0E-06	0.0E+00	4.7E-07	2.8E-06	2.3E-05	7.9E-05	2.7E-04	8.5E-04
Short As in warm climate	1	710	4.0E-05	6.3E-05	1.9E-05	4.1E-07	2.0E-06	7.9E-06	4.5E-05	1.5E-04	3.5E-04	6.3E-04
Intermediate As in warm climate	0	715	1.7E-05	2.5E-05	7.8E-06	1.4E-08	4.0E-07	2.9E-06	2.0E-05	6.3E-05	1.3E-04	1.9E-04
Intermediate As in warm climate	1	752	4.3E-05	7.4E-05	2.1E-05	3.5E-07	2.4E-06	9.3E-06	4.8E-05	1.5E-04	3.4E-04	1.1E-03
Lifetime As in warm climate	0	728	1.9E-06	3.2E-06	9.1E-07	7.3E-09	1.4E-07	4.4E-07	2.0E-06	6.5E-06	1.9E-05	3.0E-05
Lifetime As in warm climate	1	738	3.9E-06	6.0E-06	2.1E-06	8.9E-08	3.3E-07	9.3E-07	4.3E-06	1.3E-05	2.6E-05	9.9E-05
Short As in cold climate	0	742	5.0E-06	1.3E-05	1.5E-06	0.0E+00	9.8E-09	5.0E-07	4.9E-06	1.9E-05	5.1E-05	2.8E-04
Short As in cold climate	1	720	7.5E-06	1.5E-05	3.3E-06	0.0E+00	2.6E-07	1.3E-06	7.8E-06	2.5E-05	6.4E-05	2.4E-04
Intermediate As in cold climate	0	721	4.7E-06	2.3E-05	1.5E-06	0.0E+00	6.6E-08	4.9E-07	3.9E-06	1.5E-05	3.8E-05	5.4E-04
Intermediate As in cold climate	1	742	9.0E-06	1.4E-05	4.4E-06	8.5E-08	4.8E-07	1.9E-06	1.1E-05	3.0E-05	7.3E-05	1.4E-04
Lifetime As in cold climate	0	744	4.0E-07	5.5E-07	2.1E-07	3.6E-10	2.5E-08	9.6E-08	4.9E-07	1.5E-06	2.6E-06	5.4E-06
Lifetime As in cold climate	1	718	8.6E-07	1.2E-06	4.6E-07	9.5E-09	6.7E-08	2.1E-07	1.0E-06	3.0E-06	5.3E-06	1.8E-05
Short Cr in warm climate	0	726	1.9E-05	4.2E-05	7.3E-06	0.0E+00	5.1E-07	2.5E-06	1.8E-05	7.4E-05	1.8E-04	5.1E-04
Short Cr in warm climate	1	734	3.5E-05	5.8E-05	1.6E-05	1.1E-07	1.9E-06	6.1E-06	4.0E-05	1.3E-04	3.1E-04	5.7E-04
Intermediate Cr in warm climate	0	727	1.7E-05	3.0E-05	7.1E-06	1.7E-08	4.8E-07	2.5E-06	2.0E-05	6.7E-05	1.5E-04	3.2E-04
Intermediate Cr in warm climate	1	734	3.8E-05	6.2E-05	1.9E-05	3.6E-07	2.5E-06	9.0E-06	4.2E-05	1.4E-04	3.5E-04	5.4E-04
Short Cr in cold climate	0	739	4.5E-06	9.0E-06	1.5E-06	0.0E+00	2.5E-08	4.2E-07	4.6E-06	1.8E-05	4.6E-05	9.7E-05
Short Cr in cold climate	1	728	8.4E-06	1.6E-05	3.7E-06	0.0E+00	2.6E-07	1.4E-06	8.3E-06	3.2E-05	7.3E-05	2.0E-04
Intermediate Cr in cold climate	0	721	4.7E-06	1.1E-05	1.5E-06	0.0E+00	1.2E-07	5.7E-07	4.5E-06	1.9E-05	4.0E-05	2.1E-04
Intermediate Cr in cold climate	1	733	9.2E-06	1.5E-05	4.7E-06	1.0E-07	5.9E-07	1.9E-06	1.1E-05	3.4E-05	6.9E-05	1.8E-04

Table 47. Summary Statistics for Total Dose (GI + Dermal) for As and Cr (separated by children with and without decks)

Category	Deck	n	Mean	Stdev	p50	Min	p05	p25	p75	p95	p99	Max
Short As in warm climate	No	755	8.4E-05	2.2E-04	3.0E-05	0.0E+00	1.9E-06	1.1E-05	8.3E-05	2.9E-04	8.2E-04	4.1E-03
Short As in warm climate	Yes	710	1.3E-04	1.9E-04	6.5E-05	8.2E-07	6.6E-06	2.6E-05	1.5E-04	4.7E-04	9.5E-04	1.5E-03
Intermediate As in warm climate	No	715	5.9E-05	9.4E-05	2.8E-05	4.9E-08	1.7E-06	8.2E-06	6.4E-05	2.3E-04	4.3E-04	8.6E-04
Intermediate As in warm climate	Yes	752	1.3E-04	1.9E-04	6.8E-05	7.0E-07	8.8E-06	2.6E-05	1.4E-04	4.5E-04	9.6E-04	2.0E-03
Lifetime As in warm climate	No	728	6.4E-06	1.2E-05	3.0E-06	2.9E-08	4.6E-07	1.3E-06	6.8E-06	2.3E-05	6.5E-05	1.3E-04
Lifetime As in warm climate	Yes	738	1.1E-05	1.6E-05	6.1E-06	2.5E-07	1.0E-06	3.0E-06	1.3E-05	3.9E-05	8.4E-05	1.7E-04
Short As in cold climate	No	742	4.3E-05	1.0E-04	1.4E-05	0.0E+00	1.0E-07	4.0E-06	4.3E-05	1.6E-04	4.6E-04	1.3E-03
Short As in cold climate	Yes	720	6.7E-05	1.6E-04	2.5E-05	0.0E+00	2.1E-06	1.0E-05	6.8E-05	2.2E-04	7.0E-04	2.3E-03
Intermediate As in cold climate	No	721	3.7E-05	1.4E-04	1.1E-05	0.0E+00	5.7E-07	3.8E-06	3.1E-05	1.2E-04	3.9E-04	3.1E-03
Intermediate As in cold climate	Yes	742	7.0E-05	1.4E-04	3.1E-05	7.2E-07	3.9E-06	1.4E-05	7.4E-05	2.4E-04	5.9E-04	2.4E-03
Lifetime As in cold climate	No	744	3.2E-06	4.9E-06	1.5E-06	5.1E-09	1.7E-07	6.4E-07	3.5E-06	1.2E-05	2.4E-05	5.4E-05
Lifetime As in cold climate	Yes	718	6.0E-06	9.3E-06	2.9E-06	7.5E-08	4.1E-07	1.4E-06	7.0E-06	2.1E-05	4.4E-05	1.0E-04
Short Cr in warm climate	No	726	6.5E-05	1.3E-04	2.6E-05	0.0E+00	2.5E-06	1.0E-05	6.6E-05	2.4E-04	5.9E-04	2.1E-03
Short Cr in warm climate	Yes	734	1.2E-04	2.1E-04	5.6E-05	7.4E-07	7.0E-06	2.3E-05	1.4E-04	4.3E-04	9.4E-04	2.7E-03
Intermediate Cr in warm climate	No	727	5.6E-05	9.1E-05	2.3E-05	2.9E-08	1.5E-06	8.8E-06	6.2E-05	2.2E-04	4.6E-04	8.2E-04
Intermediate Cr in warm climate	Yes	734	1.2E-04	1.9E-04	5.9E-05	2.0E-06	8.4E-06	2.9E-05	1.3E-04	4.4E-04	1.0E-03	1.9E-03
Short Cr in cold climate	No	739	3.9E-05	8.6E-05	1.4E-05	0.0E+00	1.8E-07	4.1E-06	3.8E-05	1.4E-04	4.3E-04	9.5E-04
Short Cr in cold climate	Yes	728	6.9E-05	1.4E-04	3.0E-05	0.0E+00	2.0E-06	1.1E-05	7.0E-05	2.5E-04	6.7E-04	1.9E-03
Intermediate Cr in cold climate	No	721	3.9E-05	9.7E-05	1.2E-05	0.0E+00	9.7E-07	4.6E-06	3.3E-05	1.7E-04	4.1E-04	1.7E-03
Intermediate Cr in cold climate	Yes	733	7.4E-05	1.6E-04	3.4E-05	5.7E-07	4.0E-06	1.4E-05	8.0E-05	2.6E-04	4.8E-04	2.6E-03

Uncertainty Analyses

Uncertainty analyses were conducted using Pearson correlation, Spearman correlation, and stepwise regression methods as described in the Methods section above (with 189 uncertainty runs and 480 simulated individuals per uncertainty run). Tables 48, 49, and 50 present results for arsenic annual ADD. Results among the three statistical methods for the most important contributors to uncertainty in model predicted absorbed doses were similar. The three analysis methods produced the same five most important variables. These are: residue-skin transfer efficiency, wood surface residues on decks, wood surface residues on playsets, fraction of hand contacting mouth, and GI daily absorption fraction for residues.

The graphical analysis of uncertainty takes two forms. One involves displaying three complete variability distributions (CDFs), namely the variability distributions corresponding to the 5th, 50th, and 95th percentile as ranked by their medians (that is, those that have the 9th, 95th, and 180th highest medians, for 189 runs). The horizontal axis represents percentiles of the population variability. The vertical distances between the three curves represent uncertainty in each percentile of the variability distribution.

The other type of graph displays three selected variability percentiles (the 5th, 50th, and 95th) from each of the189 uncertainty runs. Here the horizontal axis represents percentiles of the uncertainty distribution, while the vertical separation between the curves measures variability.

Figure 37 uses the first of the graphical forms. It presents three uncertainty CDFs for a representative low-dose population (5th percentile), a representative medium-dose population (50th percentile), and a representative high-dose population (95th percentile). Uncertainty is read vertically in Figure 37; note that, regardless of the percentile level on the horizontal axis, there is approximately a factor of 4 spread among these three population CDFs. Conversely, the variability (difference between low and high x-axis percentiles on each CDF), approximately 2 orders of magnitude, was higher than the uncertainty.

Figure 38 uses the second graphical approach, in which uncertainty is read horizontally. Focusing on the change in the curves between the 5th and 95th percentiles (to avoid distortion form extreme values), one finds: the p05 curve changes by a factor of approximately 7, the median has an uncertainty of a factor of 3, and the 95th percentile curve changes by a factor of 4.

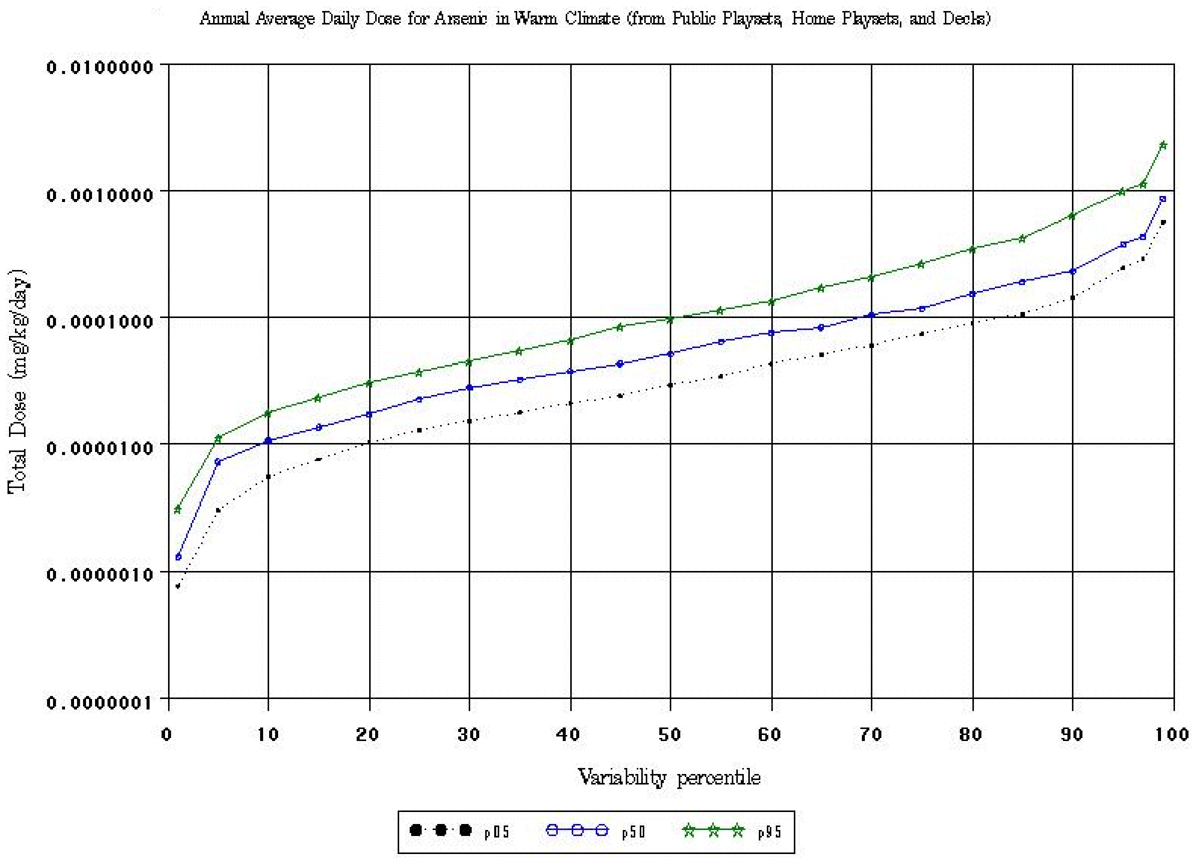


Figure 37. Uncertainty analysis CDFs for 3 selected populations ranked by median.

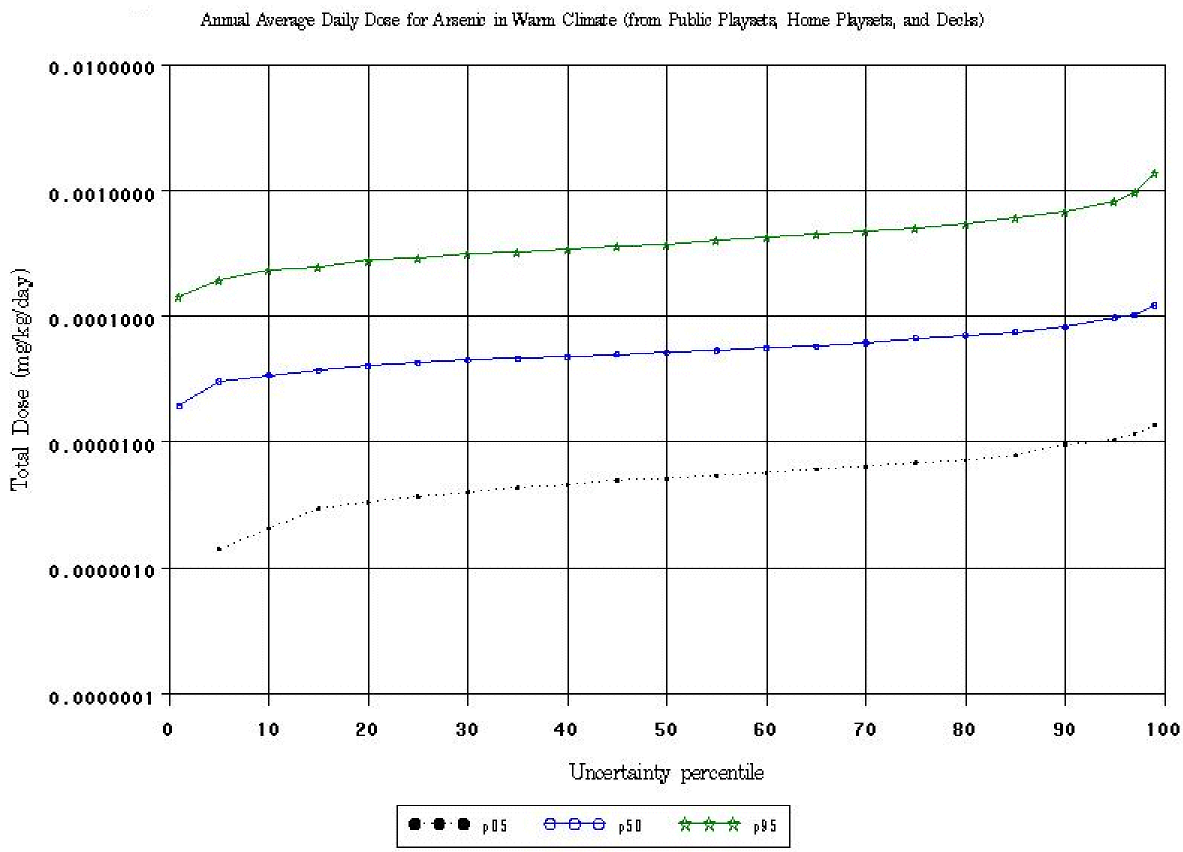


Figure 38. Uncertainty analysis CDFs for 3 percentiles across all simulated populations.

Table 48. Uncertainty Analyses for As Annual ADD (mg/kg/day) Using the Spearman Correlation Method

Variable	Spearman Correlation
Residue-skin transfer efficiency	0.519
Wood surface residues on CCA-treated deck	0.334
Wood surface residues on CCA-treated playset	0.141
GI absorption fraction per day for residues	0.117
Fraction of hand surface area mouthed per mouthing event	0.114
Daily soil ingestion rate	0.111
Avg fraction non-residential outdoor time a child plays on/around CCA-treated public playset	0.103
Soil concentrations near CCA-treated playset	0.091
Typical number of days between baths	0.047
Dermal absorption fraction per day for residues	0.032
Avg fraction residential outdoor time a child plays on/around CCA-treated residential deck	0.032
Frequency of hand-mouth activity per hour	0.027
GI absorption fraction per day for soil	0.012
Maximum dermal loading for hand	0.010
Fraction of bare skin on body (non-hands) contacting residues per time	0.005
Soil concentrations near CCA-treated deck	0.005
Dermal absorption fraction per day for soil	0.004
Avg fraction residential outdoor time a child plays on/around CCA-treated residential playset	0.003
Fraction of total body (non-hand) skin S.A. that is unclothed	0.003
Hand-mouth dermal transfer fraction	0.003
Fraction time a child on/around CCA-treated home deck is on the deck vs on the ground near the deck	0.001
Fraction of bare skin on hands contacting soil per time	0.001
Soil-skin adherence factor	0.001
Fraction time a child on/around treated playset is on ground near playset vs on playset itself	0.000
Maximum dermal loading for body	0.000
Fraction time a child on/around treated playset is on playset itself vs on ground near playset	0.000
Fraction time a child on/around CCA-treated home deck is on the ground near the deck vs on the deck	-0.001
Fraction of bare skin on hands contacting residues per time	-0.001
Fraction of bare skin on body (non-hands) contacting soil per time	-0.003
Hand-washing removal efficiency	-0.009
Bathing removal efficiency	-0.039
Hand-washing events per day	-0.095

Table 49. Uncertainty Analyses for As Annual ADD (mg/kg/day) Using the Pearson Correlation Method

Variable	Pearson Correlation
Residue-skin transfer efficiency	0.527
Wood surface residues on CCA-treated deck	0.312
Fraction of hand surface area mouthed per mouthing event	0.099
GI absorption fraction per day for residues	0.099
Wood surface residues on CCA-treated playset	0.090
Avg fraction non-residential outdoor time a child plays on/around CCA-treated public playset	0.067
Daily soil ingestion rate	0.064
Typical number of days between baths	0.056
Soil concentrations near CCA-treated playset	0.052
Avg fraction residential outdoor time a child plays on/around CCA-treated residential deck	0.031
Dermal absorption fraction per day for residues	0.030
Frequency of hand-mouth activity per hour	0.020
Maximum dermal loading for hand	0.009
GI absorption fraction per day for soil	0.007
Hand-mouth dermal transfer fraction	0.006
Fraction of total body (non-hand) skin S.A. that is unclothed	0.005
Fraction time a child on/around treated playset is on playset itself vs on ground near playset	0.005
Fraction of bare skin on hands contacting soil per time	0.003
Fraction time a child on/around CCA-treated home deck is on the deck vs on the ground near the deck	0.002
Fraction of bare skin on hands contacting residues per time	0.001
Fraction of bare skin on body (non-hands) contacting soil per time	0.001
Fraction of bare skin on body (non-hands) contacting residues per time	0.001
Soil concentrations near CCA-treated deck	0.000
Maximum dermal loading for body	0.000
Avg fraction residential outdoor time a child plays on/around CCA-treated residential playset	-0.002
Dermal absorption fraction per day for soil	-0.002
Soil-skin adherence factor	-0.002
Fraction time a child on/around CCA-treated home deck is on the ground near the deck vs on the deck	-0.002
Hand-washing removal efficiency	-0.004
Fraction time a child on/around treated playset is on ground near playset vs on playset itself	-0.005
Bathing removal efficiency	-0.033
Hand-washing events per day	-0.065

Table 50. Uncertainty Analyses for Arsenic Annual ADD (mg/kg/day) Using the Stepwise Regression Method

Variable	Step	PartialRSquare	ModelRsquare	ProbF
Residue-skin transfer efficiency	1	2.78E-01	0.278	0.000
Wood surface residues on CCA-treated deck	2	9.64E-02	0.374	0.000
GI absorption fraction per day for residues	3	1.07E-02	0.385	0.000
Fraction of hand surface area mouthed per mouthing event	4	1.02E-02	0.395	0.000
Wood surface residues on CCA-treated playset	5	8.21E-03	0.404	0.000
Daily soil ingestion rate	6	4.48E-03	0.408	0.000
Avg fraction non-residential outdoor time a child plays on/around CCA-treated public playset	7	4.37E-03	0.412	0.000
Hand-washing events per day	8	4.07E-03	0.416	0.000
Typical number of days between baths	9	3.08E-03	0.420	0.000
Soil concentrations near CCA-treated playset	10	2.54E-03	0.422	0.000
Bathing removal efficiency	11	1.03E-03	0.423	0.000
Avg fraction residential outdoor time a child plays on/around CCA-treated residential deck	12	9.52E-04	0.424	0.000
Dermal absorption fraction per day for residues	13	8.04E-04	0.425	0.000
Frequency of hand-mouth activity per hour	14	3.57E-04	0.425	0.000
Fraction of total body (non-hand) skin S.A. that is unclothed	15	5.82E-05	0.425	0.003
GI absorption fraction per day for soil	16	5.30E-05	0.425	0.005
Hand-washing removal efficiency	17	4.07E-05	0.425	0.013

Model Evaluation

Ideally, SHEDS-Wood dose estimates could be compared against real-world biomonitoring data for the modeled population of children who contact CCA-treated playsets and decks. Unfortunately, no such data for the target population currently exist. Thus, model evaluation in this section focuses primarily on model-to-model comparison, i.e., comparing SHEDS-Wood equations, inputs, and outputs against other CCA models.

Comparison of SHEDS-Wood Equations against Other CCA Model Equations

Table 51 compares the pathway-specific equations among various models that have been applied to assess CCA ADD and LADD. Because SHEDS-Wood computes exposure as a time series that includes variability within and among days, and maintains dermal exposure until a removal event, SHEDS-Wood equations and algorithms are significantly different from the other models, and are presented in detail in Appendix 2. The methods of calculating hand-to-mouth transfer and absorption are also different among models. CPSC (2003a), Gradient (2001), and Roberts and Ochoa (2001) combine residue concentration and surface area contacted with a “handload transfer” or “handloads ingested per day” term to compute residue ingestion, whereas SHEDS-Wood and Exponent (2001) combine them with a transfer efficiency, hand-to-mouth frequency, and exposure time. While the other models use a relative bioavailability term for soil and residue ingestion dose, SHEDS-Wood uses a daily GI absorption rate based on relative bioavailability.

Comparison of SHEDS-Wood Inputs against Other CCA Model Inputs

Table 52 compares SHEDS-Wood input distributions against point estimate values used in other models (for common input variables) that have been applied to assess arsenic ADD and LADD for public playset exposures. The means of the SHEDS-Wood distributions are very similar to the values used in the other models, and the distributions capture the other values in most cases. SHEDS-Wood uses a number of additional variables, not shown in Table 52 but discussed above, to simulate real-time longitudinal contact patterns with CCA-treated wood using actual time-location-activity diaries.

Table 51. Dose Equations Used in CCA Models

Study	Residue Ingestion	Soil Ingestion	Dermal Residues	Dermal Soil
SHEDS-Wood/CCA	see Appendix 2	see Appendix 2	see Appendix 2	see Appendix 2
CDHS, 1987	$\text{LADD}=\frac{\text{CxRBAxEDxEF}}{\text{BW x LT}}$	NA	NA	NA
CPSC, 2003	$\text{LADD}=\frac{\text{CxSAxHTxRBAxEDxEF}}{\text{BW x LT}}$	NA	NA	NA
Gradient, 2001	$\text{LADD}=\frac{\text{CxSAxHTxRBAxEDxEF}}{\text{BW x LT}}$	$\text{LADD}=\frac{\text{CxRBAxFSxIRxEDxEF}}{\text{BW x LT}}$	$\text{LADD}=\frac{\text{CxABSxSAxEDxEF}}{\text{BW x LT}}$	$\text{LADD}=\frac{\text{CxABSxAFxSAxEDxEFxFS}}{\text{BW x LT}}$
EWG, 2001	$\text{LADD}=\frac{\text{CxCF1xSAxHMxTExHTxETxRBAxED}}{\text{BWxLT}}$	$\text{LADD}=\frac{\text{CxIRxCF2xETxRBA}}{\text{BWxLT}}$	$\text{LADD}=\frac{\text{CxCF1xSAxTExABSxETxRBAxED}}{\text{BWxLT}}$	$\text{LADD}=\frac{\text{CxSAxAFxCF2xABS2xETxRBA}}{\text{BWxLT}}$
Exponent, 2001	$\text{LADD}=\frac{\text{CxSAxTExRBAxEDxEFxHMxET}}{\text{BW x LT}}$	$\text{LADD}=\frac{\text{CxRBAxFSxIRxFSxEDxEF}}{\text{BW x LT}}$	$\text{LADD}=\frac{\text{CxSAxTExRBAxEDxEF}}{\text{BW x LT}}$	$\text{LADD}=\frac{\text{CxABSxAFxSAxEDxEFxFS}}{\text{BW x LT}}$
Roberts and Ochoa, 2001[a]	$\text{ADD}=\frac{\text{HLDxSAxCxCF1}}{\text{BW}}$	NA	$\text{ADD}=\frac{\text{SAxABSxCxCF1}}{\text{BW}}$	NA

Footnotes:

NA= not applicable. NR= not reported. Exposure equations were not identified for EWG's Monte Carlo assessment.
ADD= Average Daily Dose (mg/kg/day)
LADD= Lifetime Average Dose (mg/kg/day).
C=Concentration. Residue concentrations for CPSC and CDHS (µg). Residue concentrations for Gradient, Exponent and Roberts (µg/cm^2). Soil concentrations (mg/kg). Note Residue concentrations are converted to mg using a 0.001 conversion factor (CF1). Soil concentrations are a converted using conversion factor of 1e-6 kg/mg (CF2).
SA=Surface Area (cm^2)
ABS=Dermal Absorption (fraction)
TE=Transfer Efficiency (fraction)
HT= Handload Transfer (fraction)
ET = Exposure Time (hr/day)
HM = frequency of hand-to-mouth contact (#/hr)
AF=Soil-Skin Adherence Factor (mg/cm^2)
EF=Exposure Frequency (days/yr)
ED=Exposure Duration (yr)
IR=Soil Ingestion Rate (mg/day)
RBA=Relative Bioavailability (fraction)
FS= Fraction of Source (fraction)
AT= Averaging Time (days)
LT= Lifetime (days)
BW= Body Weight (kg)
CF1=Conversion Factor (mg/µg).
CF2= Conversion Factor (kg/mg)
HLD=Handloads ingested per day (/day)

[a] Roberts and Ochoa (2001) did not actually calculate ADD; rather, inhalation and dermal exposures were calculated in terms of µg/day. ADD formulas were derived by taking the equations for inhalation and dermal exposure and dividing by the body weight. (Roberts assumed that the exposure frequency would be 365 days per year.)

Table 52. Values of Variables Used in SHEDS-Wood and Other CCA Models for Estimating Arsenic Absorbed Doses from Public Playsets

Exposure Factors	**SHEDS-Wood/CCA**		**CPSC, 2003**	**Gradient, 2001**	**CDHS, 1987**	**EWG, 2001**	**Exponent, 2001**	**Roberts, 2001**
Soil Concentration (C)	warm (mg/kg) mean: 33.9 stdev: 17.9 p25: 21.5 median: 30.0 p75: 41.8 p90: 56.4 p95: 67.5	cold (mg/kg) mean: 3.75 stdev: 9.04 p25: 0.66 median: 1.60 p75: 3.86 p90: 8.46 p95: 13.6	NA	4.1 mg/kg UCL (1)	NA	25.7 mg/kg CTE (1)	NA (1)	NA
Residue Concentrations (C)	warm (μg/cm^2) mean: 0.315 stdev: 0.301 p25: 0.132 median: 0.228 p75: 0.393 p90: 0.640 p95: 0.857	cold (μg/cm^2) mean: 0.326 stdev: 0.250 p25: 0.164 median: 0.258 p75: 0.409 p90: 0.620 p95: 0.791	7.6 μg [hand] (CTE) (1)	0.13 μg/cm^2 UCL (2)	1,260μg [hand] (RME) 236 μg [hand] (CTE) (1)	0.485 μg/cm^2 CTE (2)	0.21 μg/cm^2 UCL (2)	0.01 to 6.32 μg/cm^2 (1)
Surface Area (SA) Skin Mouthed	(cm^2) (1) mean: 54.4 stdev: 26.2 p25: 35.7 median: 50.6 p75: 69.9 p90: 89.3 p95: 105.9		NA (2)	132 cm^2	NA	(3)	33 cm^2	228 cm^2 (2)

Exposure Factors	SHEDS-Wood/CCA		CPSC, 2003	Gradient, 2001	CDHS, 1987	EWG, 2001	Exponent, 2001	Roberts, 2001
Surface Area (SA) Skin Exposed Dermally (hand)	(cm^2/hr) (1) mean: 939 stdev: 192 p25: 807 median: 939 p75: 1071 p90: 1187 p95: 1255		NA (2)	300 cm^2 [palms&soles] (residue dermal)	NA	(3)	286 cm^2 [palm&soles] (residue dermal)	228 cm^2 (2)
Surface Area (SA) Skin Exposed Dermally (non-hand)	(cm^2/hr) (2) warm mean: 1049 stdev: 800 p25: 478 median: 846 p75: 1398 p90: 2087 p95: 2615	(cm^2/hr) (2) cold mean: 170 stdev: 94 p25: 100 median: 153 p75: 221 p90: 297 p95: 349	NA	3317 cm^2 (soil dermal) CTE (3)	NA	(4)	3,008 cm^2 (soil dermal) CTE (3)	300 cm^2 (2)
Dermal Absorption (ABS)	% per day (3) mean: 3.01 stdev: 0.40 p25: 2.72 median: 2.99 p75: 3.28 p90: 3.60 p95: 3.70		NA	1.4% (residue) 0.5% (soil) (4)	NA	6.4% (residue) 6.4% (residue) (5)	1%(residue) 0.5% (soil) (4)	1.0% (3)

Exposure Factors	SHEDS-Wood/CCA		CPSC, 2003	Gradient, 2001	CDHS, 1987	EWG, 2001	Exponent, 2001	Roberts, 2001
Transfer Efficiency (TE)	warm (4) mean: 0.205 stdev: 0.208 p25: 0.081 median: 0.143 p75: 0.254 p90: 0.423 p95: 0.577	cold (4) mean: 0.305 stdev: 0.371 p25: 0.105 median: 0.196 p75: 0.371 p90: 0.651 p95: 0.912	NA	NA	NA (2)	<0.50 (6)	0.38 (5)	NA
Hand-to-Mouth Contact Frequency (HM)	#/hr mean: 8.58 stdev: 11.3 p25:1.23 median 4.23 p75: 11.9 P90: 21.7 P95: 31.3		NA	NA	NA	NA	6.7 per hr	NA
Handloads ingested per day (HL)	NA		NA	NA	NA	NA	NA	0.31/day (4)
Soil-Skin Adherence Factor (AF)	mg / cm^2) mean: 0.140 stdev: 0.110 p25: 0.069 median: 0.110 p75: 0.176 p90: 0.269 p95: 0.345		NA	0.34 mg/cm^2 RME	NA	(7)	0.2 mg/cm^2 CTE	NA

Exposure Factors	SHEDS-Wood/CCA		CPSC, 2003	Gradient, 2001	CDHS, 1987	EWG, 2001	Exponent, 2001	Roberts, 2001
Exposure Frequency (EF)	warm (days/yr) mean: 127.8 stdev: 49.3 p25: 94.0 median: 127.0 p75: 164.0 p90: 194.0 p95: 214.0	cold (days/yr) mean: 55.3 stdev: 21.9 p25: 40.0 median: 55.0 p75: 71.0 p90: 84.0 p95: 92.0	156 days/yr (4)	88 days/yr RME (5)	130 days/yr RME (3) 78 days/yr CTE	52 wks/yr	1 day/yr(6)	365 days/yr (5)
Exposure Time (ET) on contact days	mean: 2 hr/day (total) 1 hr/day on wood 1 hr/day on soil		NA	NA	NA	3 hrs/wk	1 hr	NA
Exposure Duration (ED)	6 yr		5 yr	5 yr	8 yr	6 yr	6 yr	5 yr
Soil Ingestion Rate (IR)	non-pica (mg/day) (5) mean: 61 stdev: 80 p25: 11.9 median: 29.8 p75: 73.4 p90: 157.8 p95: 235.7	pica (mg/day) (5) mean: 963.2 stdev: 721.2 p25: 588.5 median: 737.0 p75: 1043.3 p90: 1594.4 p95: 2170.4	NA	100 mg/day RME	NA	116.7 mg/day CTE (8)	100 mg/day RME	NA

Exposure Factors	SHEDS-Wood/CCA	CPSC, 2003	Gradient, 2001	CDHS, 1987	EWG, 2001	Exponent, 2001	Roberts, 2001
Relative Bioavailability (RBA) soil	1.0 % absorbed per day mean: 46.7 stdev: 9.9 p25: 39.8 median: 46.7 p75: 53.6 p90: 59.6 p95: 63.1	NA	0.163	0.5	0.25	0.163	NA (6)
Relative Bioavailability (RBA) wood residue	1.0 % absorbed per day mean: 27.3 stdev: 10.5 p25: 19.6 median: 26.4 p75: 34.0 p90: 41.4 p95: 45.9	1.0	0.47	NA	1.0	0.5	1.0
Lifetime (LT)	75 yr	75 yr	70 yr	70 yr	70 yr	75 yr	NA
Averaging Time (AT)	6 yr	5yr	5 yr	8 yr	6 yr	6 yr	5 yr

Exposure Factors	SHEDS-Wood/CCA	CPSC, 2003	Gradient, 2001	CDHS, 1987	EWG, 2001	Exponent, 2001	Roberts, 2001
Body Weight (BW)	mean: 17.5 kg stdev: 5.5 kg p25: 13.2 kg median: 16.7 kg p75: 21.2 kg p90: 25.2 kg p95: 27.5 kg	17.7 kg CTE(5)	17.8 kg CTE (6)	25 kg CTE(4)	(9)	16.6 kg CTE(7)	18 kg

Footnotes

NA- Not applicable. AT and LT are presented in yrs but presented in days to calculate ADD/LADD.

CTE-central tendency estimate

UCL-95% upper confidence limit of the mean.

RME Reasonable Maximum Exposure based on UCL.

SHEDS-Woo d/CCA.

For all input data sampled from distributions, p25 = 25th percentile, p75 = 75th percentile, p90 = 90th percentile, p95 = 95th percentile.

(1) Skin surface area of hands mouthed was computed by combining total hand skin surface area with fraction of hand mouthed per mouthing event

(2) Skin surface area of body exposed dermally was computed by multiplying total body surface area by fraction unclothed skin and average bare skin contact rate

(3) Dermal absorption rate in the absence of other removal processes. In practice, the net absorption rate is substantially smaller, as much of the chemical is removed by washing, bathing, or hand-to-mouth transfer before being absorbed.

(4) The transfer efficiency is dimensionless. It represents the fraction of the wood surface residue contacted that is transferred to the skin.

(5) This represents the total daily soil ingestion rate. The fraction of this amount that contains the target chemical depends on the amount of time spent on/around decks or playsets.

U.S. Consumer Product Safety Commission (CPSC), 2003. "Cancer risk assessment for arsenic exposure from CCA-treated playground structures."

(1) CPSC, 2003 detected arsenic based on a surrogate cloth wiping methodology developed in deck studies with a mean of 7.7µg and median of 3.5 µg.

(2) Palmar surface area was used to estimate area of soil contact.

(3) Assumed that 36 mg of soil in the hand would be ingested per 140 mg of soil adhered on the hand. The handload transfer is 0.26 ratio.

(4) Children play on playground equipment 156 days/yr.

(5) Body weights for children age 2-6 yr from EPA, 1997.

Gradient Corporation, 2001. "Evaluation of Human Health Risks From Exposure to Arsenic Associated With CCA-Treated Wood". Prepared for Arch Chemicals, Inc. and Osmose, Inc. October 5, 2001.

(1) Gradient 2001 used 10 decks from SCS, 2000 to predict soil concentration. The data were lognormally distributed with a mean of 23.2 mg/kg, a median of 18.3 mg/kg, and UCL of 28.7 mg/kg. Gradient used soil data from a study of arsenic in public playgrounds.
The range was 0.2 to 64 mg/kg with a mean value of 3.7 mg/kg and UCL of 4.1 mg/kg.

(2) Gradient 2001 used different hand loading concentrations depending on SCS data for the wood (SCS, 1998). The most conservative of which is treated Southern Pine with water repellant. Range of 0.0545-0.1737 µg/cm^2 mean of 0.1 µg/cm^2 and UCL of 0.13 µg/cm^2.

(3) CTE (residue) assumes 1/3 total surface of hand using Exposure Factors Handbook. CTE (soil) represents median surface area of a child assuming exposure to soil to the forearm, hands, and lower leg.

(4)Gradient used Risk Assessment Guidance Document, Vol I, (EPA, 1989) assumption of 3% dermal absorption fraction for soil. However for dermal dislodgeable residue exposures, the absorption fraction in soil was adjusted to residue by multiplying by the bioavailability of dislodgeable arsenic (47%) to obtain 1.6%. Gradient adjusted the dermal soil exposures by multiplying the dermal absorption (3%) times the bioavailability of soil (16.3%) to obtain 0.5%. The reason this adjustment was done was that the toxicity values used for the risk assessment were based oral studies. Therefore, dermal doses were actually adjusted to oral dose equivalents.

(5) For residential exposure the 90th percentile estimate that a child spends in the yard is 5.1 hours/day and the 50th percentile estimate is 1.8 hours/day (EPA, 1997). The EF is calculated by 5.1 hours/day x 7 days/wk or 35.7 hours/wk. Assuming 12 hours daylight per day gives 35.7 hours/wk x 1/12 hours/day is 3 day-equivalents/wk. Using 350 days/yr (50 weeks/yr) the EF is 150 days residential. For playground the 90th percentile is 2.9 hours/day and the 50th percentile is 1 hours/day.

(6) Based on mean body weight of boys and girls aged 2-6 from Exposure Factors Handbook (EPA, 1997).

California Department of Health Services (CDHS), 1987. Kizer, K.W. "Report to the Legislature: Evaluation of Hazards Posed by the Use of Wood Preservatives on Playground Equipment." State of California. Office of Environmental Health Hazard Assessment, Department of Health Services and Welfare Agency.

(1) The arsenic residue value represents a direct hand wipe on a newly manufactured CCA-treated playground pole. RME data is based on one adult volunteer collecting 1,260 µg of arsenic by rubbing hands over treated playground wood for 5-minutes. CTE is based on 5 volunteers rubbing CCA treated wood for three minutes and then rinsing surface residue. Average amount collected from the five volunteers was 236 µg.

(2) Assumed that entire handload was transferred. Handload transfer fraction would be 1.

(3)RME- Child visits park 5 days/week for 26 weeks/yr. CTE- Child visits park 3 days/week for 2 weeks/yr.

(4) body weight for child 1-8 yr.

Environmental Working Group (EWG), 2003. "Children's Exposure to Arsenic-treated Wood. A preliminary Monte Carlo risk assessment." Presentation to EPA's Science Advisory Panel made by Jane Houlihan, Sean Grey and Richard Wiles. October 23, 2001. Model developed in 2001. Parameters shown here are not updated since 2001, with exception of arsenic and soil contamination levels (current through June 2003), and hand-to-mouth activity (2003 update). Following a Monte Carlo modelling approach, EWG modeled children from the age of 6 months until their 7th birthday.

Each modeled child is randomly assigned a surface residue concentration, a soil concentration, a body weight percentile group, and a soil ingestion group (low, medium, high).

(1) In 2003,EWG updated their soil dataset to include 483 samples. Mean 25.7 mg/kg, median 13.2 mg/kg and range 0-350.5 mg/kg.

(2) In 2003, EWG updated their dislodgeable dataset to include 598 structures. This was based on arsenic home testing. Mean 0.485 $\mu g/cm^2$, median 0.09 $\mu g/cm^2$, and range of 0-2,813 $\mu g/cm^2$.

(3) Surface area of the hands was a CTE calculated from the child's age and total body surface area based on data presented in EPA, 1985 "Development of Standard Factor Used in Exposure Assessments". Number vary as function of total body surface area. For residue ingestion, EWG assumed that 33% of hand was exposed (based on EPA, 2001). Assumes 3 fingers in mouth for every mouthing event.

(4) Surface area of total body surface area calculated from Gehan and George, 1970 "Estimation of Human Body Surface Area from Height and Weight." Arms and legs based on EPA, 1985.

(5) Based on EPA, 2001.

(6) TE based on hand-to-wood and mouth-hand. Two scenarios examined. EPA, 2001 made an assumption that one-to-one relationship of of dislodgeable transfer from the surface of wood to skin and the removal efficiency of residues from hands by human saliva is 50% for inorganic metals such as arsenic. However, SCS, 1998 did a study in which a ratio of 4.6:1 for wood to hand. Combined with the 50% removal from hand-to-mouth from EPA, 2001 and the TE would be considerably less (0.1).

(7) EWG assumed value consistent with EPA's Child Specific Exposure Factors Handbook (EPA, 2002).

(8) EWG based soil ingestion rate on a 116.7 mg/day mean, 50.6 median and range of 0.006-6736 mg/day.

(9) Body weight distributions representing 1^{st} through 99^{th} percentiles were calculated from CDC data for 6,374 children ages 12 yr through 83 months. Body weight through times curves were calculated to represent growth of children from 1 through 6 years of age.

Exponent, 2001. "Technical Issues Associated with the Risk Assessment of Children's Exposure to Arsenic at Playground with Structures Constructed from CCA-Treated Wood." Prepared for American Chemistry Council. July 31, 2001.

(1) Exponent did not provide soil concentrations because they claimed that there was to much variability and data would be site specific.

(2) The UCL is based on Riedel et al. 1990.

(3) Residue ingestion based on the plamar surface area. Dermal contact to palms and soles of feet. Soil contact surface area to lower leg, forearms, feet, hands, and face.

(4) Dermal absorption of residue based on Wester et al, 1993. Range of 2-6.4 percent. Exponent observed that in the Wester study the absorption varied inversely with increasing dose. In other words at the highest arsenic concentrations the absorption was the lowest 2%). In addition, like Gradient, Exposent adjusted the dose to oral equivalents using RBA of 50%. For soil, Exponent used Wester et. al 1993 and adjusted based on 3.2 to 4.5% for soil and EPA, 1989 3% estimate. Gradient adjusted the dermal soil exposures by multiplying the dermal absorption (3%) times the bioavailability of soil (16.3%) to obtain 0.5%. The reason this adjustment was done was that the toxicity values used for the risk assessment were based oral studies. Therefore, dermals doses were actually adjusted to to oral dose equivalents.

(5) Based on SCS hand transfer (SCS, 1998).

(6) Highly site specific. Exponent based exposure on 1 day/yr and then indicated risk would then be multiplied by the number of days per year the child visited a playground. Comment generally indicated that the variability was too uncertain to predict. In addition, for residue ingestion it is assumed 6.7 contacts/hr and 1 hr/day contact. Therefore, for residue ingestion 6.7 contacts/year were assumed.
(7) Body weights are for young children age 1-6.

Roberts M and H Ochoa. 2001. Letter to Mr. John Ruddell, Florida Department of Environmental Protection, RE: Concentrations of Dislodgeable Arsenic on CCA-Treated Wood. April 10, 2001.
(1) Eight sets of hazard ratios and cancer risks were calculated, corresponding to eight concentration levels of dislodgeable arsenic from 1 to 632 µg/100 cm^2. The values are from three studies reviewed by Roberts and Ocha (HSWMR, 2000; CDHS, 1987; CPSC 1990).
(2) To calculate ingestion exposure, only the hand surface area (228 cm^2) was considered. To calculate dermal absorption, both hand and feet surface area together (528 cm^2) were considered.
(3) Dermal absorption of residue based on Wester et al, 1993. See note #4 under *Exponent, 2001.*
(4) Based on methodology of CPSC (1990). Taking dermal loading rates for 11-year old boys and girls, and assuming that soil dermal loading rates observed for boys and girls in Roels et al. (1980) for 11-year olds was also applicable for younger children. Hand-to mouth activity was estimated by time-averaging values for 2- and 6-year old boys and girls.
(5) The study notes that although there are circumstances where exposure frequencies may be limited, "a comprehensive risk assessment should include the full range of possibilities."
(6) Roberts conducted a study (Roberts et al, 2001) using monkeys to determine relative bioavailability in soil. Based on this study, the relative bioavailability ranges from 10.7±14.9% (mean±SD) to 24.7±3.2%, based on four soil samples.

References

CPSC (Consumer Product Safety Commission). 1990. Project on Playground Equipment - Transmittal of Estimate of Risk on Skin Cancer from Dislodgeable Arsenic on Pressure Treated Wood Playground Equipment. Washington, DC, 1990.

EPA, 1989. Risk assessment guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part A). U.S. Environmental Protection Agency, Washington, DC PB-90155581.

EPA, 1997. Exposure Factors Handbook. Volumes I-III. Office of Research and Development. Washington, D.C. EPA/600/P-05/002Fa.

EPA, 2001 Children Exposure to CCA-Treated Wood Playground Equipment and CCA Contaminated Soil. http:/www.epa.gov/scipoly/sap for meetings of Oct 23-25 2001.

EPA, 2002. Child-Specific Exposure Factors Handbook. EPA-600-P-00-002B.National Center for Environmental Assessment. Office of Research and Development. Washington DC.

Gehen E and GL George. 1970. Estimation of human body surface area from height and weight. Cancer Chemoth. Rep. 54 (4):225-235.

HSWMR (Hazardous Substance and Waste Management Research, Inc.). 2000. Development of Wood Surface Target Quantity for Arsenic Based o Exposure to Decks of Playground Equipment Constructed of CCA-Treated Wood. December, 2000.

Riedel, D.J., J. Harrison, D. Galarneau, D.C. Gregaoire, and N. Bertrand 1990. Residues of arsenic and chromium and copper on and near outdoor structures built of wood treated with 'CCA' type preservatives. Bureau of Chemical Hazards, Health and Welfare, Canada, and Mineral Resources Division, Geological Survey of Canada, Ottawa.

Roberts, S.M.; Welmar, W.R.; Venson, J.R.; Munson, J.W.; and Bergeron 2001. Measurement of Arsenic Bioavailability from Soils Using a Primate Model.

Roels HA, Buchett JP, Lauwerys RR, Bruax P, Claeys-Thoreau R, LaFontaine A, and Verduyn G. 1980. Exposure to lead by the oral and the pulmonary routes of children living in the vicinity of a primary load smelter. Environmental Res. 22:81-94.

SCS, 1998. Metal removal from CCA-treated lumber under simulated normal use conditions. Report to Osmose, Inc. Scientific Certification Systems.

Wester, R.C., H.I. Maibach, L. Sedik, J. Melendres, and M. Wade. 1993. In vivo and in vitro percutaneous absorption and skin decontamination of arsenic from water and soil. Fundam. Appl. Toxicol. 20:336-340.

Dermal Transfer Coefficient

At the August 2002 SAP meeting, the dermal transfer coefficient (TC) was discussed as a critical model input with respect to both variability and uncertainty. This variable can be thought of as skin surface area (SA) contacted per time, multiplied by a unitless residue-to-skin transfer efficiency (TE). The basic dermal residue exposure equation used by version 1 of SHEDS-Wood was: Dermal Exposure [ug] = residue concentration [ug/cm2] * dermal transfer coefficient [cm2/hr] * exposure duration [hr]. For last year's SAP the user-specified TC was estimated as SA*TE/hr, where we assumed that the fraction of skin surface area (SA) contacting residue per time was 100%/60 min and used a point estimate of 90% for TE. The SAP recommended refining this input to use distributions for both surface area contacted per time and transfer efficiency.

Thus, the new dermal residue exposure equation used in version 2 of SHEDS-Wood now is: Dermal Exposure [ug] = residue concentration [ug/cm2] * total skin SA [cm2] * fraction skin SA that is unclothed [-] * fraction unclothed skin SA contacting residue per time [1/min] * TE [-] * exposure event duration [min]. Terms 2, 3, 4, and 5 comprise the TC [cm2/min]. The total surface area for each child is derived from body weight and height, which are updated monthly. The other variables in the equation are user-specified inputs. We derived a distribution from Kissel et al. (1998) for fraction skin contacting residue per time, and used CPSC (2003b,c) and new industry data (ACC 2003b) to derive a transfer efficiency distribution. Thus, three new variables in version 2 are: fraction of hand skin surface area contacting residue per time [1/min], fraction of unclothed body (non-hand) skin surface area contacting residue per time [1/min], and residue-skin transfer efficiency [-]. The maximum dermal loading applies as previously.

Because version 2 of the code uses child-specific surface area rather than a user-specified input, the dermal transfer coefficient is no longer an explicit input to SHEDS-Wood. We did, however, conduct a simulation for 1000 children to determine the implicit distribution of annual average dermal transfer coefficient being used by the model with the new inputs shown in Table 12. For the hand dermal transfer coefficient [cm2/hr], the summary statistics were: mean 186, standard deviation 180, median 134, 5^{th} percentile 33, 95^{th} percentile 531. For the body dermal transfer coefficient [cm2/hr], the summary statistics were: mean 207, standard deviation 204, median 147, 5^{th} percentile 36, and 95^{th} percentile 575.

It was of interest to compare the SHEDS-Wood dermal transfer coefficient to other studies. Industry data (mass on one hand load per event divided by wood residue) yielded ~30 cm^2/event (ACC, 2003b), where an event is 20 adult hand passes over wood. It is not clear how to relate an adult experimental event to a child's hourly real-world exposure event. Videography data from 4 Minnesota children ages 5-7 (Freeman, pers. comm.) who contacted playsets indicate 20 contacts per 13 minutes for 1 hand in a 15-47 minute time period. If we assume that is equal to 20 adult contacts/experiment event, the dermal transfer coefficient for 2 hands would be ~60cm^2/30 min = 120 cm^2/hr, which is close to the SHEDS-Wood mean dermal hand transfer coefficient.

These values are much lower than transfer coefficients used for organophosphate pesticides: 2,600 to 5,200 cm^2/hr (short- to intermediate- term for ages 1-6 yrs) derived from adults performing 20 minutes of Jazzercise indoors on nylon carpet (US EPA, 2001b). Based on watching videotapes of children playing on playsets, CPSC (2003a) estimated a contact rate of about 15-30 contacts a minute, and about 900-1800 times an hour. They assumed a surface area contact rate of 12,900 cm2/hr (this did not include transfer efficiency).

Comparison of SHEDS-Wood Arsenic Results Against Other CCA Model Results

Table 53 shows the arsenic ADD and LADD from public playsets, by pathway and aggregate, for the same set of models examined in Tables 51 and 52. The SHEDS-Wood variability results (bounding estimates for warm and cold climates), based on inputs and algorithms developed independently of the other models, are within a factor of 2 of the Gradient (2001) results for all pathways and aggregate dose. The upper percentiles for the SHEDS-Wood warm climate scenario are close to the CPSC results for the dominant pathway (residue ingestion). The CDHS (1987) results appear to be higher than the other model results because the single term combining surface concentrations, hand area, and transfer efficiency is higher than the comparable product in the other models. Roberts and Ochoa (2001) results appear to be higher in part because they assumed 365 exposure days per year. EWG (2001) results appear to be higher than SHEDS-Wood results because of assumed replenishment of residues on hands after dermal contact, higher assumed relative bioavailability of residues, and higher assumed soil ingestion rates. The Exponent (2001) results appear to be lower than the other model results because they only allow one contact day per year, whereas the other models have a typical range of 50-150 contact days. Multiplying the Exponent residue ingestion result by 100 gives results that are close to the other model results.

SHEDS-Wood and Gradient (2001) also computed arsenic ADD and LADD from residential decks. The Gradient (2001) point estimate ADD values (mg/kg/day) for residue ingestion, soil ingestion, dermal residue contact, dermal soil contact, and aggregate absorbed dose, respectively, are: 4.66e-05, 5.30e-06, 1.26e-05, 1.87e-06, and 6.64e-05. The corresponding values for LADD (mg/kg/day) are: 3.33e-06, 3.79e-07, 9.00e-07, 1.33e-07, 4.74e-06. The deck results are also very close between the two models, as seen by comparing these numbers to Tables 16 and 17 for ADD and to Tables 14 and 15 for LADD.

Table 53. ADD/LADD Model Estimates Obtained with SHEDS-Wood and Other CCA Models[a]

Exposure Routes	SHEDS-Wood/CCA[b] (mg/kg/day) warm	cold	CDHS,1987 (mg/kg/ day)	CPSC, 2003 (mg/kg/ day)	Gradient, 2001[c] (mg/kg/day)		EWG, 2001 (mg/kg/ day)	Exponent, 2001 (mg/kg/day)	Roberts and Ochoa, 2001[e] (mg/kg/day)
Average Daily Doses (ADDs)									
Residue Ingestion	mean: 3.83e-5 stdev: 7.94e-5 p25: 4.92e-6 median: 1.35e-5 p75: 3.87e-5 p90: 9.27e-5 p95: 1.45e-4	mean:3.06e-5 std: 6.69e-5 p25: 4.23e-6 median: 1.18e-5 p75: 3.01e-5 p90: 6.90e-5 p95: 1.17e-4	8.98e-3	1.59e-4	4.66e-05	2.73e-05	NE	2.91e-6	NE2
Soil Ingestion	mean: 1.05e-5 stdev: 3.48e-5 p25: 5.79e-7 median: 2.12e-6 p75: 7.70e-6 p90: 2.20e-5 p95: 4.21e-5	mean: 3.91e-7 stdev: 1.24e-6 p25: 1.2e-8 median: 4.8e-8 p75: 2.16e-7 p90: 8.27e-7 p95: 1.69e-6	NA	NA	5.30e-06	8.89e-07	NE	NA	NA
Dermal Residues	mean: 1.94e-5 stdev: 4.31e-5 p25: 2.86e-6 median: 7.71e-6 p75: 1.99e-5 p90: 4.58e-5 p95: 7.21e-5	mean: 4.59e-6 stdev: 8.24e-6 p25: 7.31e-7 median: 2.00e-6 p75: 4.94e-6 p90: 1.13e-5 p95: 1.65e-5	NA	NA	1.26e-05	3.25e-06	NE	3.8E-8	NE2
Dermal Soil	mean: 1.61e-6 stdev: 2.51e-6 p25: 3.28e-7 median: 8.15e-7 p75: 1.93e-6 p90: 3.95e-6 p95: 5.64e-5	mean: 3.0e-8 stdev: 9.8e-8 p25: 2.0e-9 median: 7.0e-9 p75: 2.2e-8 p90: 6.3e-8 p95: 1.29e-7	NA	NA	1.87e-06	3.13e-07	NE	NA	NA

Exposure Routes	SHEDS-Wood/CCA[b] (mg/kg/day) warm	cold	CDHS,1987 (mg/kg/ day)	CPSC, 2003 (mg/kg/ day)	Gradient, 2001[c] (mg/kg/day)		EWG, 2001 (mg/kg/ day)	Exponent, 2001 (mg/kg/day)	Roberts and Ochoa, 2001[e] (mg/kg/day)	
Aggregate[c]	mean: 6.98e-5 stdev: 1.22e-4 p25: 1.30e-5 median: 3.23e-5 p75: 7.46e-5 p90: 1.64e-4 p95: 2.55e-4	mean: 3.56e-5 stdev: 7.34e-5 p25: 5.48e-6 median: 1.45e-5 p75: 3.64e-5 p90: 7.88e-5 p95: 1.36e-4	NA	NA	6.64e-05	3.18e-05	NE	NA	*Conc. (µg/cm²)* .010 .100 .250 .350 .500 1.00 2.50 6.32	*ADD* 4.22e-05 4.22e-04 1.05e-03 1.48e-03 2.12e-03 4.22e-03 1.06e-02 2.68e-02
Lifetime Average Daily Doses (LADDs)										
Residue Ingestion	mean: 3.09e-6 stdev 5.90e-6 p25: 4.87e-7 median: 1.23e-6 p75: 3.26e-6 p95: 1.22e-5	mean: 2.40e-6 stdev 3.95e-6 p25:4.26e-7 median:1.03e-6 p75: 2.70e-6 p95: 9.39e-6	1.03e-3	1.06e-5	3.33e-06	1.95e-06	mean: 4.2e-5 stdv: NE p25 : 2.0e-6 p50 : 1.1e-5 p75 : 4.4e-5 p90 : 1.1e-4 p95 : 2.2e-4	2.33e-07	NA	
Soil Ingestion	mean: 6.51e-7 stdev 1.21e-6 p25: 7.77e-8 median: 2.07e-8 p75: 6.78e-7 p95: 2.82e-6	mean: 3.29e-8 stdev 1.69e-7 p25:1.63e-9 median:6.11e-9 p75: 2.14e-8 p95: 1.09e-7	NA	NA	3.79e-07	6.35e-08	mean: 4.2e-6 stdv: NE p25 : 4.3e-7 p50 : 1.5e-6 p75 : 4.2e-6 p90 : 1.0e-5 p95 : 1.7e-5	NA	NA	

Exposure Routes	SHEDS-Wood/CCA[b] (mg/kg/day) warm	cold	CDHS,1987 (mg/kg/ day)	CPSC, 2003 (mg/kg/ day)	Gradient, 2001[c] (mg/kg/day)		EWG, 2001 (mg/kg/ day)	Exponent, 2001 (mg/kg/day)	Roberts and Ochoa, 2001[e] (mg/kg/day)
Dermal Residues	mean: 1.54e-6 stdev 2.42e-6 p25: 2.85e-7 median: 7.06e-7 p75: 1.77e-6 p95: 6.04e-6	mean: 3.78e-7 stdev 5.03e-7 p25:8.28e-8 median:1.96e-7 p75: 4.61e-7 p95: 1.40e-6	NA	NA	9.00e-07	2.32e-07	mean: 3.4e-6 stdv: NE p25 : 1.7e-7 p50 : 8.7e-7 p75 : 3.5e-6 p90 : 8.6e-6 p95 : 1.8e-5	3.01e-9	NA
Dermal Soil	mean: 1.31e-7 stdev 2.10e-7 p25: 3.84e-8 median: 8.10e-8 p75: 1.56e-7 p95: 3.92e-7	mean: 2.75e-9 stdev 8.46e-9 p25:2.72e-10 median:8.35e-10 p75: 2.09e-9 p95: 1.16e-8	NA	NA	1.33e-07	2.24e-08	mean: 4.2e-7 stdv: NE p25 : 1.2e-7 p50 : 2.4e-7 p75 : 4.7e-7 p90 : 8.9e-7 p95 : 1.3e-6	NA	NA
Aggregate[d]	mean: 5.42e-6 stdev 8.24e-6 p25:1.28e-6 median:2.97e-6 p75: 5.87e-6 p95: 1.81e-5	mean: 2.81e-6 stdev 4.38e-6 p25:5.47e-7 median:1.29e-6 p75: 3.35e-6 p95: 1.05e-5	NA	NA	4.74e-06	2.27e-06	mean: 5.0e-5 stdv: NE p25 : 5.6e-6 p50 : 1.7e-5 p75 : 5.3e-5 p90 : 1.2e-4 p95 : 2.5e-4	NA	NA

Footnotes

NA- Not available. Route of exposure has not been presented in this study.
NE- Not evaluated. Data was presented and there was not enough information to calculate the exposure doses.
NE2 - Not evaluated. Although it appears that the values were calculated for this study, the results were not presented for this parameter.

[a]Table 53 presents the ADD/LADD exposure doses for selected CCA exposure references. Refer to tables 51 for exposure algorithms and 52 for exposure factors and full annotated references to the selected studies.
[b]EPA results are for public playsets only, left column for warm climate scenario and right column for cold climate scenario. Percentiles are across children in modeled population; p25 = 25th percentile, p75 = 75th percentile, p90 = 90th percentile, p95 = 95th percentile.

[c]Gradient includes calculations for residential deck exposure on the left column and playground exposure on the right column.

[d]Aggregate present the sum of the risks from all exposure routes. If some routes of exposure were not available then Aggregate was assigned an NA.

[e]Roberts, 2001 only presents doses in terms of µg/day. However, using the reported body weight of 18 kg and the reported exposure frequency of 365 days/year, average daily doses have been calculated for this table. Average daily doses were calculated for a range of concentrations of dislodgeable arsenic.

DISCUSSION

In response to the October 2001 SAP recommendation to use probabilistic modeling to estimate children's exposure to wood preservatives from playsets and home decks (US EPA, 2001b), the SHEDS-Wood model was developed. The methodology of SHEDS-Wood was presented to the August 30 2002 SAP, and comments from both the Panel and public were incorporated into a refined model and analyses to conduct an assessment for children's exposures and absorbed doses to Chromated Copper Arsenate (CCA) on and around playsets and decks. This report has presented the exposure and absorbed dose estimates that will be used as part of OPP's risk assessment for CCA.

The most critical exposure pathways to arsenic (As) and chromium (Cr) residues from CCA treated decks and playsets were consistently residue ingestion and residue contact, and variables associated with these were important in sensitivity and uncertainty analyses, which can be used to guide future data collection efforts towards wood preservative exposure assessments. Sensitivity analyses conducted for As annual average absorbed doses in this assessment revealed that the four most critical input variables with respect to model variability were: wood surface residue-to-skin transfer efficiency; wood surface residues on CCA-treated decks; fraction of hand surface area mouthed per mouthing event; and hand washing events per day. Uncertainty analyses revealed that the most important variables with respect to uncertainty in As and Cr model estimates were: wood surface residue-skin transfer efficiency; soil concentrations near CCA-treated playsets; daily soil ingestion rate; wood surface residues on CCA-treated decks; average fraction non-residential outdoor time a child plays on/around CCA-treated residential decks; and wood surface residues on CCA-treated playsets. It is important to note that data were available for almost all of the key model inputs identified with these analyses.

Although the best available data sets were used in the CCA assessment, there were few or no data for many inputs. In particular, information specific to average number of days per year a child plays on or around a residential or public CCA-treated playset or a home deck was not available. Similarly, information was not available on the fraction of time a child is actually contacting a CCA treated playset or deck when he or she is on or around a CCA treated playset or deck. Very limited data were available on pica soil ingestion rates of children which could be used to quantify short or long-term pica soil ingestion rates of the studied population. Multi-day and multi-year time-activity diaries for young children and spatial and temporal variability of soil and residue concentrations were also poorly known. Thus, it is quite important for future studies to collect longitudinal time-activity diary information on children and spatial and temporal measurements of residue and soil concentrations on or near CCA treated playsets and decks.

We conducted a comparison of SHEDS-Wood model results with other model results in order to evaluate the consistency of our basic findings. The inter-model comparison was especially important because the SHEDS-Wood CCA results were found to be consistent with estimates of the other models, whose algorithms and inputs were derived independently. Only two other models (Gradient 2001 and EWG 2001), however, estimated absorbed dose for all pathways in SHEDS-Wood, as well as aggregate absorbed dose. Most of the other models (except the Monte Carlo assessment by EWG 2001) are deterministic; the probabilistic approach taken by SHEDS-Wood is advantageous for characterizing the range of possible doses for children exposed to playsets and decks based on different activity patterns, concentrations contacted, and exposure factors, and for identifying critical variables with respect to variability and uncertainty.

A number of special simulations were also conducted, including examination of children exposed to public playsets only, age group selection, pica behavior, increased GI absorption, decreased dermal absorption, impact of reducing wood residues, and hand washing after play events. Most of these analyses did not significantly impact the baseline results, except for the impact of reducing wood residues (e.g., through the use of sealants). In collaboration with OPP and CPSC, ORD's National Risk Management Research Laboratory is currently conducting additional research to assess the impact of sealants on wood residues, which could be used to formulate appropriate risk management decisions.

REFERENCES

Agency For Toxic Substances and Disease Registry (ATSDR). (2001). Summary Report for the ATSDR Soil-Pica Workshop, June 2000, Atlanta, Georgia.

American Chemistry Council (ACC). (2002). Report Results of Soil Sampling Analysis -Chromated Copper Arsenate Treated Wood at Playground Structures. Prepared by Malcolm Pirnie, Inc.

American Chemistry Council (ACC). (2003a).CCA fixation and its implications on availability of hexavalent chromium (Cr^{VI}) for dislodgeability and leaching. Prepared by Paul A. Cooper, University of Toronto. Submitted for publication.

American Chemistry Council (ACC). (2003b). CCA Workgroup. Transmittal document submitted to Dr. Winston Dang, US EPA, dated June 23, 2003, "Assessment of Exposure to Metals in CCA-Preserved Wood: Full Study."

American Chemistry Council (ACC). (2003c). CCA Workgroup. "Relative Bioavailability of Dislodgeable Arsenic from CCA-Treated Wood." Prepared by Veterinary Medical Diagnostic Laboratory College of Veterinary Medicine. University of Missouri, Columbia, Missouri and Syracuse Research Corporation, Denver, Colorado.

American Chemistry Council (ACC). (2003d). CCA Workgroup. "Relative Bioavailability of Arsenic in Soil Affected by CCA-Treated Wood." Prepared by Veterinary Medical Diagnostic Laboratory College of Veterinary Medicine. University of Missouri. Syracuse Research Corporation, Denver, Colorado.

Black K, Shalat SL, Freeman NCG, Jimenez M, Donnelly KC, Calvin JA. (2003). "Children's mouthing and food handling behavior in an agricultural community on the U.S. Mexico border." In preparation.

Buck, RJ, Özkaynak H, Xue J, Zartarian VG and Hammerstrom K. (2001). Modeled Estimates of Chlorpyrifos Exposure and Dose for the Minnesota and Arizona NHEXAS Populations. *Journal of Exposure Analysis and Environmental Epidemiology,* 11: 253-268.

Calabrese, EJ, Barnes R, Stanek EJ, Pastides H, Gilbert, CE, Venman P, Wang X., Lasztity A, and Kostecki PT. (1989). How much soil do young children ingest: An epidemiologic study. *Regul. Toxicol. Pharmacol.*, 10, 123-137.

California Department of Health Services (CDHS). (1987). Kizer, K.W. "Report to the Legislature: Evaluation of Hazards Posed by the Use of Wood Preservatives on Playground Equipment." State of California. Office of Environmental Health Hazard Assessment, Department of Health Services and Welfare Agency.

Camann DE, Majumdar TK, Geno P., 1995. Determination of Pesticide Removal Efficiency from Human Hands Wiped with Gauze Moistened with Three Salivary Fluids. Final report to the US EPA by ManTech under contract 68-D5-0049. Research Triangle Park, NC: ManTech 1995.

Cassady, Alison. (2003). Research Director, USPIRG. Personal Communication.

CFA and USPIRG (2002). "Playing It Safe: The Sixth Nationwide Safety Survey of Public Playgrounds", June 2002, Consumer Federation of America, U.S. Public Interest Research Group Education Fund http://uspirg.org/reports/playground2002/FINALwithAppx.pdf.

Consumer Product Safety Commission (CPSC). (2003a). Briefing Package. Petition to Ban Chromated Copper Arsenate (CCA)-Treated Wood in Playground Equipment (Petition HP 01-3). February 2003.

Consumer Product Safety Commission (CPSC). (2003b). Memorandum dated January 13, 2003 from Mark S. Levenson to Patricia Bittner, "Statistical Analysis of CCA-Treated Wood Study Phase III."

Consumer Product Safety Commission (CPSC). (2003c). Memorandum dated January 24, 2003 from Mark S. Levenson to Patricia Bittner, "Statistical Analysis of CCA-Treated Wood Study Phase IV."

Cullen AC and Frey HC. (1999). Probabilistic Techniques in Exposure Assessment: A Handbook for Dealing with Variability and Uncertainty in Models and Inputs. Plenum Press. New York, NY.

Dang, W. (2003). A Probabilistic Risk Assessment for Children Who Contact CCA-Treated Playsets and Decks. US EPA. Office of Pesticide Programs, Antimicrobials Division. To be submitted to December 2003 OPP FIFRA SAP, Arlington, VA.

Davis S, Waller P, Buschom R, Ballou J, and 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. *Archives of Environmental Health*, 45(2), 112-122.

DeGroot, RC, Popham TW, Gjovik LR, and Forehand T. (1979). Distribution Gradients of Arsenic, Copper, and Chromium Around Preservative-Treated Wooden Stakes. Journal of Environmental Quality. 8(1): 39-41.

Doyle E, and Malaiyandi M. (1992) Field study to investigate the leaching and dislodgeability of copper, chromium, and arsenic from CCA-treated lumber and to evaluate means for reducing environmental contamination and user exposure. Health and Welfare Canada, Ontario, Canada.

Environmental Working Group (EWG) (2001). "Children's Exposure to Arsenic-treated Wood. A preliminary Monte Carlo risk assessment." Presentation to EPA's Science Advisory Panel made by Jane Houlihan, Sean Grey and Richard Wiles. October 23, 2001.

Exponent (2001). "Technical Issues Associated with the Risk Assessment of Children's Exposure to Arsenic at Playground with Structures Constructed from CCA-Treated Wood." Prepared for American Chemistry Council. July 31, 2001.

FIFRA SAP (2001). SAP Report No. 2001-12. (December 12, 2001) FIFRA Scientific Advisory Panel Meeting, October 23-25, 2001, held at the Sheraton Crystal City Hotel, Arlington, Virginia, A Set of Scientific Issues Being Considered by the Environmental Protection Agency Regarding: "Preliminary Evaluation of the Non-dietary Hazard and Exposure to the Children from Contact with Chromated Copper Arsenate (CCA)-treated Wood Playground Structures and CCA-contaminated Soil."

FIFRA SAP (2002). "A Set of Scientific Issues Being Considered by the Environmental Protection Agency Regarding: STOCHASTIC HUMAN EXPOSURE AND DOSE SIMULATION MODEL (SHEDS): System Operation Review of a Scenario Specific Model (SHEDS-Wood) to Estimate Children's Exposure and Dose to Wood Preservatives from Treated Playsets and Residential Decks Using EPA's SHEDS Probabilistic Model FIFRA Scientific Advisory Panel Meeting", August 30, 2002 Meeting Minutes No. 2002-06, Arlington, Virginia.

Freeman NCG, Jimenez M, Reed KJ, Gurunathan S, Edwards RD, Roy A, Adgate JL, Pellizzari ED, Quackenboss J, Sexton K, Lioy PJ. (2001) Quantitative analysis of children's microactivity patterns: The Minnesota Children's Pesticide Exposure Study. Journal of Exposure Analysis and Environmental Epidemiology. 11(6): 501-509.

Frey HC. Zheng J, Zhao Y, Li S and Zhu Y. 2002. Technical Documentation of the AuvTool Software Tool for Analysis of Variability and Uncertainty. Unpublished contract report submitted to US EPA, Feb 2002 (PR-RT-02-00381).

Gradient Corporation (2001). "Evaluation of Human Health Risks From Exposure to Arsenic Associated With CCA-Treated Wood." Prepared for Arch Chemicals, Inc. and Osmose, Inc. October 5, 2001.

Graham SE and McCurdy T. (2003). Developing meaningful cohorts for human exposure models. Journal of Exposure Analysis and Environmental Epidemiology. Accepted for publication.

Holmes KK, Shirai JH, Richter KY, Kissel JC (1999). Field Measurement of Dermal Soil Loadings in Occupational and Recreational Activities, Environmental Research Section A 80, 148-157.

International Play Equipment Manufacturers Association (IPEMA) (2001). Personal communication between Doreen Aviado of EPA and Bill Duffy of IPEMA.

Johnson T. (1989). Human Activity Patterns in Cincinnati, Ohio. Electric Power Research Institute, Palo Alto, CA.

Kissel, John. (2003). Associate Professor of Environmental and Occupational Health Sciences, Environmental Health Program, University of Washington, Seattle, WA. Personal Communication.

Kissel JC, Richter KY, Fenske RA. (1996). Factors Affecting Soil Adherence to Skin in Hand-Press Trials. Bull. Environ. Contam. Toxicol. 56: 722-728.

Kissel JC, Shirai JH, Richter KY, Fenske RA. (1998). Investigation of Dermal Contact with Soil in Controlled Trials. Journal of Soil Contamination, 7(6): 737-752.

Klepeis, N, Tsang A, and Behar JV. (1995). Analysis of the National Human Activity Pattern Survey (NHAPS) Respondents from a Standpoint of Exposure Assessment. National Exposure Research Laboratory, U. S. Environmental Protection Agency, Las Vegas, NV.

Leckie JO, Naylor KA, Canales RA, Ferguson AC, Cabrera NL, Hurtado AL, Lee K, Lin Y, Ramirez A, Vieria JD. (2000). Quantifying Children's Microlevel Activity Data from Existing Videotapes. Contract Report Submitted to US EPA, ORD, NERL, Reference Number U2F112OT-RT.

Lewis, Robert. (2003). US EPA, National Exposure Research Laboratory, Research Triangle Park, NC. Personal Communication.

The Lifeline Group, Inc. (2001). Technical Manual, Lifeline™ version 1.1, Software for Modeling Aggregate and Cumulative Exposures to Pesticides.

MacIntosh DL, Xue J, Özkaynak H, Spengler JD, Ryan PB, 1995, A Population-Based Exposure Model for Benzene. *Journal of Exposure Analysis and Environmental Epidemiology* 5(3): 375-403.

Malaiyandi, M. (1993). Determination of residues of arsenic, chromium and copper associated with structures built of pressure treated wood. Health and Welfare Canada, Ontario, Canada.

Malaiyandi, M. (1993) Determination of residues of arsenic, chromium, and copper associated with structures in playground environmental samples.

McCurdy T, Glen G, Smith L, and Lakkadi Y (2000). The National Exposure Research Laboratory's Consolidated Human Activity Database. *Journal of Exposure Analysis and Environmental Epidemiology* 10:566-578.

Midgett, J.D. (2003). Children's Contact with Playground Structures. U.S. Consumer Product Safety Commission. January 13, 2003.

Nico PS, Fendorf SE, Lowney YW, Holm SE, Ruby MV. (2003). Chemical Structure of Arsenic and Chromium in CCA-Treated Wood: Implication of Environmental Weathering. Submitted for Publication. August 2003.

O'Rourke, Mary Kay. (2003). Research Assistant Professor of Medicine, Respiratory Sciences Center, University of Arizona, Tucson, AZ. Personal Communication.

Özkaynak H., Zartarian V, Xue J, 1999, "A Modeling Framework for Estimating Children's Residential Exposure and Dose to Chlorpyrifos via Dermal Residue Contact and Non-Dietary Ingestion," International Society for Exposure Analysis (ISEA) Conference, Athens, Greece, September 1999.

Özkaynak H., Zartarian V, 1999, "Status of Advances in Probabilistic Pesticide Exposure and Dose Modeling by ORD/NERL," US EPA Office of Pesticide Program's FIFRA Science Advisory Panel Meeting, Arlington, VA, September 21, 1999.

Reed KJ (1998). “Quantification of Children’s Hand and Mouthing Activities Through a Videotaping Methodology,” PhD dissertation, Graduate School-New Brunswick, Rutgers University.

Reed KJ, Jimenez M, Freeman NCG, and Lioy PJ. (1999). “Quantification of children’s hand and mouthing activities through a videotaping methodology.” J. Exp. Anal. Environ. Epidem. 9: 513-520.

Riedel D, Galarneau D, Harrison J, Gregoire DC and Bertrand N. (February, 1991). Residues of arsenic, chromium and copper on and near playground structures built of wood pressure-treated with CCA type preservatives (unpublished). Health and Welfare Canada.

Roberts SM and Ochoa H. (2001). Letter to Mr. John Ruddell, Florida Department of Environmental Protection, RE: Concentrations of Dislodgeable Arsenic on CCA-Treated Wood.

Shook SR and Eastin IL, CINTRAFOR (Center for International Trade in Forest Products). (1996) Working paper abstract no. 56 (www.cintrafor.org/RESEARCH) “North American Residential Decking and Siding Markets”.

Solo-Gabriele H.; Townsend T, Hosein N, Khan B, Stook K, Tolaymat T, Song J. (2001). New Lines of CCA-Treated Wood Research: In-service and Disposal Issues. State University System of Florida, Florida Center for Solid Hazardous Waste Management. Gainesville, FL.

Stallings C, Glen G, Smith L, Zartarian VG, Xue J, Özkaynak H, "SHEDS-Wood (Stochastic Human Exposure and Dose Simulation Model for a Wood Preservative Scenario) User's Manual, 2002,, prepared for August 30, 2002 US EPA/OPP FIFRA Science Advisory Panel (SAP) meeting.

Stanek. EJ, and Calabrese EJ. (2000). Daily Soil Ingestion Estimates at a Superfund Site. *Risk Anal*: 20 (5): 627-635.

Stanek EJ, Calabrese EJ and Zorn M. (2001). Soil Ingestion Distributions for Monte Carlo Risk Assessment in Children. *Human Ecol Risk Assess.*7 (2): 357-368.

Stilwell, D. (1998) Arsenic from CCA-treated wood can be reduced by coating. Frontiers of Plant Science. 51(1): 6-8.

Thompson KM. and Burmaster DE. (1991), Parametric distribution for soil ingestion by children. *Risk Anal*, 2, 339-342.

Tsang AM. and Klepeis NE. (1996). Descriptive Statistics Tables from a Detailed Analysis of the National Human Activity Pattern Survey (NHAPS) Data. EPA/600/R-96/148. U. S. Environmental Protection Agency, Las Vegas, NV.

Tulve NS, Suggs J, McCurdy T, Cohen Hubal E, Moya J (2002). Frequency of Mouthing Behavior in Young Children. Journal of Exposure Analysis and Environmental Epidemiology. 12: 259-264.

U.S. Census Bureau. (2000) GCT-P7. Households and Families (www.factfinder.census.gov/bf/.....).

U.S. Consumer Product Safety Commission (CPSC) (1990). "Estimation of Hand-to-Mouth Activity by Children Based on Soil Ingestion for Dislodgeable Arsenic Exposure Assessment." Memorandum from B. Lee to E.A. Tyrell. February 7, 2000.

U.S. Environmental Protection Agency (2001a). Risk Assessment Guidance (RAG) for Superfund. Volume I. Human health evaluation manual (Part A). Office of Emergency and Remedial Response. EPA/540/R/99/005 Washington, D.C.

U.S. Environmental Protection Agency (2001b). Policy 12. Recommended Revisions to the Standard Operating Procedures (SOPs) for residential exposure assessments (Draft). Science Advisory Council for Exposure.

U.S. Environmental Protection Agency (2002.) Child-Specific Exposure Factitors Handbook (Interim Report). EPA-600-P-00-002B. 01 Sep 2002. US EPA, Office of Research and Development, National Center for Environmental Assessment, Washington Office, Washington, DC, 448.

Van Wijnen JH., Clausing P, and Brunekreff B. (1990). Estimated soil ingestion by children. Environ. Res. 51: 147-162.

Versar (2002). An Analysis of the Distribution of Chromium and Arsenic in Dislodgeable Residues from CCA-Treated Wood Structures and in the Adjacent Soil Using the Existing Data. Prepared for the US EPA, Office of Pesticide Programs, Antimicrobials Division, Contract 68-W-01-036. Prepared by Versar, Inc., Springfield, MA.

Weintraub, Rachel. (2003). Assistant General Counsel. CFA. Personal Communication.

Wester RC, Maibach HI., Sedik L, Melendres J, Wade M (1993). "In Vivo and in Vitro Percutaneous Absorption and Skin Decontamination of Arsenic from Water and Soil," Fundamental and Applied Toxicology, 20: 336-340.

Wester RC, Hui X, Barbadillo S, Maibach HI, Lowney YW, Schoof RA, Holm SE, Ruby MV. (2003). In Vivo Percutaneous Absorption of Arsenic from Water and CCA-Treated Wood Residue. Submitted for Publication. August 2003.

Wiley JA., Robinson JP, Cheng YT, Piazza T, Stork L, and Pladsen K. (1991). Study of Children's Activity Patterns. Survey Research Center, University of California, Berkeley, CA.

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(6 Pt 1):509-17.

Xue J, McCurdy T, Spengler J, Özkaynak H. (2003). submitted to *Journal of Exposure Analysis and Environmental Epidemiology.* Intra- and inter-individual activity considerations in human exposure modeling.

Zartarian VG, Xue J, Özkaynak H, Glen G, Stallings C, Smith L, Dang W, Cook N, Aviado D, Mostaghimi S, Chen J (2002a). Technical Manual: Using SHEDS-Wood (Stochastic Human Exposure and Dose Simulation Model for a Wood Preservative Scenario) for the Assessment of Children's Exposure and Dose from Treated Wood Preservatives on Playsets and Residential Decks," 2002, Technical Report prepared for August 30, 2002 US EPA/OPP FIFRA Science Advisory Panel (SAP) meeting.

Zartarian V.G., Xue J., Özkaynak H. 2002b. "Quantifying Aggregate Chlorpyrifos Exposure and Dose to Children using a Physically-Based Two-Stage Monte Carlo Probabilistic Model,", Society for Risk Analysis Conference, December 8-11, 2002, New Orleans, LA.

Zartarian VG., Xue J., Dang W., Özkaynak H., Cook N., Aviado D., Mostaghimi S., Chen, J. 2002c. "Modeling Exposure and Dose of Children to Wood Treatment Preservatives from Playsets and Home Decks,"Society for Risk Analysis Conference, December 8-11, 2002, New Orleans, LA.

Zartarian VG., Xue J., Dang W., Özkaynak H., Cook N., Aviado D., Mostaghimi S., Chen, J. 2002d. "Modeling Exposure and Dose of Children to Wood Treatment Preservatives from Playsets and Home Decks," 2002, International Society for Exposure Analysis Conference, August 2002, Vancouver, B.C.

Zartarian V.G., Özkaynak H, Xue J., 2001a. "Assessing Residential Exposure Using the Stochastic Human Exposure and Dose Simulation (SHEDS) Model", International Society for Exposure Analysis (ISEA) Conference, Charleston, SC, November 2001.

Zartarian V.G., Özkaynak H, Xue J., 2001b."Quantifying Aggregate Chlorpyrifos Exposure and Dose to Children Using a Physically-Based Two-stage Monte Carlo Probabilistic Model", International Society for Exposure Analysis (ISEA) Conference, Charleston, SC, November 2001.

Zartarian V.G., Özkaynak H., Xue J., Smith L., Glen G., Stallings C. 2001c. "SHEDS-Pesticides: Model Overview and Scenario Outputs for the Aggregate Residential Model Comparison Workshop,", Aggregate Residential Exposure Model Comparison Workshop, October 10-11, 2001, Research Triangle Park, NC.

Zartarian VG, Özkaynak H., Burke JM, Zufall MJ, Rigas ML, and Furtaw Jr. E.J. 2000a. A Modeling Framework for Estimating Children's Residential Exposure and Dose to Chlorpyrifos via Dermal Residue Contact and Non-Dietary Ingestion. Environmental Health Perspectives. 108(6):505-514.

Zartarian V., Özkaynak H., Xue J., Glen G., Furtaw E. 2000b. "Modeling Aggregate Chlorpyrifos Exposure and Dose to Children," International Society for Exposure Analysis Conference, October 2000, Monterey, CA.

Zartarian V., Özkaynak H., Burke J., Zufall M., Rigas M., Furtaw E. 1999a. "Estimating Children's Exposures to Pesticides Using EPA's Residential SHEDS Model," 1999,, December 1999, Society for Risk Analysis Conference, Atlanta, GA.

Zartarian V., Özkaynak H., Burke J., Zufall M., Rigas M., Furtaw E., Xue J, 1999b. "The Stochastic Human Exposure and Dose Simulation Model for Pesticides," Aggregate Exposure Assessment Model Evaluation and Refinement Workshop, International Life Sciences Institute, Health and Environmental Sciences Institute, October 19-21, 1999, Baltimore, MD.

Zartarian VG, Ferguson AC, and Leckie JO. (1998). Quantified mouthing activity data from a four-child pilot field study. J. Exp. Anal. Environ. Epidem. 8: 543-554.

APPENDIX 1: Summary of August 30, 2002 SAP Meeting Panel Comments and Agency Responses

Age-Group Issues

- Add a 6 month-to-1-year cohort to the model to account for exposure in mobile but non-walking children.

EPA: There are currently insufficient data for this cohort (e.g., CHAD diaries, time spent on/around treated wood structures) to include it in the model. There needs to be a sufficient amount of data for age, gender, season, weekend/weekday cohort for longitudinal activity simulations. There is only 1 child in CHAD, for example, for females less than 1 year with a diary on a weekend in winter.

- Determine whether the upper age range should be expanded to include children up to age 13.

EPA: Little or no data are available for many model inputs, especially for children ages 7-13 years. We did, however, conduct analyses to project the difference in As LADD for 1-13 year-olds assuming that 7-13 year-olds have 25%, 50%, 75%, and 100% dose of 1-6 year-olds.

CHAD Issues

- The SHEDS-Wood model addresses child behavior and general exposure risk in part by stratifying the linkage of diary inputs by outdoor activity level—high, medium, low—but unweighted CHAD data alone do not guarantee population representation of children by activity level or their likely exposure to treated surfaces. There are likely differences in playscape and deck usage patterns between urban, suburban, and rural children and perhaps for children of differing socio-economic status (SES) and region. CHAD can not guarantee that the SHEDS-Wood model is correctly representing the target population's conditional distributions (that is, given their age and gender) for geography, climate, likelihood of contact (home type, school and preschool attendance, use of parks and areas with structures, etc.), and personal exposure-related behaviors.

EPA: The points made in the review comment are well-taken. While CHAD does not contain many of the variables mentioned, the SHEDS-Wood model allows the user to alter input parameters to adjust for these characteristics. For example, climate dependence was addressed in the warm and cold bounding scenarios, and geographical dependence could be addressed similarly, if the user had suitable data. In light of the review comment, the CHAD database was examined. CHAD contains 7680 diaries for children 1-13 years; unfortunately, 5071 of these (67%) are missing information on state of residence. Utilizing the diaries with geographic location, it was found that location alone did not significantly affect time spent outdoors. However, time outdoors did vary by the combination of location and season of the year. For long-term simulations, the total time outdoors for the simulated individuals will not change much by location. Thus, LADD and ADD, which depend strongly on the average time outdoors, will not be affected by the stratification of CHAD diaries by geographic region. In addition, there are not enough CHAD diaries to support further stratification without sacrificing one or more of the current stratification variables such as age or gender.

- Using simulated diaries not specific to an individual child creates serial correlations in activity patterns that may or may not be realistic. Other model structures, such as not varying activity parameters for events like playing on decks and other sporadic events, use fixed patterns of activity to represent additional assumptions. Not varying activity patterns tends to extend and thicken the upper tail, but without additional data there is little that can be done to challenge this assumption. One suggestion is to use empirical data from CHAD to develop distributions of activities over time versus drawing from a particular child's activity pattern. That is, facilitate modeling activity rather than replicating activity pattern.

EPA: The SHEDS approach for constructing time series of exposures based on actual activity patterns was selected to capture within-day variability that may have toxicologically significant impacts on dose. The SHEDS-Wood model attempts to balance repetition of activities from day to day with temporal variation by selecting eight diaries per year per child. Even when the same activity diary is re-used, the playset and deck contact events are randomly determined (as subsets of the same potential contact events) on each day. Contact events therefore do vary from day to day.

- The current approach tends to hold only time outdoors constant and not fix individual preferences for playing or not playing in specific environments/equipment (i.e., a child may prefer playsets over the deck). This may cause the model to predict less long-term variability in exposures than would actually be the case. It would seem reasonable to explore the alternative model in which other parameters were held constant for a child (such as preferences for various types of play involving home or school playsets).

EPA: SHEDS-Wood does not fix time outdoors to be constant; it uses the time outdoors reported in the diary. It assumes the fraction of time a child outdoors at home plays on playsets and decks is independent of fraction of time a child outdoors away from home plays on playsets. There are currently no data available to understand personal playset and deck playing preferences. However, our sensitivity analyses do include these variables.

Model Scenario Issues

- It is stated that SHEDS-Wood does not separate CHAD diaries by warm and cold regions. Yet the examples presented calculate outputs based on warm or cold weather that would be considered more representative of temperate US regions rather than areas such as Southern California, Texas, Arizona, Florida, etc. The clothing habits used for the two temperature categories seem somewhat unrealistic and may not truly represent regional variations and the range of clothing habits of children. It is unclear how the 8 diary model was used in the two examples (warm and cold temperature scenarios). Sampling from each of 4 seasons would, in some cases, include both warm and cold temperatures so an example that takes this into account would not be unreasonable to include.

EPA: Geographic location is related to seasonal temperature, time spent outdoors, clothing habits, and a number of other factors affecting SHEDS-Wood results. Although CHAD diaries are stratified by season for each 1-year simulation per person, there are not enough CHAD data to stratify by geographic location (see above). Given this lack of data, the current approach is to conduct separate warm climate and cold climate simulations, modifying factors such as dermal transfer coefficient (function of unclothed skin surface area) and time on playsets and decks. Because these inputs are not specified for different seasons (since temperature in seasons is location-dependent), the warm climate and cold climate runs represent two extremes for exposure: warm climate clothing and time on playsets/decks every day of the year, or cold climate clothing and time on playsets/decks every day of the year. While these may not be realistic for all areas of the U.S., they suggest bounding estimates for the entire U.S. population of children. More data for activity patterns in each state would allow us to refine the SHEDS-Wood model and generate analyses that reflect geography-dependent exposures more realistically.

- Investigate whether current videography data support inclusion of mouthing of surfaces relevant to decks or playsets such as floors, railings, chair seats and backs, etc.

EPA: Sample sizes are too small to justify adding new pathways to the SHEDS-Wood model at this time.

- Consider potential exposure (via deterministic calculations) to high risk groups (children with autism, pica behavior, Down syndrome, etc.).

EPA: We do not know whether/how children's activity patterns are different from CHAD diaries for these high risk groups. If they are not different, then our SHEDS-Wood distributions should reflect these cases. If they are different, we do not have activity data to adequately address these special groups at this time. A special analysis was done that examined pica behavior.

- Broaden SHEDS-Wood exposure scenarios to consider other possible routes or sources of exposure to wood preservatives, including contact with wooden docks, siding and fences.

EPA: These exposure pathways are not included in SHEDS-Wood because they are considered to be less important than those for playsets and decks, and because there are insufficient data currently to justify their inclusion.

- In future versions of SHEDS-Wood, include dietary and drinking water routes for aggregate exposure assessment to wood preservatives.

EPA: This suggestion is out of the scope of this report.

Longitudinal Activity Pattern Issues

- Address Panel concerns about the reality of the independence/dependence in temporal patterns of activity events created by the SHEDS-Wood method for simulating 365-day longitudinal activity patterns. The assumption that the 8 diaries adequately reflect individual variability over a year or a 3-month period needs to be tested. Conduct sensitivity analyses on the selection of number of CHAD diaries (currently 8 days/year) used for generation of 365 day activity patterns.

EPA: A paper submitted to the *Journal of Exposure Analysis and Environmental Epidemiology*, October 8, 2002, "Intra- and inter-individual activity considerations in human exposure modeling," J. Xue, T. McCurdy, J. Spengler, H. Özkaynak, explores this issue based on a Southern California study of 160 children. It suggests that 8 days/year is a reasonable number to use for longitudinal activity simulations with respect to daily time spent outdoors.

- Examine more closely individual profiles and absorption temporal patterns to determine whether the sample generated that forms the basis for the analysis is reasonable. An associated analysis requires the ability to examine extreme patterns to see how extreme things can get.

EPA: One of the special analyses examines the top 5% and top 2 exposed individuals out of a sample of 1000. The behavior patterns and exposure results are discussed in this report and appear to be reasonable.

- The dataset classifies children into low-, medium-, and high- potential exposure groups, and this classification is used to provide consistency from year-to-year in such factors as the amount of time spent in outdoor locations. Statistical weights are applied to assure appropriate age and gender representation in the sample, but it is not clear whether in some scenarios the whole sample would be generated from, for example, only the high-potential group. It does not seem reasonable to allow this to happen, yet there does not seem to be anything in the model that would eliminate this possibility.

EPA: While an individual child in SHEDS-Wood may be in the high, medium, or low group (reflecting an overall behavioral tendency), this does not imply that the child has a correspondingly high (or medium, or low) outdoor time on every day of the year. If children remained within their designated group on every day of the simulation, the result would be a trimodal distribution of mean exposure, with a cluster of exposures around the mean for each group. Instead, it is recognized that a child belonging to the 'high' group will tend to have a high outdoor time on most days, but not all days. The methodology used to assign probabilities in this way is described in the *Classification of Diaries into "High", "Medium," or "Low" Potential Exposure Categories* section of the report.

- The underlying studies come from two age-group cohorts; a 1-3 year age group and a 4-6 year age group. This "consistency matching" has the potential to drive the upper tails of the dose distribution. Examine the impact of allowing consistency in the 1-3 year age group but changing it in the 4-6 age year group.

EPA: Based on new data obtained for hand-to-mouth frequency, hand washing frequency, and bathing frequency, the same distributions were used for each age 1-6 years.

Data Source Issues

- In general, the Agency may have to take a more active approach to generate the following needed information, from a variety of economic groups, for SHEDS-Wood:
  - child behavior related to frequency of contact with treated surfaces
  - frequency and duration of child contact with treated wood structures and contaminated soils
  - rates of dermal transfer
  - hand-to-mouth activities
  - saliva removal efficiency
  - soil ingestion rates
  - fraction of hands mouthed
  - spatial and temporal variability in wood surface and soil concentrations
  - distribution of wood structures and residues that populations of children may be exposed to
  - urine monitoring and hand wipes in conjunction with wood wipe and soil data
  - Longitudinal activity data which can be used to verify results of CHAD sampling strategies

EPA: The Agency is currently involved in data collection efforts that address some of these data needs. Some have been incorporated into this CCA assessment, and other data will not be available in time.

- Consider the following data sources:
  - playscape exposure study in Florida (Stuart Shalat at EOHSI and FL colleagues). It will be more than a year before these data are available.
  - In the Minnesota Children's Pesticide Exposure Study, 4 children (ages 5-7 years) out of 19 videotaped children used playscapes.
  - In the work of Reed et al (1999) one pilot child used a home playscape (none of the 10 urban children used park playscapes or decks).
  - There are data from various studies on parental estimates of daily hand washing that may provide better estimates that those used in the current EPA analysis. For dermal loading of pesticides on children's hands both the Arizona (O'Rourke et al, 2000) and Texas (Shalat et al 2002, Black et al, 2002) border studies may provide better data.
  - The Texas border study includes data on 50 children between 7 months and 48 months, with repeated observations over 6 months on 45 of the children. Hand-to-mouth activity outdoors is one of the quantified variables. It might be useful to compare this with data from Beamer et al (2002) and Canales et al (2002). These data may also be useful for assessing hand washing over a 4-hour period. The Washington group (Fenske, 2002, Kissel et al, 2002, Lu and Fenske, 1999) or David Camann (2000) may also have data they could share.
  - Firms in the pesticide and wood treatment industries may have data for number of US houses with treated decks and treated wood playsets.

- Trade press publications for (1) the community of people who design, purchase, and market playground equipment to municipalities, (2) large corporate retailers of home playsets, and (3) lumber and hardware marketers who sell wood and supplies to contractors who build home decks may have playset/home deck usage information.
- People who advise communities on playground capacity and expected usage levels may be able to shed light on differences in usage in different climates and seasons.
- Designers and distributors of preservative-treated playground structures to determine where these products are sold in order to characterize the demographics of the purchasing communities and individuals who will eventually use the structures.

EPA: We considered these data sources where possible as well as additional ones for updating the SHEDS-Wood input distributions. All data sources used in SHEDS-Wood are listed in tables discussing input variables.

Model Input Issues

- Rethink, revise as needed, conduct/report sensitivity analyses, and document in more detail, assumptions for SHEDS-Wood variable distributions and parameter uncertainty distributions used.

EPA: . Various sensitivity analyses were conducted and are reported. Discussions on each input variable are now provided. A fuller description of the revised method of determining uncertainty distributions has been included.

- The soil ingestion distribution used in the current version of SHEDS-Wood model leads to the assumption that a non-negligible portion of the population engages in what would be considered soil pica on a daily basis, and should be reexamined.

EPA: We revised the soil ingestion rate input distributions considering new studies and conducted a special analysis for pica children.

- The current method for estimating a surface-to-skin transfer coefficient is highly uncertain. One Panel member was concerned that use of a normal distribution for both the variability and the uncertainty could lead to substantial understatement of the uncertainty in this factor. In particular, the model as implemented had the variance of the mean surface-to-hand transfer coefficient less than the variance among children in surface-to-hand transfer factor. Given that the variance in surface-to-hand transfer coefficients is limited by the variability in hand surface area among children, this was considered highly implausible.

EPA: The approach presented to the 2002 SAP was revised to eliminate these concerns. To replace point estimates used previously, new data from the American Chemistry Council were used for a distribution of dermal transfer efficiency, and published data were used for a distribution of fraction of bare skin contacting residues per time.

- Sensitivity analyses should be conducted for the following model assumptions:
    - a child is bathed every day, regardless of the CHAD diary entry

- the child's total bare skin surface area is covered by residue exactly once in an hour
- the surface-to-skin residue transfer efficiency is 90%

These assumptions address model inputs which should be assigned distributions (uniform or triangular) and included in the sensitivity and uncertainty analyses.

EPA: Bathing frequency is now a random variable (children may go as long as seven days between baths). The rate of dermal contact and the surface-skin transfer efficiency are now separate input variables and the distributions are based on published data.

Probability Distribution Issues

- Where subjective estimates are the source of uncertainty distributions, it is important to take precautions to guard against the bias of overconfidence—underestimation of uncertainty. It would be valuable to have several "experts" independently construct input distributions and compare the resulting uncertainty analyses. The EPA Superfund Guidance document (EPA 2001) cites several helpful sources of established expert elicitation procedures (e.g. Morgan and Henrion, 1990; Hora, 1992; US EPA, 1982).

EPA: We attempted to elicit expert opinion on key and highly uncertain model inputs. We also broadened the uncertainty distributions generated from the bootstrap in some cases.

- Conduct sensitivity analyses on distributions used for inputs. For example, change the distribution assumption for a parameter, e.g. uniform to lognormal, while keeping the same mean and variance, and plot both results on the same graph, to see how the tails of the quantile plots are affected.

EPA: For nonfractional variables where data were available, Weibull (e.g., hand-to-mouth frequency) or lognormal distributions (e.g., soil concentrations, surface residues, surface residue-skin transfer efficiency, soil ingestion rate, soil-skin adherence factor, maximum dermal loading, frequency of hand washing) were fit to the data using the method of moments or the maximum likelihood estimator. Goodness-of-fit tests (Kolmogorov-Smirnov, Cramer-von Mises, Anderson-Darling and Chi-Square) were applied to verify the selection. For fractional input variables (i.e., values between 0 and 1), beta distributions were fit based on analyses comparing fits with normal, lognormal, triangular, and beta distributions.

- The Panel disagreed somewhat on the use of the bootstrap approach for fitting uncertainty distributions when some data are available. Some Panel members felt the method was unnecessarily complicated and could leave the user with a false sense of objectivity whereas other Panel members supported the method because of its objectivity and repeatability.

EPA: We continued to use a bootstrap approach, but in a modified version.

- One Panel member stated that the uniform distribution is only appropriate in cases where (1) it is physically impossible for the parameter to take on values outside the limits, and (2) there is no greater likelihood for values close to the center of the range rather than at either end.

Extensive use of uniform distributions to represent either uncertainty or variability should be discouraged (except in cases where the limits can be firmly based on physical principles) in favor of parametric distributions that do not have such strictly defined limits. Another Panel member commented that the use of a uniform distribution may well reflect a complete lack of knowledge about the input parameter but reflects an enormous amount of model uncertainty relative to the case where even a small amount of empirical data can help us to begin to focus our estimation of the true value (or prior distribution) of that parameter.

EPA: We replaced the uniform distributions for fractional variables with beta distributions, based on analyses described in the report.

- Factors that cause exposure to differ from one individual to another tend to interact multiplicatively—leading, when these factors are numerous, to expectations of a lognormal distribution. When one or more categorical factors are likely to have a strong influence on exposure (e.g., wearing short-sleeved vs. long-sleeved shirts) it is desirable to create mixtures of lognormal distributions, weighted by their expected frequency, to represent the influence of those different known cases.

EPA: We used lognormals, but we do not have enough data to create mixtures of lognormals. While one may often expect a lognormal exposure distribution, it is not necessary to explicitly determine the theoretical shape of the combined effect of multiple factors in SHEDS-Wood. The independent sampling of individual factors and the model structure are used to generate the exposure distribution.

- The model should also allow use of Beta, Gamma and Weibull distributions, mixtures of any of the available distributions, and the ability to establish a distribution with a spike of probability at 0.

EPA:. Beta, gamma, and Weibull distributions are now used in SHEDS-Wood. Mixtures of distributions are not supported.

Sensitivity and Uncertainty Analysis Issues

- It was not clear whether a true “multivariate stepwise regression” was performed. This would imply that the stepwise regression is performed on a multivariate response vector (e.g. playset surface dermal dose, playset soil dermal dose, deck surface dermal dose, deck soil dermal dose) and contributions of model variables to the joint distribution of the response vector is being assessed. It was deemed more likely that a number of univariate stepwise regressions were used to assess input variable importance. Stepwise regression uses multiple predictors and hence is sometimes referred to as multiple stepwise regression. The term multivariate typically is used to refer to the situation with multiple responses.

EPA: We used a vector of independent variables and a single dependent variable. We changed “multivariate stepwise regression” to “multiple stepwise regression” in the manuals.

- Perform an efficient sensitivity analysis by generating an activity history and holding it fixed while running a factorial design on the exposure parameters.

EPA:. The activity diaries were held constant while the inputs were changed. A full factorial design was not practical due to the number of inputs. Instead, one input was varied systematically while the others were held fixed, for each input in turn.

- The value of stepwise regression in the uncertainty analysis is limited. The p-values will depend on the range of uncertainty set for the scenario and will not necessarily indicate whether a factor is important or not. Also, since there is no other source of exposure considered here, the intercept could be removed from the regression.

EPA: We used contribution of variance, not p-values, in evaluating sensitivity. We examined the impact of removing the intercept from the regression.

- Sensitivity analyses should be conducted by varying each parameter up or down by 1 standard deviation (or to the 17^{th} and 84^{th} percentiles) rather than applying a uniform 2-fold change for parameters that have very different amounts of variability or uncertainty.

EPA: We did this and also compared both approaches.

- The Panel recommends further development of uncertainty analysis. Several Panelists also called for a simpler model focusing on variability analysis with sensitivity analysis.

EPA: We further developed uncertainty analyses by expanding the types of parametric distributions allowed for conducting uncertainty analyses. SHEDS-Wood has the option of running variability only without uncertainty.

- Uncertainty analysis may be more manageable if EPA were to reduce the model to a core of important factors (from the sensitivity analysis) and then explore the impact of variability and uncertainty factor distributions on various quantiles of the predicted exposure distribution. Other members of the SAP expressed the opinion that there is value in performing a full sensitivity analysis, even at this early stage in understanding, but would not fully support reductions of the model or the analysis approach suggested.

EPA: . The latter approach (full sensitivity analysis) was taken.

- Uncertainties assessed by the Frey et al. (2002) bootstrapping approach would not capture the effects of unsuspected measurement error and possible lack of representativeness of the group of people studied.

EPA: The concerns expressed in the review comment are valid. They were addressed by seeking additional data sources, soliciting opinions from individuals knowledgeable in specific areas, expanding the range of distributions allowed for uncertainty analyses, and modifying the bootstrap approach used.

- When the parametric bootstrap method is used, the method is applied with bootstrap samples of a size that approximates the number of empirical data points used to estimate the parameters of the distribution for a model input (e.g. n=3 one year old (non-hand) dermal transfer coefficient or n=20 for two-year-old frequency of hand-to-mouth activity per hour). In such cases, the repeated bootstrap sampling and parameter estimation generates a sampling distribution for the parameter that reflects the uncertainty (primarily sampling variance) in the estimation of a point estimate from the available data. For small sample sizes, the empirical distribution from the bootstrap simulation should be compared to the assumed parametric form of this distribution to verify the approximate fit. In particular, if the SHEDS-Wood model assumed an uncertainty distribution of uniform or lognormal for a parameter, does the bootstrap distribution for that parameter also look uniform or lognormal? For larger sample sizes (e.g. n=20 to 30), by the central limit theorem this simulated "sampling distribution" should converge to a normal distribution about the point estimate regardless of the underlying distribution of the data points used to develop the sample estimate of the parameter. Therefore, as the user-specified bootstrap sample size increases, the SHEDS-Wood documentation should caution the user that the use of non-normal distributions (such as the uniform or even the lognormal) will tend to lead to uncertainty draws that are "over-dispersed" compared to the true sampling distribution of the parameter estimate. If the amount of empirical data available to the parameters of an input distribution is large (>30) an alternative to the parametric technique would be to draw the bootstrap samples (with replacement) directly from the sample of observations (the nonparametric bootstrap). Again, if the number of observations is large (> 30) this bootstrap distribution should be approximately normally distributed about the overall sample estimate.

EPA: We addressed these concerns by modifying the bootstrap approach used. The updated method ties the final uncertainty sampling distribution for parameter values more closely to the results of the original studies.

- Another Panel member suggested that using the current bootstrap procedure to define uncertainty distributions is both unnecessary and gives a false sense of objectivity. This Panel member considered the process to be somewhat complicated and to some extent arbitrary (choice of sample size), making the results of the model harder to justify. This panelist believes that it is too narrow to think of uncertainty distributions as sampling distributions; rather it would be better to conceive of them as Bayesian prior distributions. This suggests that conjugate priors would be good choices for uncertainty distributions. Conjugate priors have many advantages; in particular, they do not give inadmissible values. There was some discussion from the Panel concerning the possibility of using correlated joint distributions for the uncertainty distributions, to avoid unlikely combinations of parameters. In Bayesian analysis the prior distributions are generally univariate and uncorrelated, and that correlated prior distributions do not appear to be an issue in the Bayesian context.

EPA: We will consider Bayesian methods for a future version of the SHEDS model. As mentioned above, the bootstrapping approach has been changed. This alteration makes the choice of the bootstrap sample size less arbitrary.

- One Panel member was concerned there is a lack of assumed correlations in the outputs of the current bootstrap procedure. In assigning prior distributions to the mean and variance of the uncertainty distribution, the fact should be considered that the sample mean and variance are not always distributed independently of each other, particularly for non-normal distributions. Assuming independent marginal distributions and not accounting for correlations, a fair fraction of the mean and variance combinations generated in the uncertainty analysis may be unrealistic. Other Panel members recommended that some comparative testing be undertaken of the outputs from the SHEDS model for particular parameters against the distribution of bootstrap input values that were used to derive the fitted uncertainty parameters. This should help resolve whether the current approach of using the bootstrap model outputs inappropriately excludes correlations in the estimated means and variances for the statistical sampling error uncertainties that should be captured by the bootstrap procedure.

EPA: Using the modified bootstrap approach in the revised SHEDS-Wood analyses addresses these concerns. The new method does not independently sample the distributional parameters.

- Several Panel members argued that if this model were to be merged with models for other routes of exposure, a smaller, simpler version without the uncertainty analysis might be preferable. They were concerned that the use of uncertainty analyses in support of regulatory decisions may be complex and difficult to communicate. They therefore recommended that an alternative model be developed, focusing on variability analysis but adding well-developed features for sensitivity analysis.

EPA: The user has the option of running only variability without uncertainty in SHEDS-Wood. No alternative model was developed; however, the user may "turn off" certain features of the model by the choice of point values for relevant inputs.

Model Code/Algorithm Issues

- Consider the use of a "Poisson one-hit model" with a lognormal transfer factor to assure that no more than 100% of material deposited on the skin is absorbed, while capturing the basic lognormal expectation for inter-individual differences in absorption rates. In this model "Fraction absorbed" = $1 - e^{-kt}$, where k follows a lognormal distribution and t is the exposure time. A similar equation can be used for removal of pesticide from the hands on washing.

EPA: We considered this approach but did not adopt it. The SHEDS-Wood code already contains a check to ensure that no more than 100% of the chemical can be absorbed or removed. For absorption, the model uses the linear approximation (fraction absorbed = kt) which is quite good since the product 'kt' is small. For hand washing, distributional data for both k and t would be required, whereas the existing method only requires a distribution for one variable (for which data were available); we are not aware of sources of data for k and t separately.

- For short-term exposures it may be better to let the simulation always start on a specific fixed date for all individuals in the simulation. Starting at uniform random dates over the year will average the exposure over seasonal differences and should inflate the variability of the results.

EPA: We now have an option to allow the user to fix a common start date for all individuals in a simulation. This preserves season-specific differences.

- For one year old children, in both the intermediate and long term calculation, there is no increase in body weight over the 3-month or 1-year period of simulation. This assumes that an average body weight is used for the time period. Ultimately, this may be an important issue in that the body weight increases found in children of this age group also reflect the rapid growth, metabolism, and other changes specific to this age group that are not accounted for in any of the variables.

EPA: We now use monthly body weight for all ages 1-6 years; the body weights are based on the NHANES III data.

- Update body weight and hand size more frequently than annually.

EPA: We now do this monthly.

APPENDIX 2: Pathway-Specific Absorbed Dose Equations in SHEDS-Wood

Introduction

SHEDS–Wood is essentially a mass balance model that involves simulating the movement and fate of the pollutant of interest after it has come into contact with the exposed individual. The SHEDS-Wood model follows simulated individuals through time, keeping track of the additions and subtractions to the *cumulative exposure loading.* An ‘exposure’ is a new contact with the target chemical; hence ‘exposure’ can only occur at places where the chemical is present (in this case, decks or playsets). Once exposure occurs, the chemical remains present on or in an individual until it is removed. The cumulative exposure loading is the total amount of the chemical currently in contact with the person; this can be non-zero even when away from decks and playsets. It is analogous to a bank balance, with new exposures corresponding to deposits and removal processes to withdrawals. In the equations below, a distinction is made between the amount of new exposure E from a single macroactivity event, and the current loading or cumulative exposure CE. The size of CE cannot be determined solely from the record of exposures, but also depends on the frequency and size of the removal terms (the withdrawals in the bank account analogy).

New dermal exposure, once contacted, remains on the skin until removed by one of a competing set of processes. These include washing and bathing, hand-to-mouth transfer, physical removal when load limits are exceeded, and dermal absorption. Because these processes compete, an increase in the frequency of hand washing will produce deceases in the amounts that can be removed by the other processes. Thus, the net impact of changes in washing frequency (or other behavioral changes) on the absorbed dose can be estimated using SHEDS-Wood. For ingested (GI tract) exposures, the removal processes are gastrointestinal absorption and daily voiding of the GI tract.

The SHEDS-Wood model simultaneously tracks 12 cumulative exposure loadings, eight dermal and four for the GI tract. The eight dermal ones are for 2 body parts (‘hands’ and the remainder, called ‘body’) times 2 routes (soil and wood surface residues) times 2 structures (decks and playsets). The four GI tract exposures correspond to the 2 routes for each of the 2 structures. The GI tract exposures are assumed to be non-interacting, but the dermal exposures may interfere with each other since they are subject to limitations on their sum for each body part (the dermal maximum loading limit).

In SHEDS-Wood the new exposures occur only when the person is near a structure containing CCA-treated wood, such as a deck or a playset. This happens only during specific diary events that are flagged as contact events. However, the removal processes for the cumulative exposure, particularly the dermal absorption, take place continually (on every diary event), once an initial exposure is contacted. Hand-to-mouth transfer is continual while the individual is awake. So while the new exposures occur at discrete points in time, the removal processes tend to be continuous. SHEDS-Wood treats both new exposures and removal processes by breaking time into a set of *time steps*. The time steps are the same as the macroactivity events described on the activity diary, thus they have variable duration (ranging from 1 minute to 1 hour). The mean duration of a time step while awake is 30 minutes; relatively few are shorter than 10 minutes. Compared to the size of a time step, the absorption processes are quite slow and can be modeled accurately using linear approximations. However, washing, bathing, and hand-to-mouth transfer can move significantly to completion even within a single time step. The effects of hand washing and bathing are considered in their entirety as instantaneous changes to the cumulative exposure loadings. Hand-to-mouth transfer is the most difficult removal process to model as its time scale is similar to the size of a time step, therefore one cannot assume that it happens slowly (and can be linearized), nor is it rapid enough to reach completion. The net effect of hand-to-mouth transfer during one time step entails determining the cumulative effect of multiple hand-to-mouth contacts spread over the macroactivity event. The derivation of the hand-to-mouth transfer equation is explained below. It is the only non-linear equation in the SHEDS-Wood model.

The SHEDS model considers four removal processes for dermal exposures: dermal absorption, hand-to-mouth transfer, hand washing, and bathing (including showering). Additional removal processes could be considered; for example, residue could be removed by touching various objects other than decks and playsets. However, data are lacking to adequately parameterize such processes.

The basis for the changes to the cumulative exposure loading is the macroactivity *time step*, or *event*. Within a single time step, the SHEDS-Wood model does not model processes as continuous changes in time, but instead treats them as a sequence of instantaneous adjustments or changes to the cumulative loading, one for each process under consideration. The order of the adjustments is: first, new exposure contact (if any) is added; second, the cumulative loadings are compared to the maximum dermal loading limits and reduced if necessary; third, the effects of absorption are determined; fourth, hand-to-mouth transfer occurs; fifth, hand washing (if present); and sixth, bathing (if present). The presence and the size of each adjustment is based on the activity events reported in the human activity diaries taken from the CHAD database and on the settings of several of the input variables. Letting CE_i represent the cumulative exposure loading after adjustment 'i', then schematically the SHEDS-Wood model performs the following steps:

$CE_0 = CE_6$ from previous event
$CE_1 = CE_0$ + new exposure contact (only when contact occurs)
$CE_2 = CE_1$ - adjustment for maximum dermal loading (if applicable)
$CE_3 = CE_2$ - adjustment for absorption
$CE_4 = CE_3$ plus or minus adjustment for hand-to-mouth transfer (if applicable)
$CE_5 = CE_4$ - adjustment for hand washing (if applicable)

$CE_6 = CE_5$ - adjustment for bathing (if applicable)

This set of changes is repeated every diary event, so the final result CE_6 for the current event becomes CE_0 for the next event. This is repeated throughout the simulation period, up to one year. Each year begins with the cumulative exposure loadings set to zero. Note that the hand-to-mouth adjustment is a subtraction for the dermal hand loadings, but it is an addition for the GI tract loadings. Once per day, at 6 a.m., there is an additional adjustment to account for voiding the GI tract loadings. Note that if a particular process is not applicable, then no adjustment is made. Hence, for the body dermal exposures and the GI tract exposures, $CE_5 = CE_4$. Such identity relationships are not shown in the equations below.

For the chemical sources under consideration, the initial exposures are primarily through dermal contact. However, the rates of dermal absorption for Arsenic and Chromium are small (around 3% per day) compared with the absorption rates for these chemicals in ingested form (25% - 50% per day). Evidently, if only a small fraction of the dermal exposure (say, one tenth) is transferred to the mouth and hence to the gastrointestinal (GI) tract, this latter pathway can provide doses comparable to, or even in excess of, the dermally absorbed dose.

It is known that the CHAD activity diaries tend to under-report events that are of short duration, generally meaning those lasting less than 15 minutes. Usually, such events are 'lumped' into a general description which covers a longer time period. For example, a diary might say 'Sleeping until 7 a.m., then getting dressed from 7:00 to 7:30.' Such a description may omit to mention the existence of a shower or bath during the dressing event. In CHAD, 50% of the diaries contain no explicit bath or shower event. Since a year-long diary is constructed from only eight CHAD diaries, it is not that unusual for the resulting diary to go long periods of time without any baths or showers. This is not representative of behavior in general, as other data sources indicate that very few people go more than one week without a shower or bath. Therefore, SHEDS-Wood includes a distribution for the interval between baths (data are summarized in Table 13 in this report). If the CHAD diaries indicate baths more frequently than this, the baths in the diaries are used. Otherwise, a bath is forced once the selected interval has passed without one. More than one-half the population are required to bathe once per day, but some may go up to seven days between baths. Note that the terms 'bath' and 'shower' are interchangeable in SHEDS-Wood.

The equations below contain a term for the maximum dermal loading. Conceptually, as one contacts CCA-treated wood a large number of times, there will come a point where there is no longer any net transfer of chemical from the wood to the skin. This limit can be thought of as an equilibrium point for transfer in each direction. CPSC (2003) determined that "a maximum hand load of As can be reached when an increasing number of hand rubs are applied to the same location on a board; a point exists after a sufficient amount of wood contact where an equilibrium between the amount of As transferred to the hand and the amount removed from the hands is approached." Maximum dermal loading may depend on particle size, moisture content of the wood and hand, and other variables.

In SHEDS-Wood, the maximum dermal loading is set to the product of the wood surface residue concentration times the transfer efficiency. The transfer efficiency is viewed as an effective 'partition coefficient'. Thus, a transfer efficiency of X% is interpreted as meaning that whenever skin contacts wood, any dislodgeable residue present divides itself between the two (that is, X% on the skin and (100%-X%) on the wood). Under this hypothesis, the hand will never be able to acquire a dermal loading that is more than X% of the concentration on the wood surface. SHEDS-Wood samples the transfer efficiency once per child from a distribution (and similarly for the wood surface concentration), hence each child will have a personal value for the maximum dermal loading.

The implementation of the maximum dermal loading in SHEDS-Wood is straightforward. As long as the current dermal exposure loading is below the limit, it plays no role. Thus, a hand that is already at one-half of its maximum will acquire the same amount of additional exposure upon contact with wood as a hand without any prior exposure, as long as the new exposure does not push the total exposure loading over the maximum. But if the maximum is exceeded as a result of a new contact, the dermal exposure loading is reduced back to the limit and any excess is lost. Both the hands and the body have the same limit (expressed as mass per unit area of exposed skin), since both are equal to the product of the transfer efficiency and the wood surface residue concentration. However, since exposure is tracked separately for hands and body, it is possible for one to reach the limit without the other doing so. In such cases, only one set of exposures is reduced; the other is unaffected. Note that the maximum applies to the sum of the various exposures for the given body part; thus, the hand maximum applies to the sum of the four hand dermal exposure variables (playset residues, soil near playset, deck residues, soil near deck). If the limit is exceeded, the same reduction proportionality factor is applied to each of the four exposures, so their sum becomes equal to the limit.

As a cross-check on the use of the maximum dermal loading in SHEDS-Wood, model runs were made with the maximum dermal loading input as a single quantity as opposed to the product of the residue concentration and transfer efficiency. A lognormal distribution was fit using data from the ACC and CPSC studies. Probability distributions for this input for As were obtained from ACC warm weather hand wipe data (ACC 2003b); the resultant fit was a lognormal(GM=0.033, GSD=2.46) distribution. For ACC (2003b) and CPSC (2003a,b) cold weather arsenic hand wipe data the fitted distribution was a lognormal(GM=0.051,GSD=2.55). For Cr, ACC warm weather data were used to obtain a lognormal(GM=0.030, GSD=2.43) distribution (used in the warm climate scenario). ACC Cold weather Cr data were used to obtain a lognormal(GM=0.05, GSD=2.51) distribution for the cold climate scenario. In the ACC and CPSC studies, the maximum dermal loading was determined by repeated hand rubs on the same area of CCA-treated wood. No data are available to determine how the maximum dermal loading would differ for cases where the skin repeatedly contact different areas of wood containing CCA residues. The results of these model runs with modified dermal maximum loading limits are discussed in the section on Special Analyses.

New Dermal Exposure to Wood Surface Residues

$$E_{dermal,\ res,\ j,\ k,\ e} = SR_{res,\ k} * SA_{j} * F_{uncl,\ j} * F_{contact,\ res,\ j} * T_{res,\ k,\ e} * TE_{surf\text{-}skin}$$

where

$E_{dermal,\ res,\ j,\ k,\ e}$ = new dermal exposure to target chemical [ug/event] for a given macroactivity event 'e' and body part 'j', from wood surface residues on structure 'k'; the body part may either be 'hands' or 'body' (all skin other than hands); the structure may be 'playset' or 'deck'.

$SR_{res,\ k}$ = concentration of target chemical [ug/cm2] in surface residues on treated wood, for structure 'k';

SA_{j} = surface area of skin [cm2] for body part 'j';

$F_{uncl,\ j}$ = fraction of skin surface area that is unclothed [-] for body part 'j', this is always one for 'hands' but may vary daily for 'body';

$F_{contact,\ res,\ j}$ = fraction of unclothed skin that contacts wood residues per minute [1/min], for body part 'j'.

$T_{res,\ k,\ e}$ = duration of play on structure 'k' [min/event] for given macroactivity event 'e';

$TE_{surf\text{-}skin}$ = residue transfer efficiency from wood surface to skin [-];

Above, and in subsequent equations, the symbol 'ug' represents micrograms. Units are indicated by square brackets, and powers are not superscripted but are written as suffixes. For example, [ug/cm2] means micrograms per square centimeter.

New Dermal Exposure to Soil

$$E_{dermal,\ soil,\ j,\ k,\ e} = C_{soil,\ k} * Adh_{soil\text{-}skin} * SA_{j} * F_{uncl,\ j} * F_{contact,\ soil,,j} * T_{soil,\ k,\ e}$$

where

$E_{dermal,\ soil,\ j,\ k,\ e}$ = new dermal exposure to target chemical [ug/event] for a given macroactivity event 'e' and body part 'j', from soil near structure 'k';

$C_{soil,\ k}$ = concentration of target chemical [ug/g soil] in soil near structure 'k';

$Adh_{soil\text{-}skin}$ = soil-to-skin adherence factor [g soil/cm2];

SA_{j} = surface area of skin [cm2] for body part 'j';

$F_{uncl,\ j}$ = fraction of skin surface area that is unclothed [-] for body part 'j', this is always one for 'hands' but may vary daily for 'body';

$F_{contact,\ soil,j}$ = fraction of unclothed skin that contacts soil per minute [1/min] for body part 'j'.

$T_{soil,\ k,\ e}$ = duration of play on soil near structure 'k' [min/event] for given macroactivity event 'e';

Cumulative Dermal Exposure Loading before considering Removal Processes

$$\mathbf{CE}_{1,\,dermal,\,route,\,j,\,k,\,e} = \mathbf{CE}_{6,\,dermal,\,route,\,j,\,k,\,e-1} + \mathbf{E}_{dermal,\,route,\,j,\,k,\,e}$$

where

$CE_{1,\,dermal,\,route,\,j,\,k,\,e}$ = first change to the cumulative dermal exposure loading on body part 'j' during event 'e', originating from 'route' (either soil or residues) at structure 'k';

$CE_{6,\,dermal,\,route,\,j,\,k,\,e-1}$ = final value for cumulative dermal exposure loading [ug] on body part 'j' at end of event 'e-1', originating from 'route' (either soil or residues) at structure 'k'; this is the amount that is carried over (retained) from the previous macroactivity event;

$E_{dermal,\,route,\,j,\,k,\,e}$ = new dermal exposure to target chemical [ug/event] for a given event 'e' and body part 'j', originating from 'route' near structure 'k';

Check for Maximum Dermal Loading

For the maximum dermal loading check, it is assumed that the dermal exposure to soil and the dermal exposure to wood surface residues compete for available skin space. Therefore, the sum of the two types of exposure is checked against the loading limits. An alternative approach is to assume that the two types of loadings can coexist without interference, in which case each could be checked against the limit separately.

There is a check for each body part (hands and body). The limits are expressed as loadings per unit area of skin. The current cumulative exposure loading (summed over route and structure), divided by the bare (unclothed) skin area, is compared to the maximum permitted dermal loading for that body part. If the current loading exceeds the maximum, then each of the four components of the current loading is reduced by a factor sufficient to make the current loading equal to the maximum.

$$\mathbf{Load}_{dermal,\,j,\,e} = (\sum \mathbf{CE}_{1,\,dermal,\,route,\,j,\,k,\,e}) / (\mathbf{SA}_j * \mathbf{F}_{uncl,\,j})$$

if $(\mathbf{Load}_{dermal,\,j,\,e} > \mathbf{MaxLoad}_j)$ **then**

$$\mathbf{CE}_{2,\,dermal,\,route,\,j,\,k,\,e} = \mathbf{CE}_{1,\,dermal,\,route,\,j,\,k,\,e} * \mathbf{MaxLoad}_j / \mathbf{Load}_{dermal,\,j,\,e}$$

else $\mathbf{CE}_{2,\,dermal,\,route,\,j,\,k,\,e} = \mathbf{CE}_{1,\,dermal,\,route,\,j,\,k,\,e}$

where

$Load_{dermal,\,j,\,e}$ = sum of initial cumulative exposure loadings per unit unclothed surface area [ug / cm2], for body part 'j' during event 'e'; sum is over route (soil or residue) and structure (playset or deck);

$CE_{1,\,dermal,\,route,\,j,\,k,\,e}$ = result of the addition of new exposure to cumulative dermal exposure loading [ug] on body part 'j' during event 'e', originating from 'route' (either soil or residues) near structure 'k';

$CE_{2, dermal, route, j, k, e}$ = cumulative exposure loading [ug] after maximum dermal loading check;

SA_j = surface area of skin [cm2] for body part 'j';

$F_{uncl, j}$ = fraction of skin surface area that is unclothed [-] for body part 'j', this is always one for 'hands' but may vary daily for 'body';

$MaxLoad_j$ = maximum dermal loading limit [ug/cm2] for body part 'j';

When the IF condition holds, the second equation is applied to each of the four CE terms in the sum; that is, each CE term is multiplied by ($MaxLoad_j$ / $Load_{dermal, j, e}$).

Absorbed Dose

dermal:

$$\mathbf{AD_{dermal, route, j, k, e} = CE_{2, dermal, route, j, k, e} * AbsR_{dermal, route} * T_e}$$

ingestion:

$$\mathbf{AD_{ingest, route, k, e} = CE_{2, ingest, route, k, e} * AbsR_{ingest, route} * T_e}$$

where

$AD_{dermal, route, j, k, e}$ = new dermally absorbed dose [ug/event] for body part 'j' during event 'e', originating from 'route' (soil or residue) near structure 'k';

$AD_{ingest, route, k, e}$ = new gastrointestinal absorbed dose [ug/event] during event 'e', originating from 'route' (soil or residue) near structure 'k';

$CE_{2, dermal, route, j, k, e}$ = result of the maximum dermal loading check on cumulative dermal exposure loading on body part 'j' during event 'e', originating from 'route' near structure 'k';

$CE_{2, ingest, route, k, e}$ = cumulative GI tract exposure loading [ug] at start of event 'e', originating from 'route' near structure 'k'; (for ingestion, $CE_2 = CE_1$);

$AbsR_{dermal, route}$ = dermal absorption rate constant [1/hr] for 'route' (soil or residue); this is 1/24 of the daily demal absorption rate constant;

$AbsR_{ingest, route}$ = gastrointestinal absorption rate constant [1/hr] for 'route' (soil or residue); this is 1/12 of the daily rate constant (See methods section for detailed discussion).

T_e = duration of the macroactivity event [hr]; Note that a check is made to ensure that the products ($AbsR_{dermal,route}$ * T_e) and ($AbsR_{ingest, route}$ * T_e) do not exceed unity, as it is not physically possible to absorb more than is present.

Reduction of Cumulative Exposure Loading for Removal of Absorbed Dose

dermal:

$$\mathbf{CE_{3, dermal, route, j, k, e} = CE_{2, dermal, route, j, k, e} - AD_{dermal, route, j, k, e}}$$

ingestion:

$$\mathbf{CE}_{\mathbf{3, ingest, route, k, e}} = \mathbf{CE}_{\mathbf{2, ingest, route, j, k, e}} - \mathbf{AD}_{\mathbf{ingest, route, k, e}}$$

where

$CE_{3, dermal, route, j, k, e}$ = third change to cumulative dermal exposure loading [ug] for body part 'j' during event 'e', originating from 'route' (soil or residue) near structure 'k';

$CE_{2, dermal, route, j, k, e}$ = result of the maximum dermal loading check on cumulative dermal exposure loading [ug] for body part 'j' during event 'e', originating from 'route' (soil or residue) near structure 'k';

$AD_{dermal, route, j, k, e}$ = new dermally absorbed dose [ug/event] for body part 'j' during event 'e', originating from 'route' (soil or residue) near structure 'k';

$CE_{3, ingest, route, k, e}$ = cumulative ingested exposure loading [ug] after absorption during event 'e', originating from 'route' (soil or residue) near structure 'k';

$CE_{2, ingest, route, j, k, e}$ = cumulative ingested exposure loading [ug] at start of event 'e', originating from 'route' (soil or residue) near structure 'k';

$AD_{ingest, route, k, e}$ = new gastrointestinal absorbed dose [ug/event] during event 'e', originating from 'route' (soil or residue) near structure 'k';

Hand-to-Mouth Transfer of Dermal Residues

It is known that children tend to put their own hands and fingers in their mouths quite frequently. In order to estimate the potential for hand-to-mouth transfer of Arsenic and Chromium, several specific modeling steps are taken. First, the amount of exposure on the hands is tracked separately from the amount on the rest of the body. The assumption is that the former is susceptible to being placed in the mouth while the latter is not. Therefore, most of the exposure equations have a subscript 'j' to indicate the body part. This can take on the two values 'hand' or 'body'. The term 'hand' (or 'hands') refers to the sum for both hands. The term 'body' is a short form for 'rest of the body', meaning everything other than the two hands. It is assumed that no hand-to-mouth events occur overnight while the child is sleeping.

$$\mathbf{E}_{\mathbf{ingest, res, k, e}} = \mathbf{(1/2)\ CE}_{\mathbf{3, dermal, res, hands, k, e}} * \mathbf{F}_{\mathbf{hand\text{-}mouth}} * \mathbf{[1 - (1 - F}_{\mathbf{hm\text{-}remov}}\mathbf{)\ \hat{}\ (N}_{\mathbf{hm}} * \mathbf{T}_{\mathbf{e}}\mathbf{)\ ]}$$

where

$E_{ingest, res, k, e}$ = amount of dermal hand exposure loading transferred to mouth during event 'e' [ug/event], originating from surface residues on structure 'k';

$CE_{3, dermal, res, hands, k, e}$ = result of the absorbed dose adjustment to cumulative exposure loading on hands [ug] during event 'e', originating from surface residues on structure 'k'; the factor of 1/2 accounts for the loading on one hand only;

$F_{hand\text{-}mouth}$ = the fraction of a (single) hand that is placed in the mouth during one hand-mouth contact [-];

$F_{hm\text{-}remov}$ = the mouthing removal efficiency [1/mouthing event]; this is the fraction of the amount (chemical mass) that enters the mouth that remains in the mouth as a result of one hand-mouth contact;

N_{hm} = the hand-to-mouth contact rate [mouthing events / hour]; this is set to zero when the child is sleeping but is allowed at all other times;

T_e = the macroactivity event duration [hours/event];

Note that the symbol '^' means raising to a power. The derivation of this equation is explained elsewhere in the manual. Note also that a similar expression is used to remove soil loading from the hands, but is not added to the soil ingestion (to prevent double counting). This equation is

$$\mathbf{E_{hand\text{-}remov,\, soil,\, k,\, e} = (1/2)\, CE_{3,\, dermal,\, soil,\, hands,\, k,\, e} * F_{hand\text{-}mouth} * [1 - (1 - F_{hm\text{-}remov})\ \hat{}\ (N_{hm} * T_e)\ ]}$$

The hand-to-mouth transfer equation takes account of multiple hand-mouth contacts within a single macroactivity event. It assumes that during one macroactivity event, the repeated mouth contacts involve the same portion of the hand. The second and subsequent mouth contacts therefore involve a reduced loading, as that part of the hand has been partially cleaned. Each mouth contact is assumed to remove the same fraction of the chemical mass that is physically placed in the mouth. The combined effect of multiple hand-mouth contacts can be determined analytically. First, at the start of the macroactivity event, the amount of chemical on the portion of the hand that is placed in the mouth is

$$M = (\text{hand fraction}) * CE / 2$$

The hand fraction is the fraction of the hand surface area that enters the mouth, and CE/2 is the loading on one hand. This assumes that the chemical is evenly spread over the hands at the start of a macroactivity event. If each mouthing event transfers a fraction F of the chemical to the mouth, then after one mouthing event a mass [M * (1-F)] will remain on that portion of the hand. A second mouthing event will result in a mass [M * (1-F)] * (1-F) remaining on that portion of the hand. Similarly, the mass remaining after N such mouth contacts will be [M * (1-F) ^ N] (the symbol '^' is used to represent raising to a power). Since this portion of the hand started with a mass M and ended with a mass [M * (1-F) ^ N], the mass has been removed from the hand is M - [M * (1-F) ^ N], or M * [1 - (1-F) ^ N]. The amount removed from the hand is the same as the amount entering the GI tract via mouthing. The number of hand-mouth contacts N during a macroactivity event is given by the product of the contact rate N_{hm} and the event duration T_e.

For the next macroactivity event, the hand loading is once again assumed to be evenly spread over the skin surface. This reflects the assumption that the mouthed portion may be 'recharged' once per macroactivity event, or equivalently that when the nature of the macroactivity changes, the details of the mouthing behavior (which parts of the hand contact the mouth) may change.

Soil Ingestion

$$\mathbf{E}_{\textbf{ingest, soil, k, e}} = \mathbf{C}_{\textbf{soil, k}} * \mathbf{IR}_{\textbf{soil}} * \mathbf{T}_{\textbf{soil, k, e}}$$

where

$E_{\text{ingest, soil, k, e}}$ = amount of soil ingested during event 'e' [ug/event], near structure 'k';
$C_{\text{soil, k}}$ = concentration of target chemical [ug/g soil] in soil near structure 'k';
IR_{soil} = soil ingestion rate [g soil/hour outdoors];
$T_{\text{soil, k, e}}$ = duration of play on soil near structure 'k' [hours/event] for given macroactivity event 'e';

Note that soil ingestion may occur during other events away from the treated wood structures 'k'; these terms are not tracked since they are assumed to contain no concentration of the target chemical ($C_{\text{soil}} = 0$). The mean daily soil ingestion rate input to the model is converted into a rate per hour outdoors (IR_{soil}) using the mean time spent outdoors from the activity diaries (3 hours outdoors per day).

Adjustments to Cumulative Exposure Loadings for Ingestion Processes

dermal:

$$\mathbf{CE}_{\textbf{4, dermal, res, hands, k, e}} = \mathbf{CE}_{\textbf{3, dermal, res, hands, k, e}} - \mathbf{E}_{\textbf{ingest, res, k, e}}$$
$$\mathbf{CE}_{\textbf{4, dermal, soil, hands, k, e}} = \mathbf{CE}_{\textbf{3, dermal, soil, hands, k, e}} - \mathbf{E}_{\textbf{hand-remov, soil, k, e}}$$

ingestion:

$$\mathbf{CE}_{\textbf{4, ingest, res, k, e}} = \mathbf{CE}_{\textbf{3, ingest, res, k, e}} + \mathbf{E}_{\textbf{ingest, res, k, e}}$$
$$\mathbf{CE}_{\textbf{4, ingest, soil, k, e}} = \mathbf{CE}_{\textbf{3, ingest, soil, k, e}} + \mathbf{E}_{\textbf{ingest, soil, k, e}}$$

where

$CE_{\text{4, dermal, res, hands, k, e}}$ = fourth adjustment to cumulative dermal exposure loading [ug] for the hands for event 'e', for residues originating on structure 'k';
$CE_{\text{3, dermal, res, hands, k, e}}$ = result of the adjustment for absorption to cumulative dermal exposure loading [ug] for the hands for event 'e', for residues originating on structure 'k';
$E_{\text{ingest, res, k, e}}$ = amount of dermal hand exposure loading transferred to mouth during event 'e' [ug/event], originating from surface residues on structure 'k';
$CE_{\text{4, dermal, soil, hands, k, e}}$ = fourth adjustment to cumulative dermal exposure loading [ug] for the hands for event 'e', for soil originating near structure 'k';
$CE_{\text{3, dermal, soil, hands, k, e}}$ = result of the adjustment for absorption to cumulative dermal exposure loading [ug] for the hands for event 'e', for exposure originating in soil near structure 'k';
$E_{\text{hand-remov, soil, k, e}}$ = removal term for dermal hand loading [ug] for event 'e', for soil originating near structure 'k';

$CE_{4,\, ingest,\, res,\, k,\, e}$ = fourth adjustment to cumulative ingested exposure loading [ug] for event 'e', originating from residues on structure 'k';

$CE_{3,\, ingest,\, res,\, k,\, e}$ = result of the adjustment for absorption to cumulative ingested exposure loading [ug], for residues originating on structure 'k';

$E_{ingest,\, res,\, k,\, e}$ = amount of dermal hand exposure loading transferred to mouth during event 'e' [ug/event], originating from surface residues on structure 'k';

$CE_{4,\, ingest,\, soil,\, k,\, e}$ = fourth adjustment to cumulative ingested exposure loading [ug] for event 'e', originating from soil near structure 'k';

$CE_{3,\, ingest,\, soil,\, k,\, e}$ = result of the adjustment for absorption to cumulative ingested exposure loading [ug], originating from soil near structure 'k';

$E_{ingest,\, res,\, k,\, e}$ = amount of chemical ingested in soil during event 'e' [ug/event], originating from soil near structure 'k';

Hand washing removal

$$\mathbf{CE_{5,\, dermal,\, route,\, hands,\, k,\, e} = CE_{4,\, dermal,\, route,\, hands,\, k,\, e} * (1 - F_{hw})}$$

where

$CE_{5,\, dermal,\, route,\, hands,\, k,\, e}$ = fifth adjustment to cumulative dermal exposure loading [ug] for the hands for event 'e', for 'route' (soil or residue) at structure 'k';

$CE_{4,\, dermal,\, route,\, hands,\, k,\, e}$ = result of the adjustment for hand-to-mouth transfer to cumulative exposure loading [ug] on the hands during event 'e', originating from 'route' (soil or residue) near structure 'k';

F_{hw} = fraction of loading on hands removed by one hand washing event;

Bathing removal

$$\mathbf{CE_{6,\, dermal,\, route,\, j,\, k,\, e} = CE_{5,\, dermal,\, route,\, j,\, k,\, e} * (1 - F_{bath})}$$

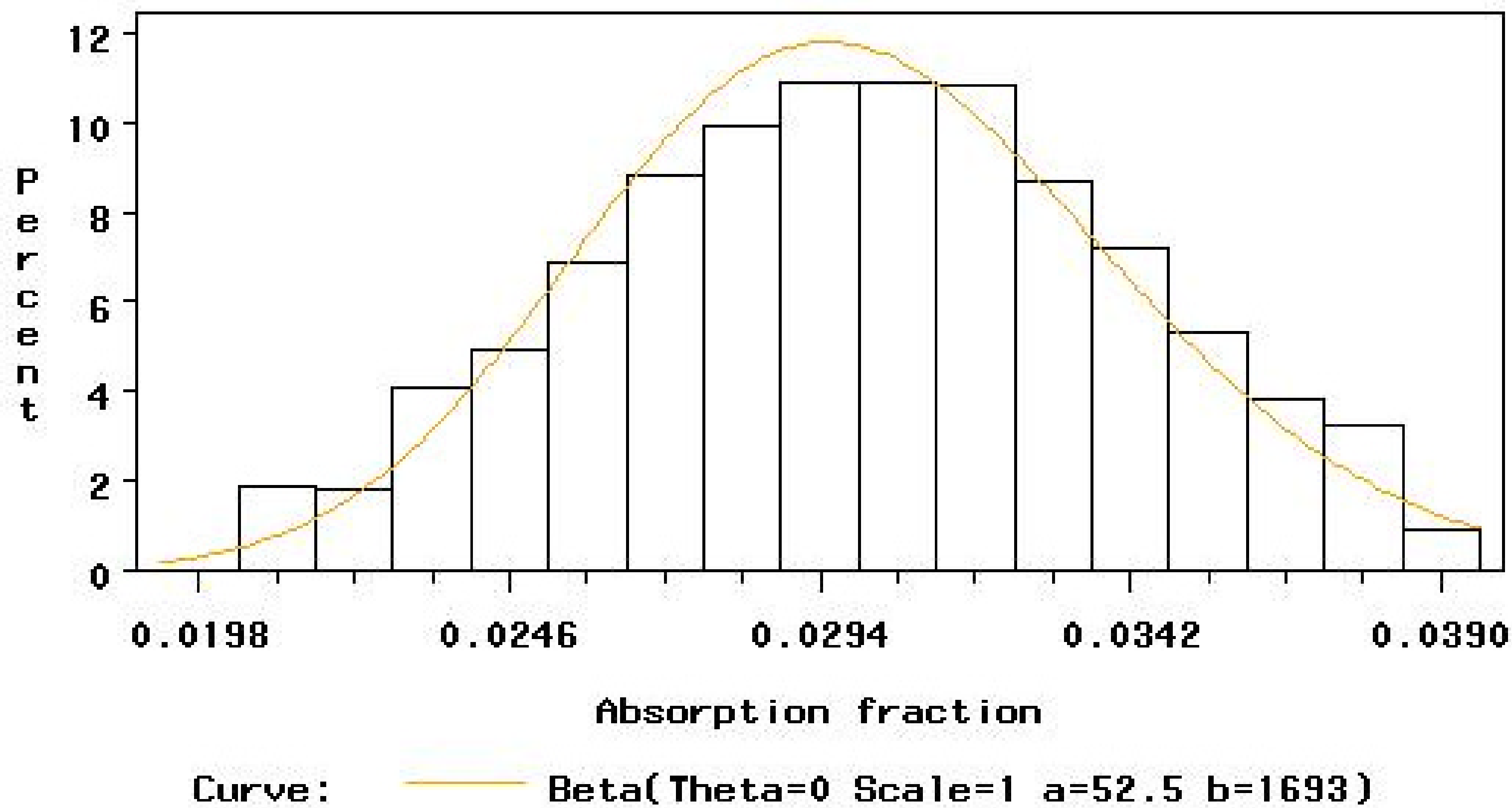
where

$CE_{6,\, dermal,\, route,\, j,\, k,\, e}$ = sixth adjustment to cumulative dermal exposure loading [ug] for body part 'j' for event 'e', for 'route' (soil or residue) at structure 'k';

$CE_{5,\, dermal,\, route,\, j,\, k,\, e}$ = result of the adjustment for hand washing to cumulative exposure loading [ug] for body part 'j' during event 'e', originating from 'route' (soil or residue) near structure 'k';

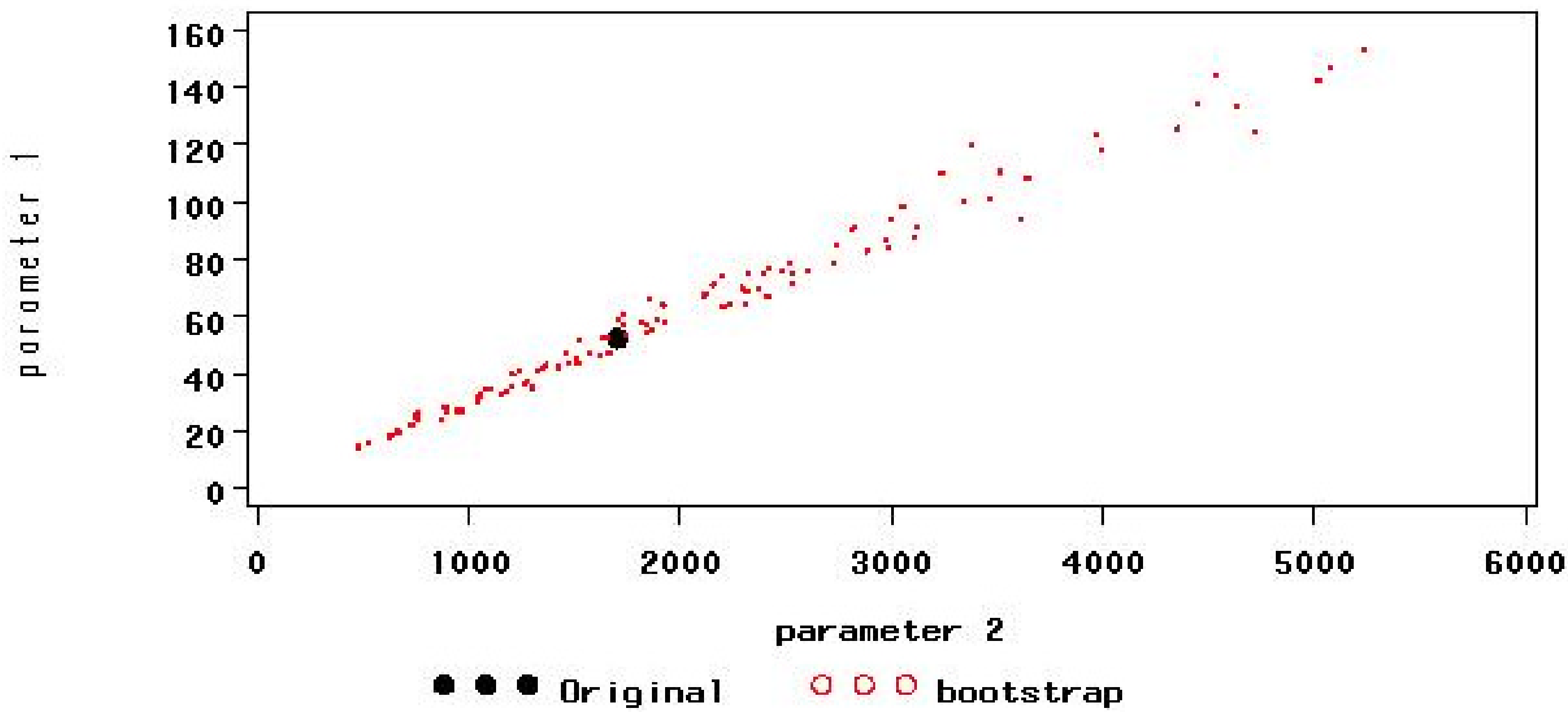
F_{bath} = fraction of loading removed by one bathing event; this includes showers as well as baths.

Residue As Dermal Absorption Fraction per Day

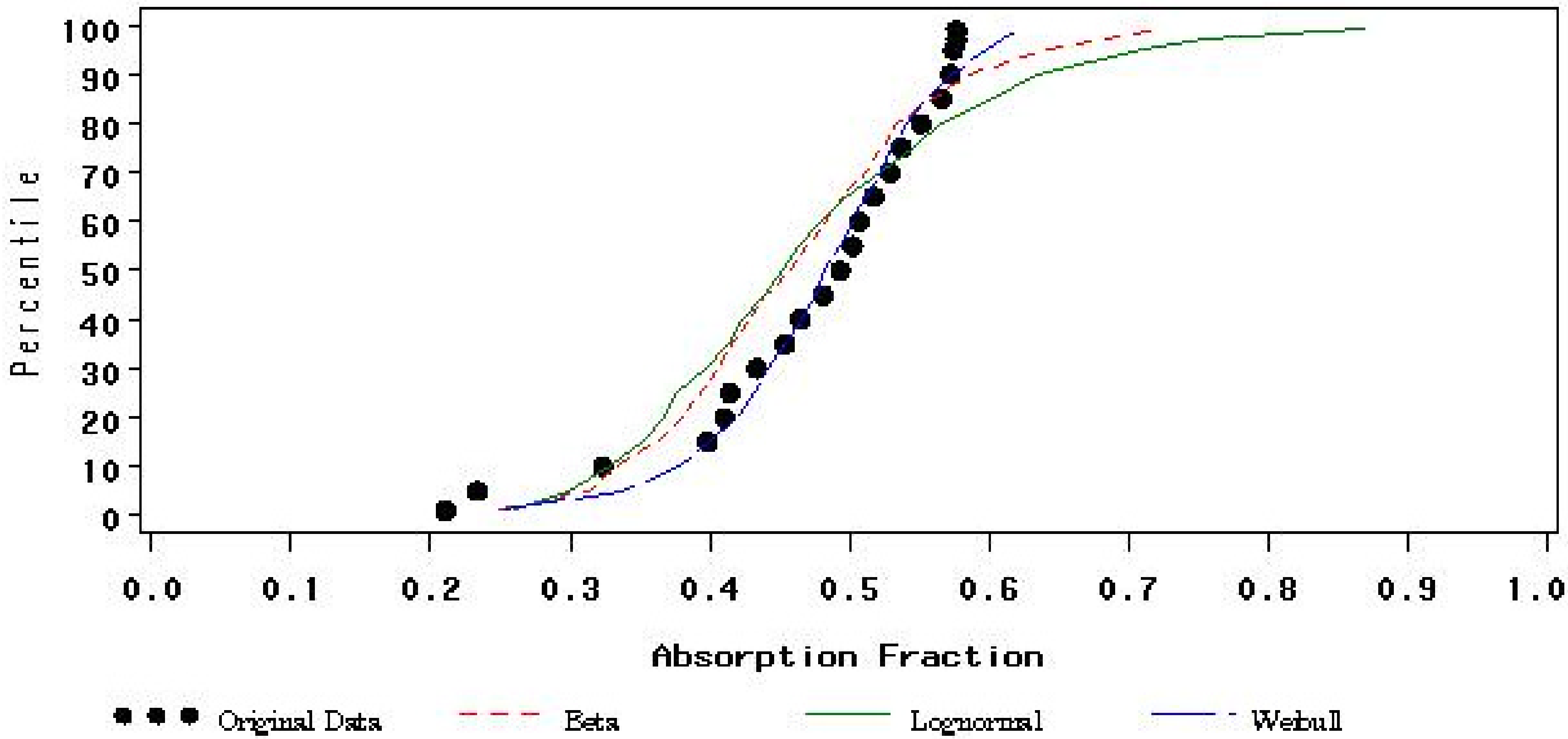


Residue As Dermal Absorption Fraction per Day Uncertainty

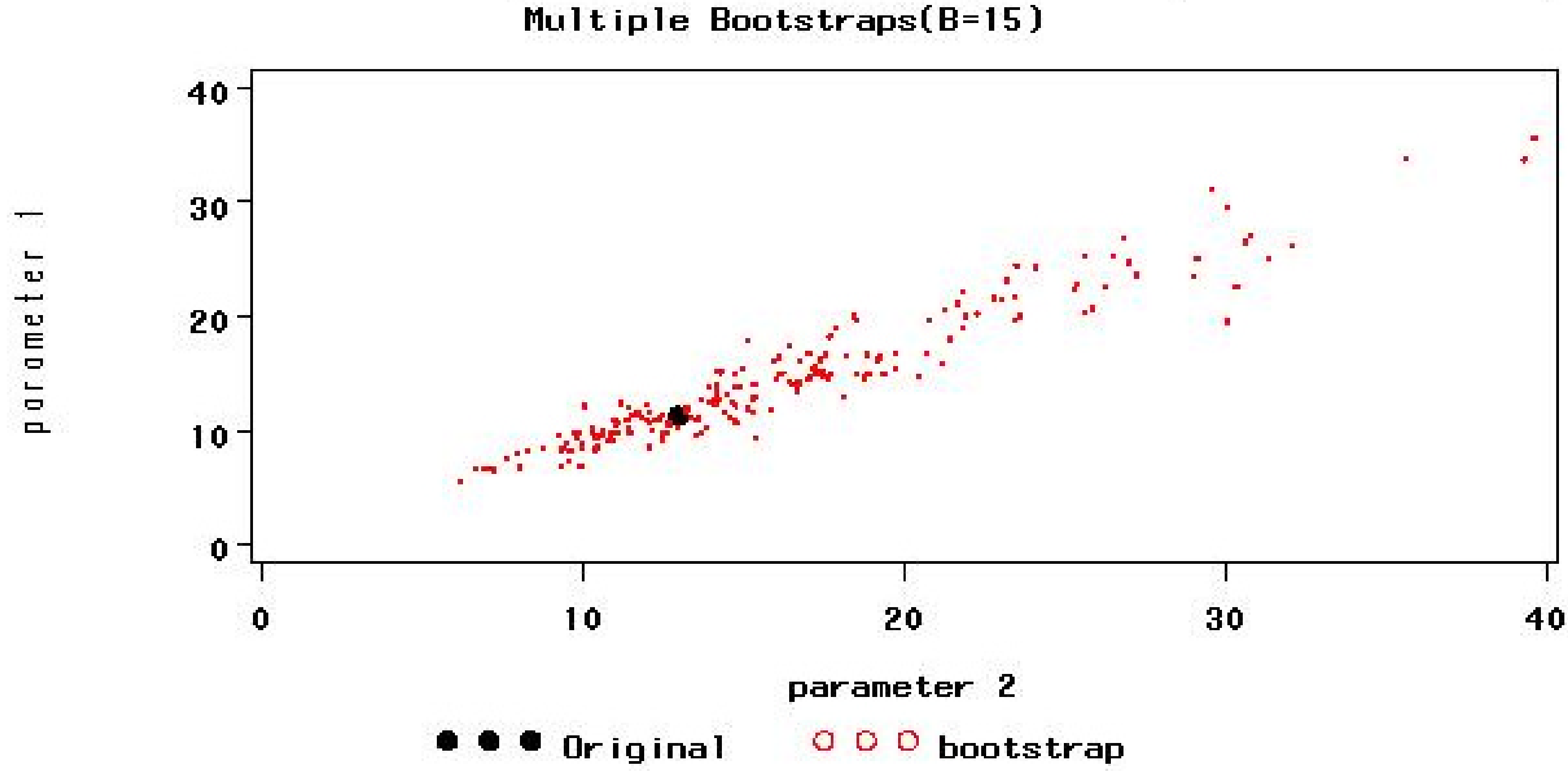
Multiple Bootstraps(B=4)



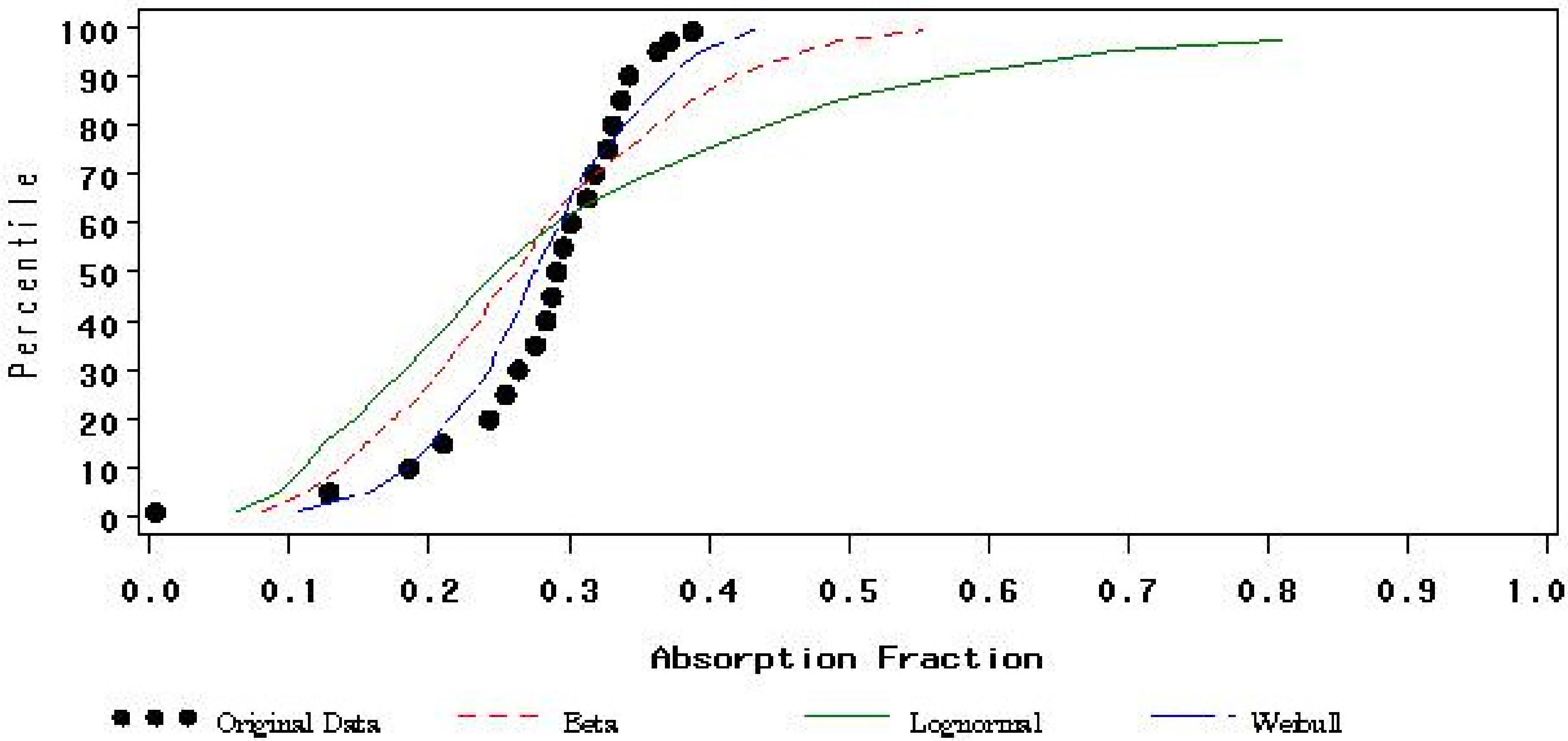
Soil As GI Absorption Fraction per Day



Soil As GI Absorption Fraction per Day Uncertainty

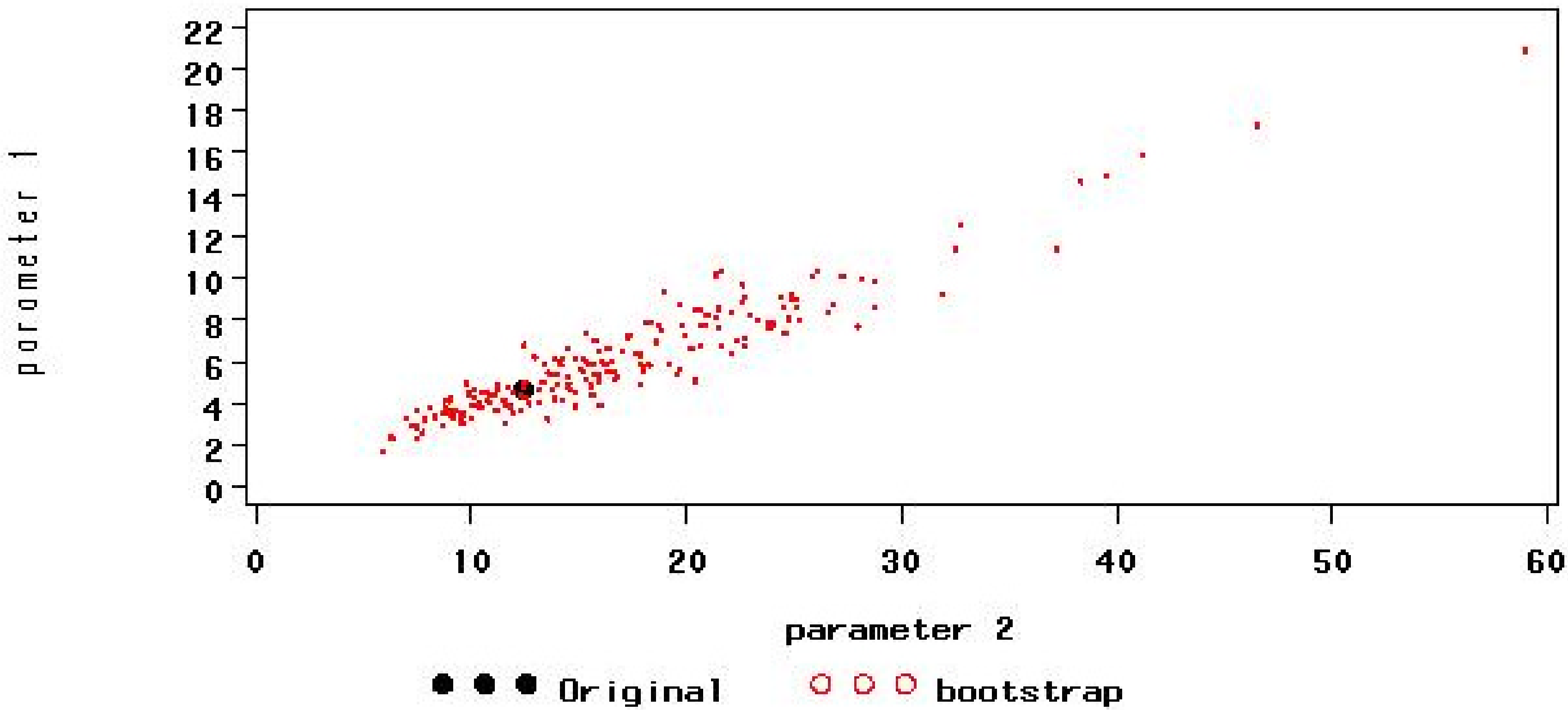


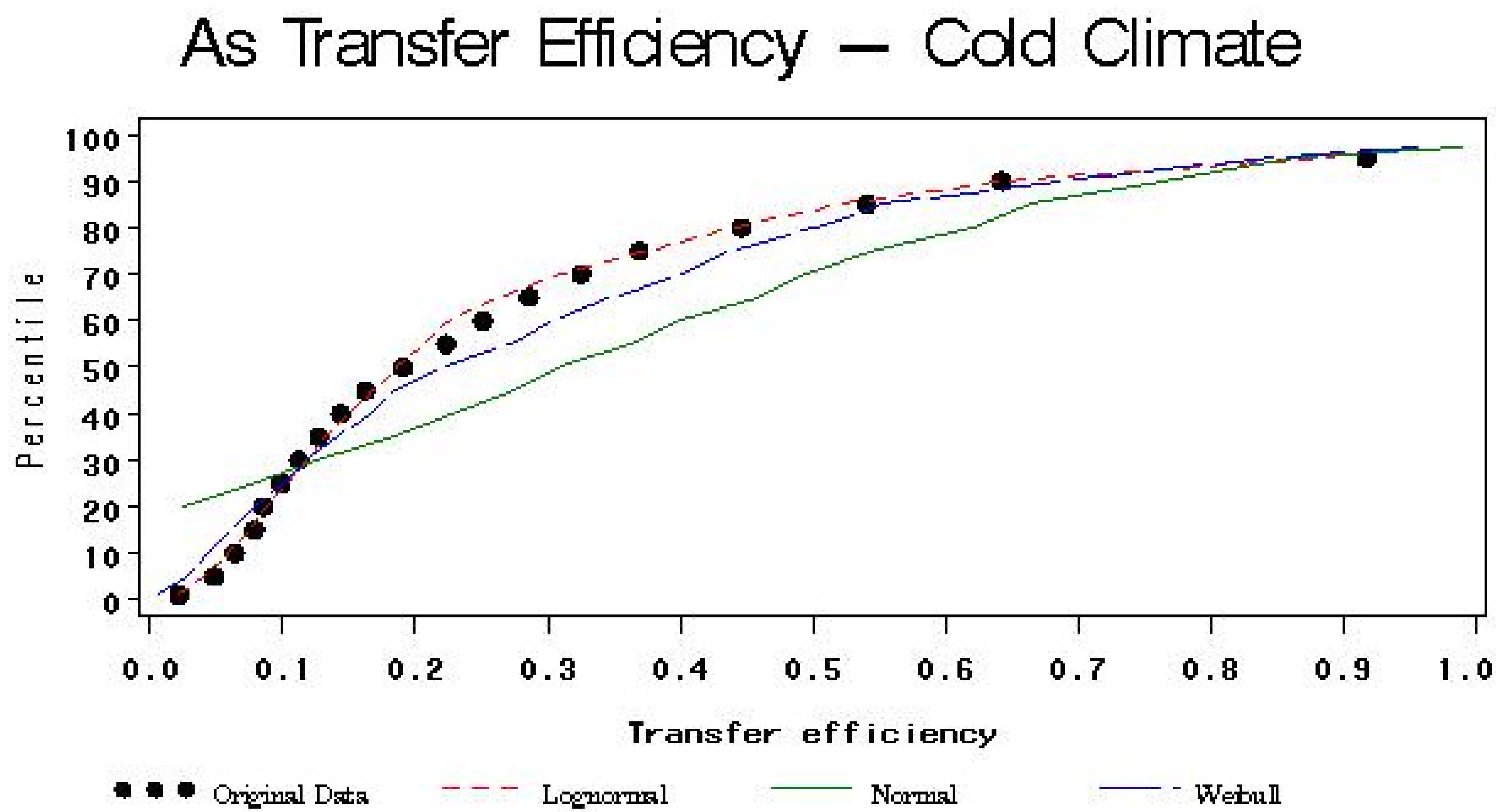
Residue As GI Absorption Fraction per Day



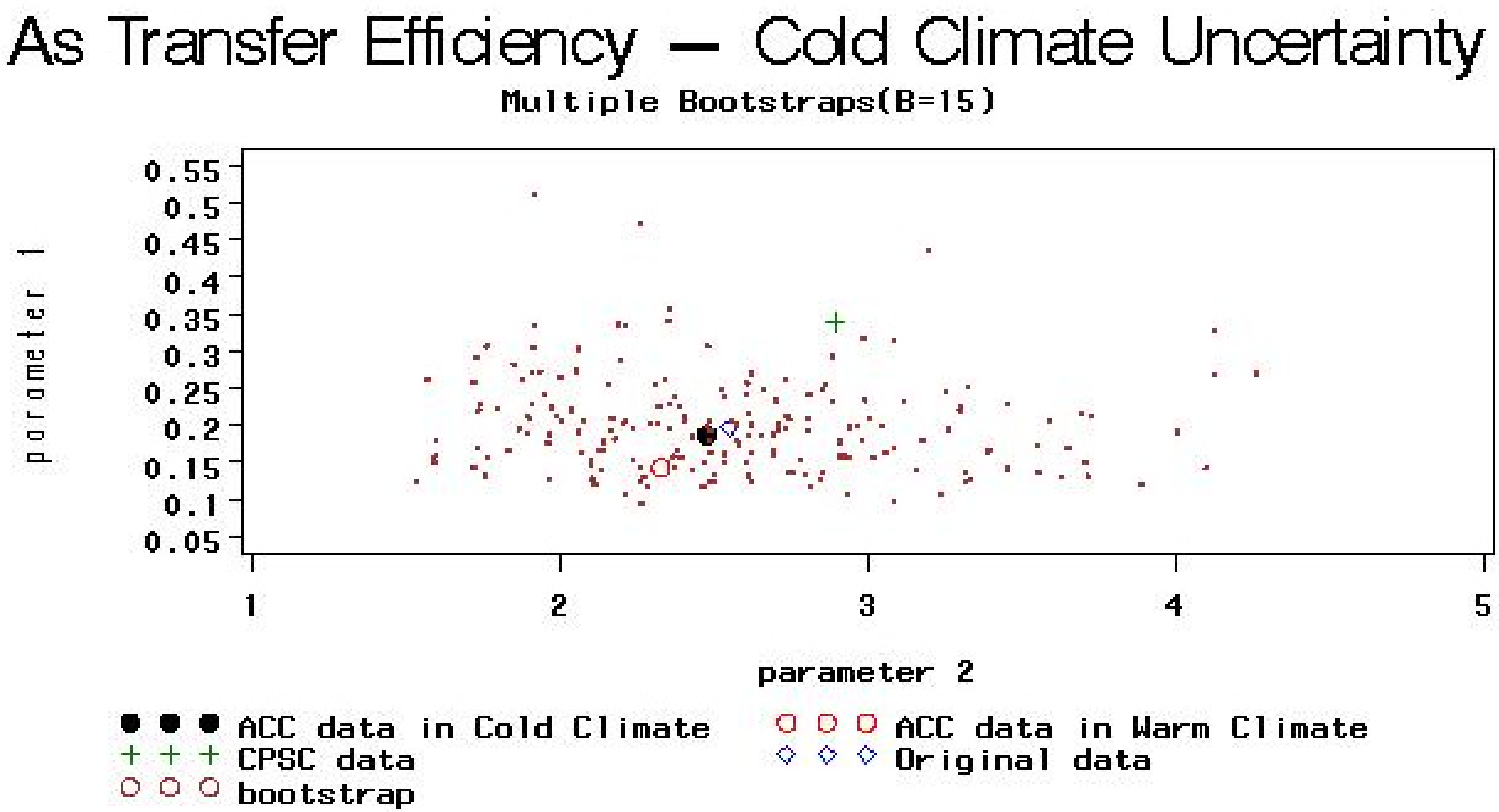
Residue As GI Absorption Fraction per Day Uncertainty

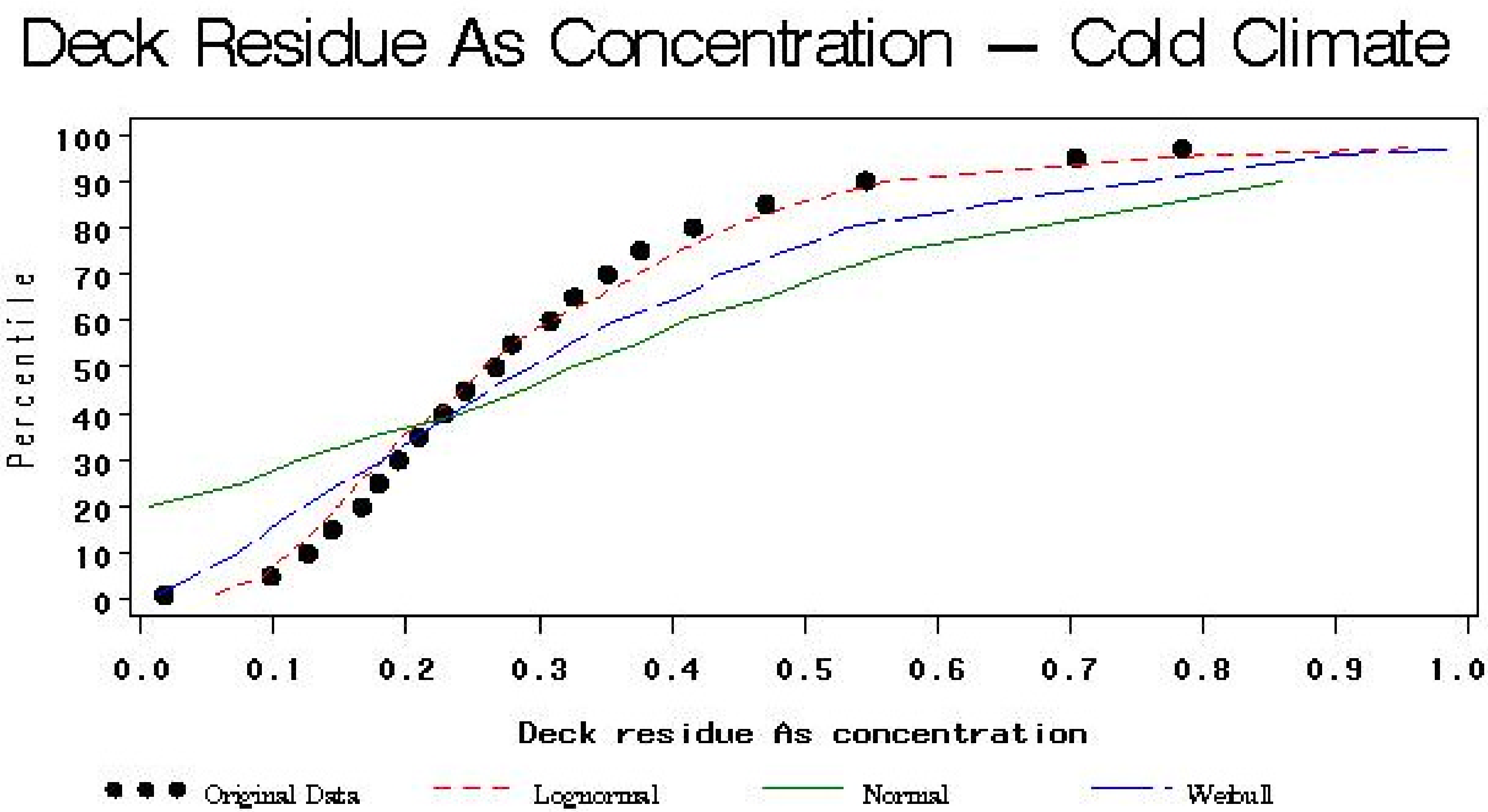
Multiple Bootstraps(B=15)

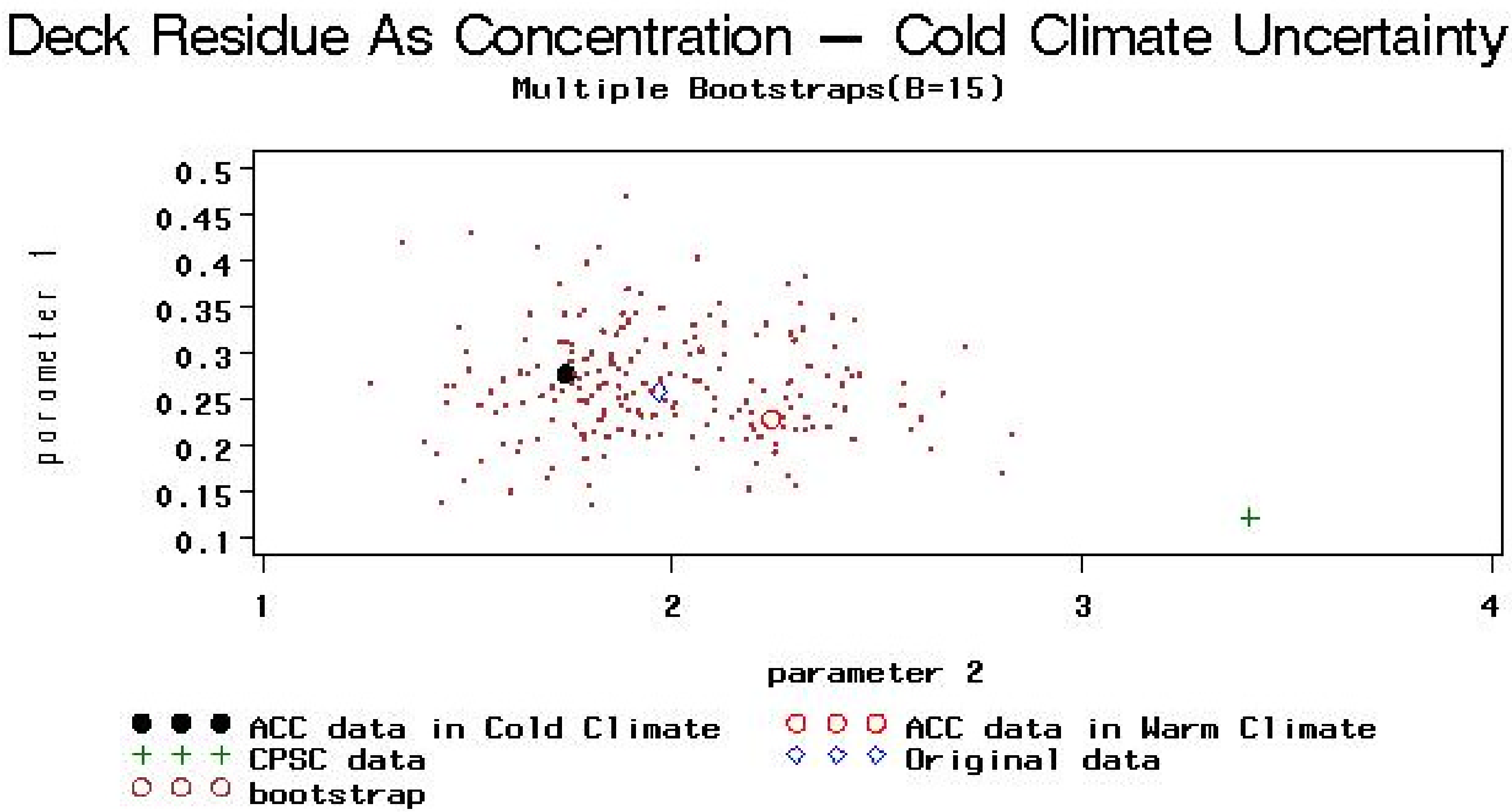




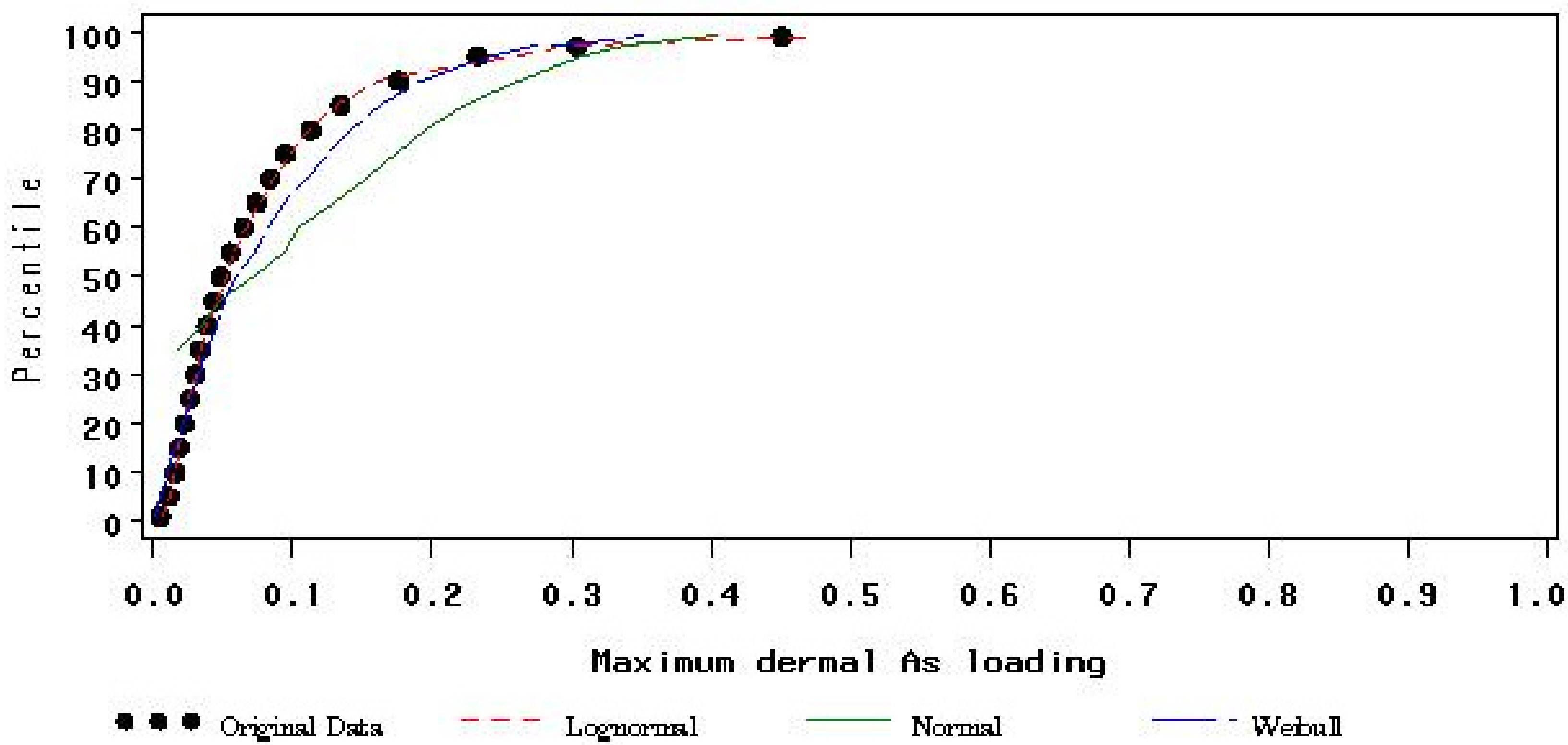
As Transfer Efficiency – Cold Climate
Percentile
0
10
20
30
40
50
60
70
80
90
100
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Transfer efficiency
Original Data
Lognormal
Normal
Weibull

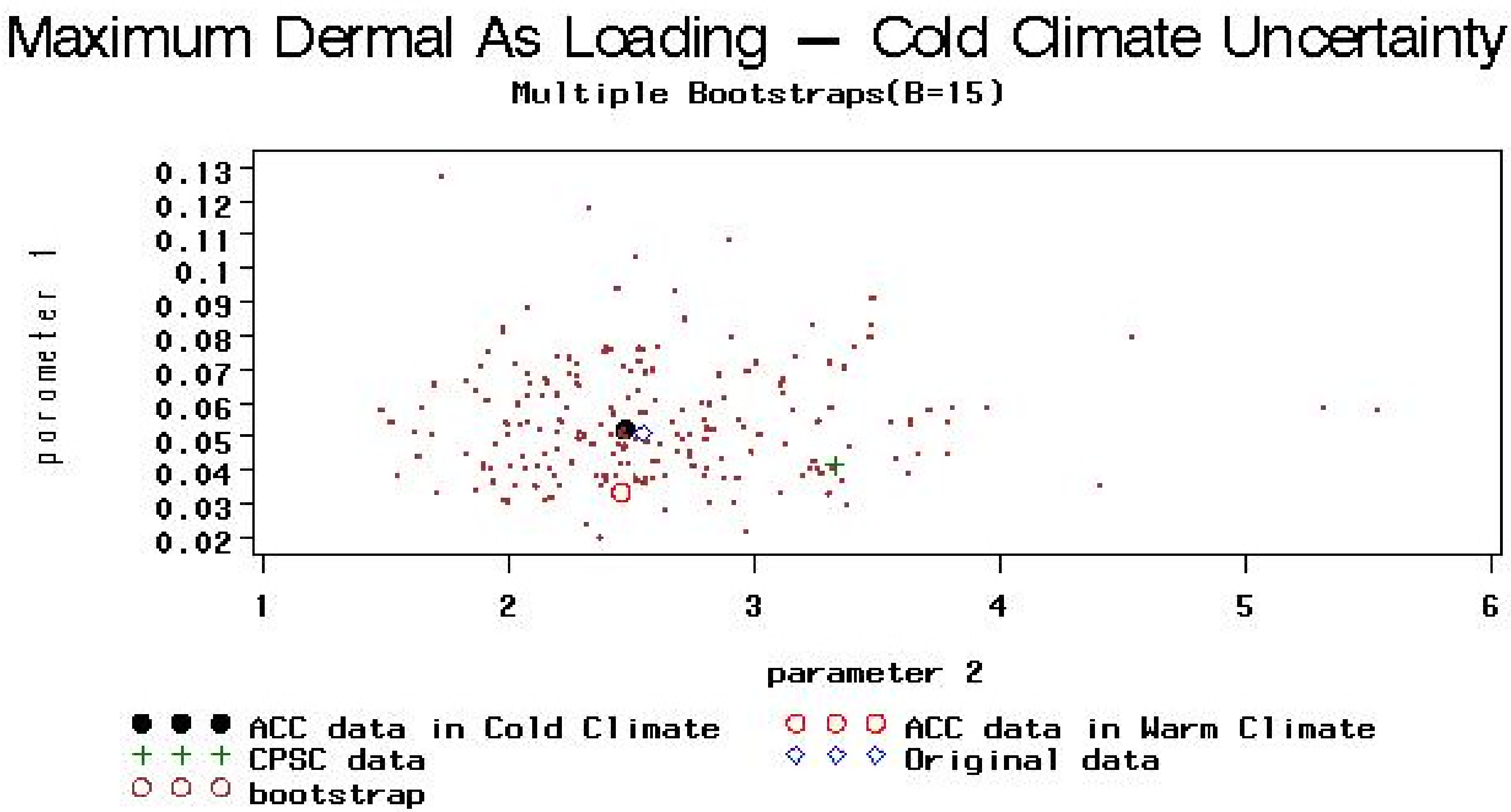

As Transfer Efficiency — Cold Climate Uncertainty
Multiple Bootstraps(B=15)
parameter 1
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
1
2
3
4
5
parameter 2
ACC data in Cold Climate
CPSC data
bootstrap
ACC data in Warm Climate
Original data


Deck Residue As Concentration – Cold Climate
100
90
80
70
60
50
40
30
20
10
0
Percentile
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Deck residue As concentration
Original Data
Lognormal
Normal
Weibull


Deck Residue As Concentration — Cold Climate Uncertainty
Multiple Bootstraps(B=15)
parameter 1
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
1
2
3
4
parameter 2
ACC data in Cold Climate
CPSC data
bootstrap
ACC data in Warm Climate
Original data

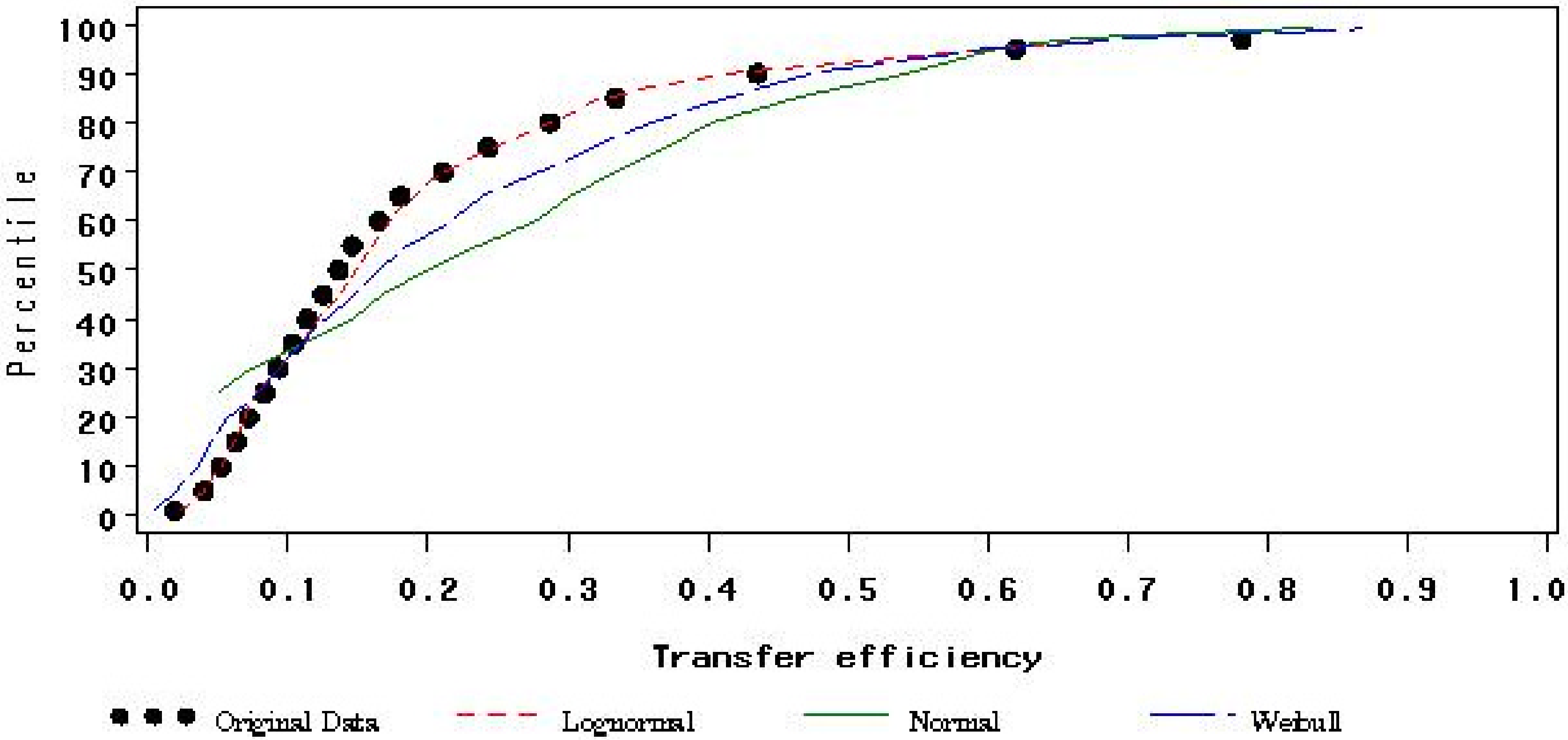
Maximum Dermal As Loading – Cold Climate



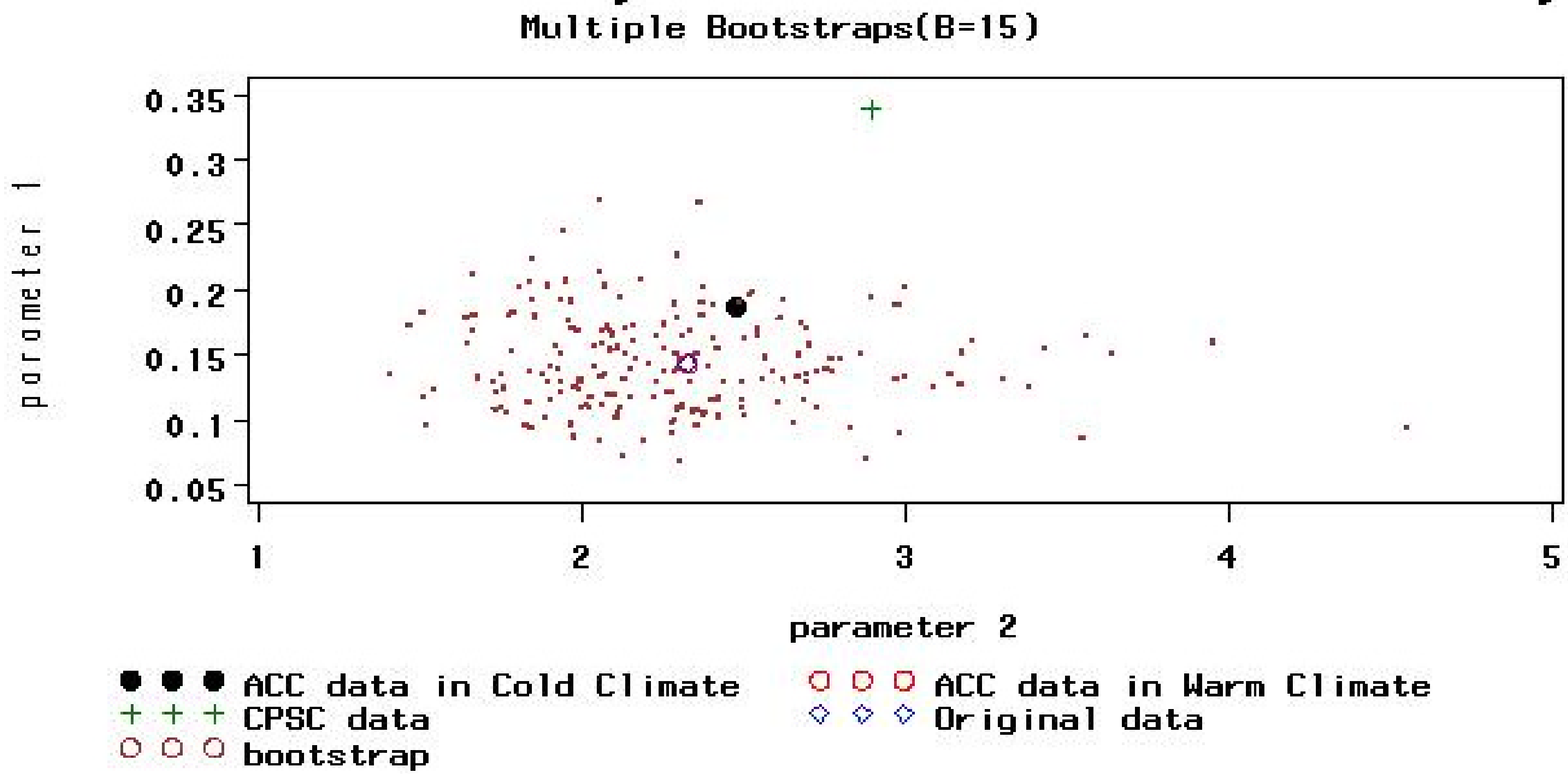


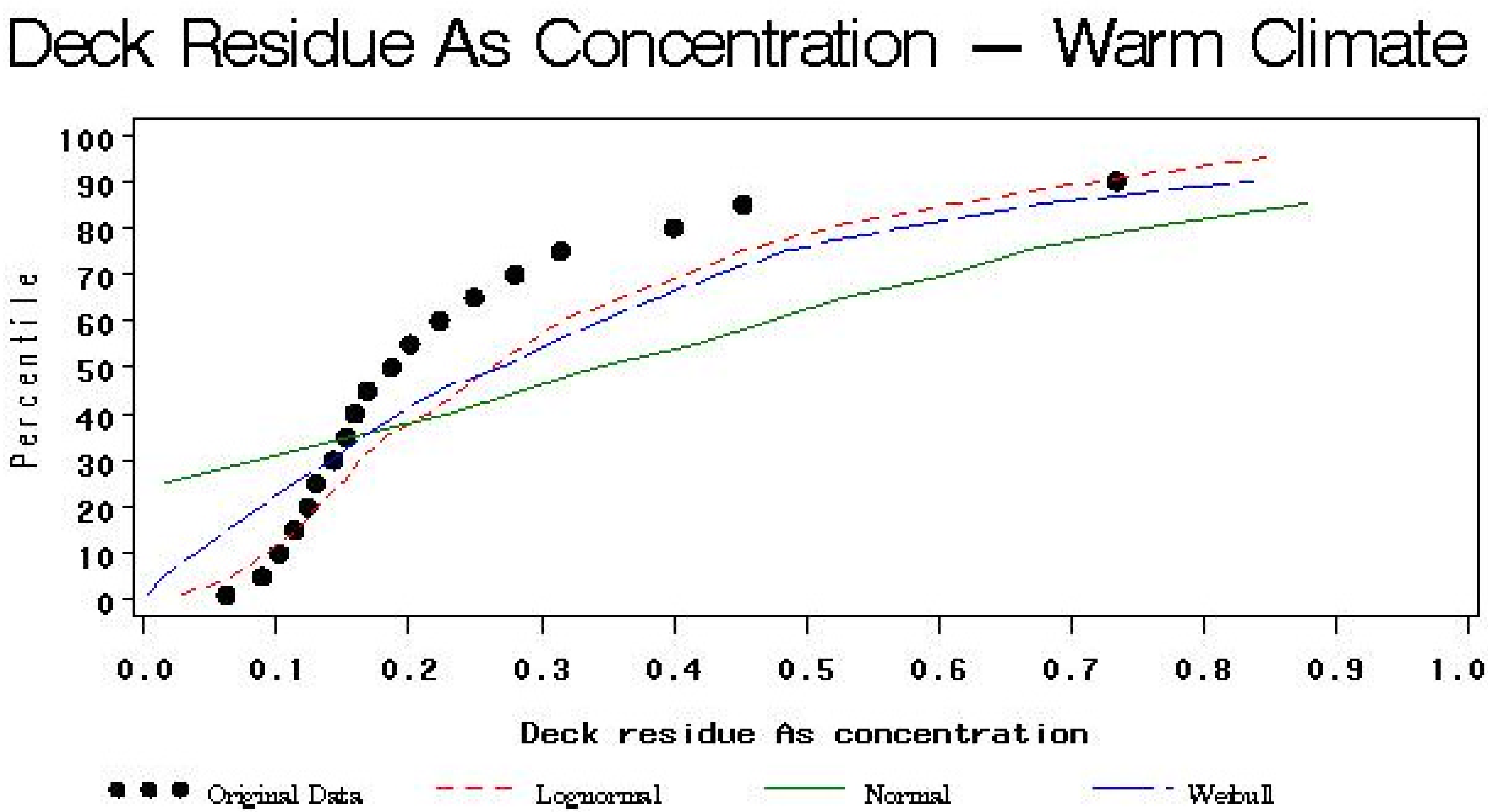
Maximum Dermal As Loading — Cold Climate Uncertainty
Multiple Bootstraps(B=15)
parameter 1
0.13
0.12
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
1
2
3
4
5
6
parameter 2
ACC data in Cold Climate
ACC data in Warm Climate
CPSC data
Original data
bootstrap

As Transfer Efficiency – Warm Climate

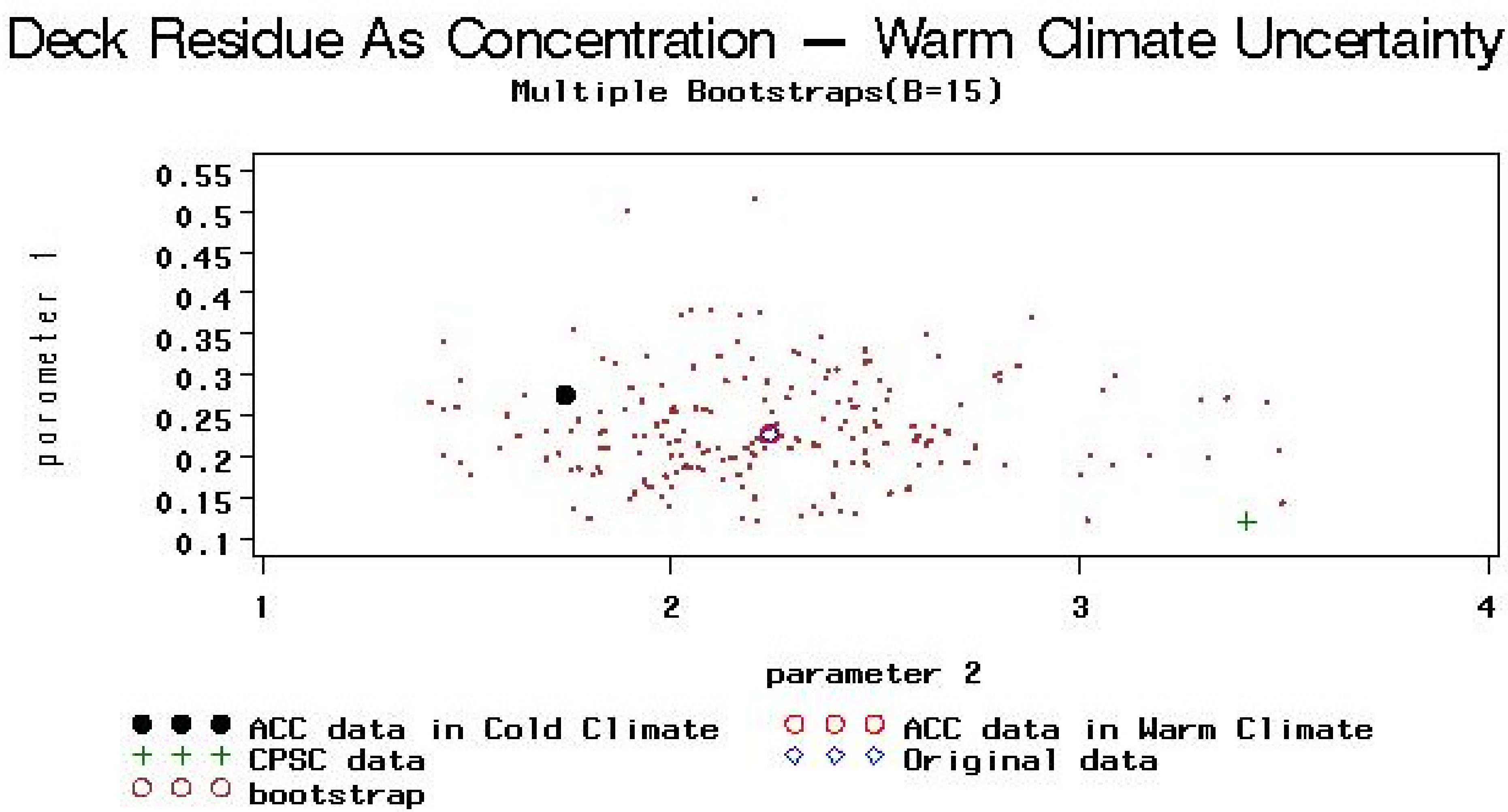


As Transfer Efficiency — Warm Climate Uncertainty



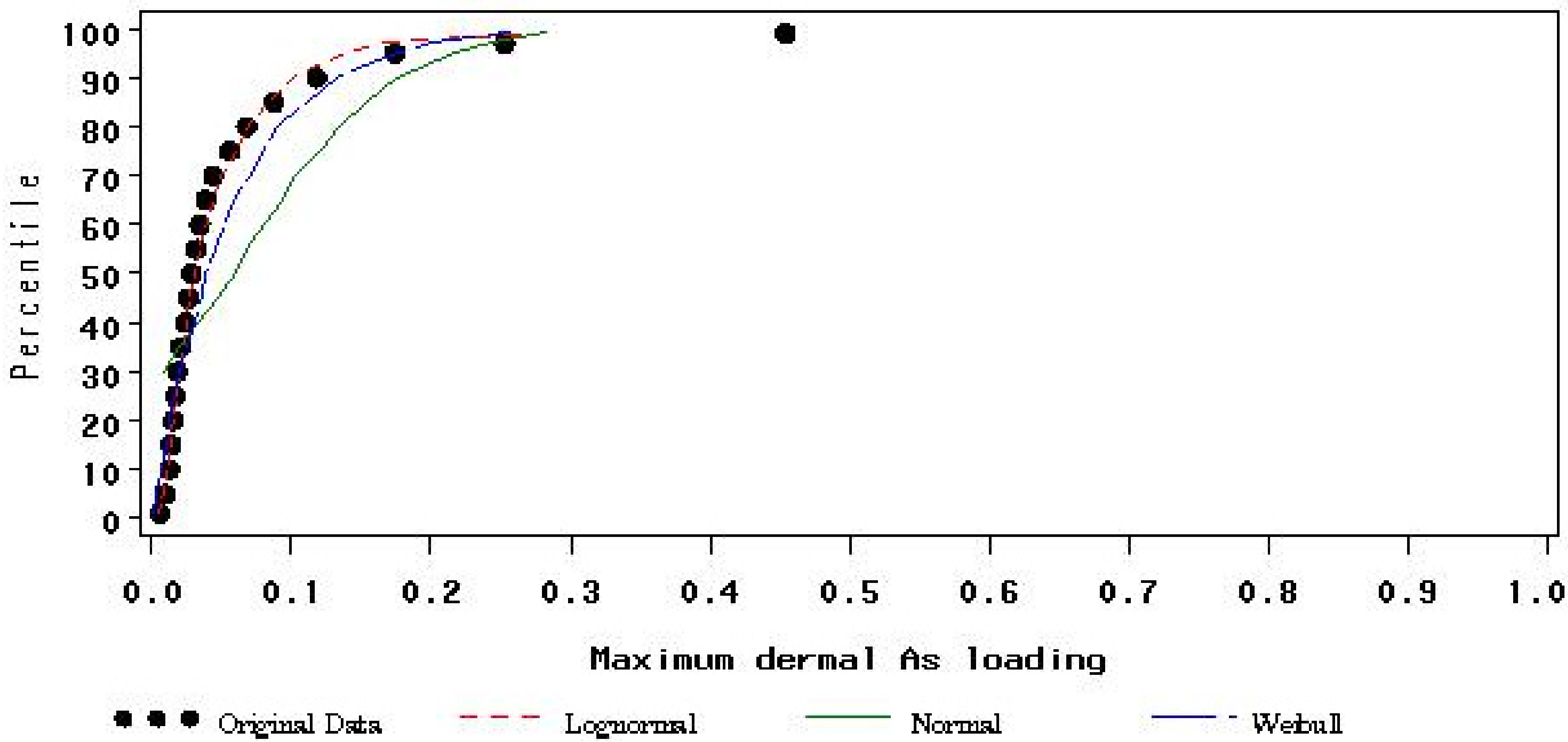


Deck Residue As Concentration — Warm Climate
Percentile
100
90
80
70
60
50
40
30
20
10
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Deck residue As concentration
Original Data
Lognormal
Normal
Weibull



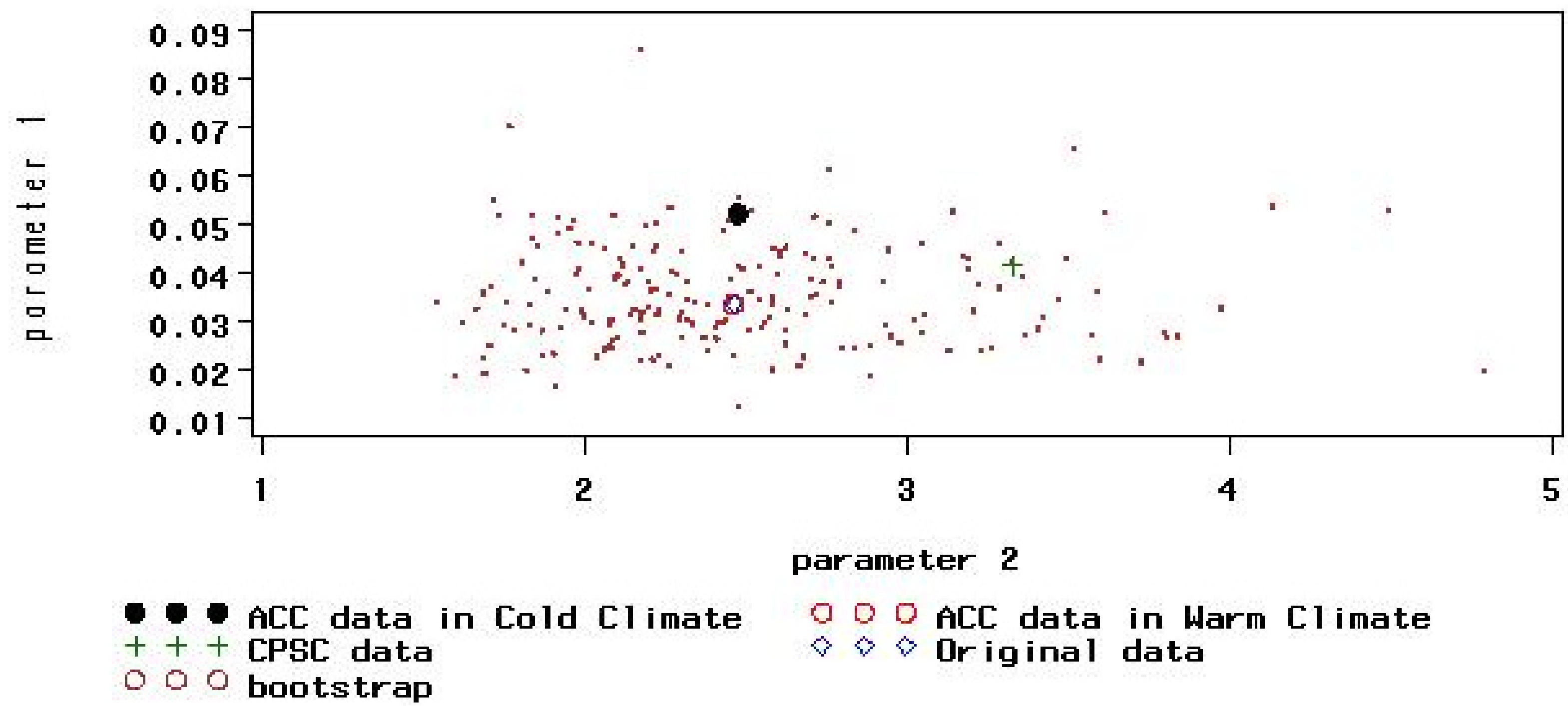
Deck Residue As Concentration — Warm Climate Uncertainty
Multiple Bootstraps(B=15)
parameter 1
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
1
2
3
4
parameter 2
ACC data in Cold Climate
ACC data in Warm Climate
CPSC data
Original data
bootstrap

Maximum Dermal As Loading – Warm Climate

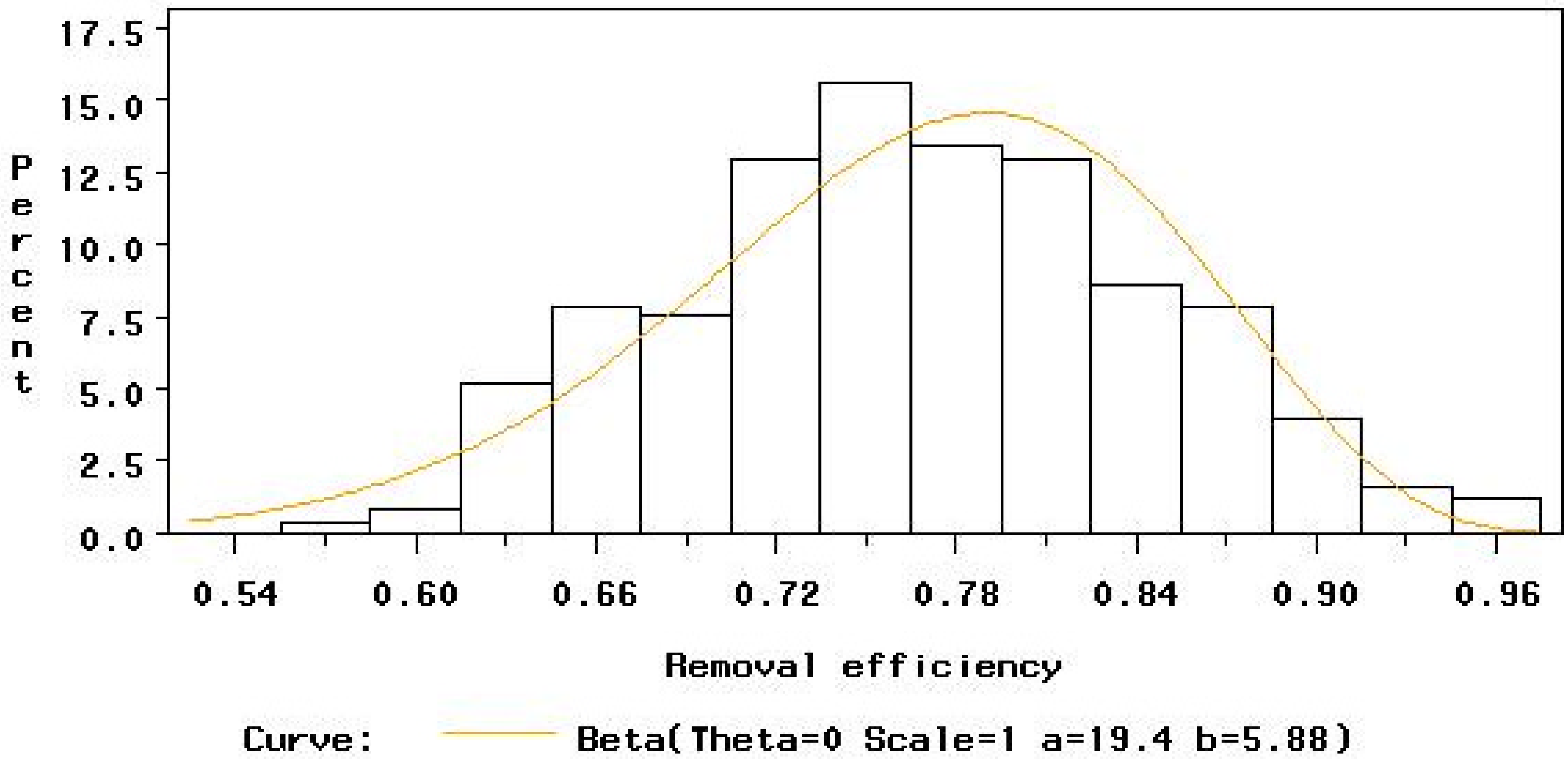


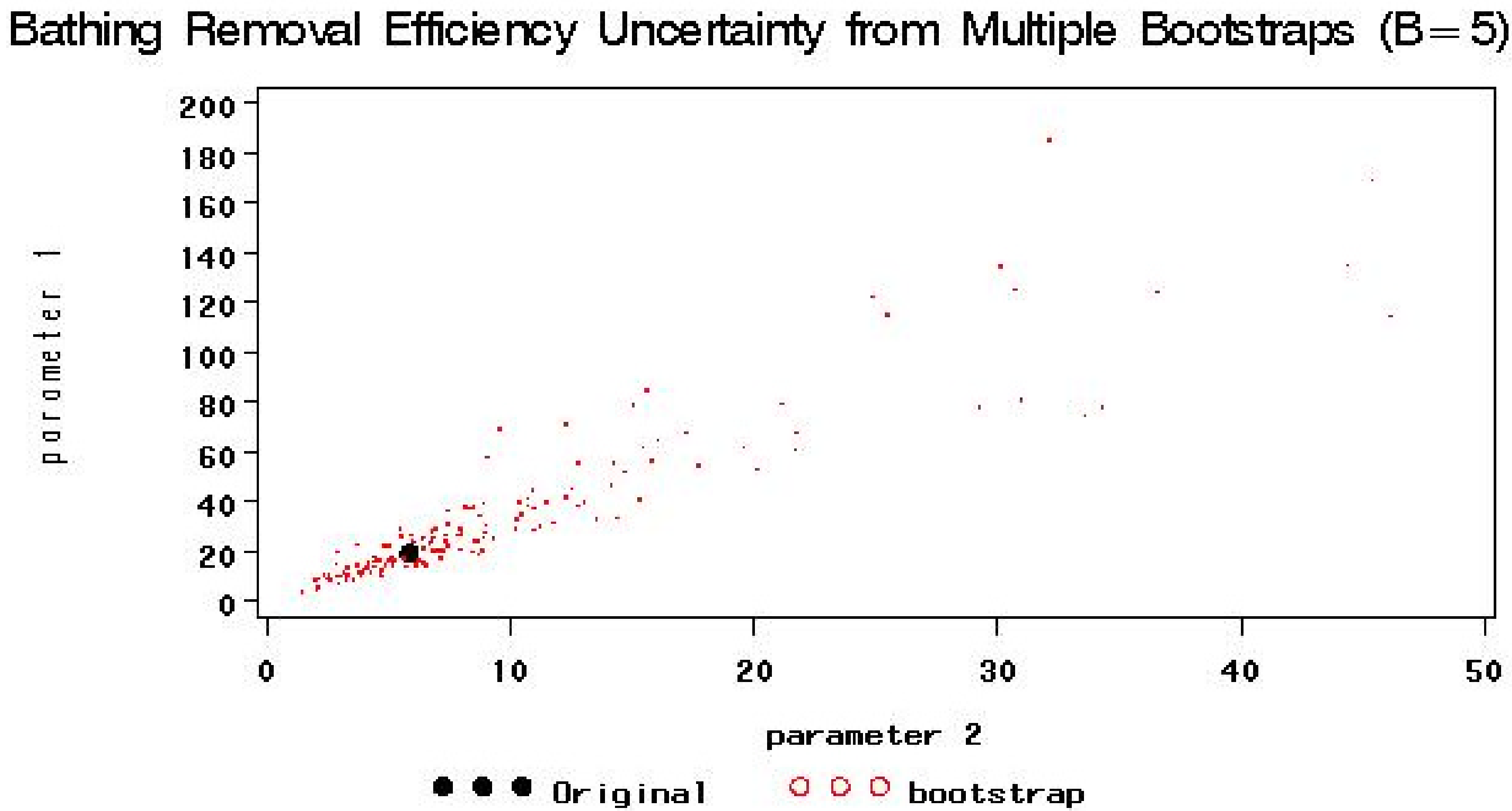
Maximum Dermal As Loading — Warm Climate Uncertainty

Multiple Bootstraps(B=15)

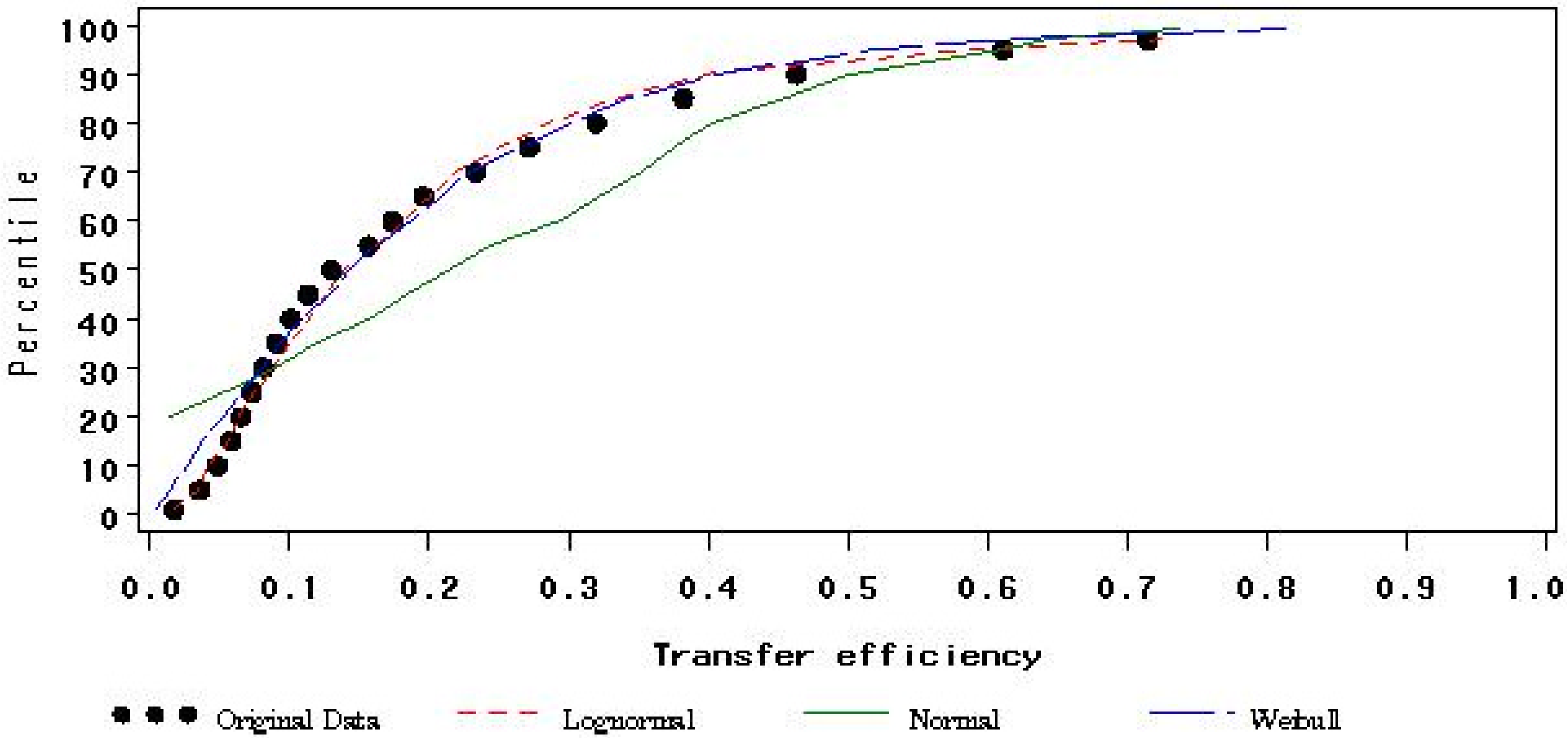


Bathing Removal Efficiency

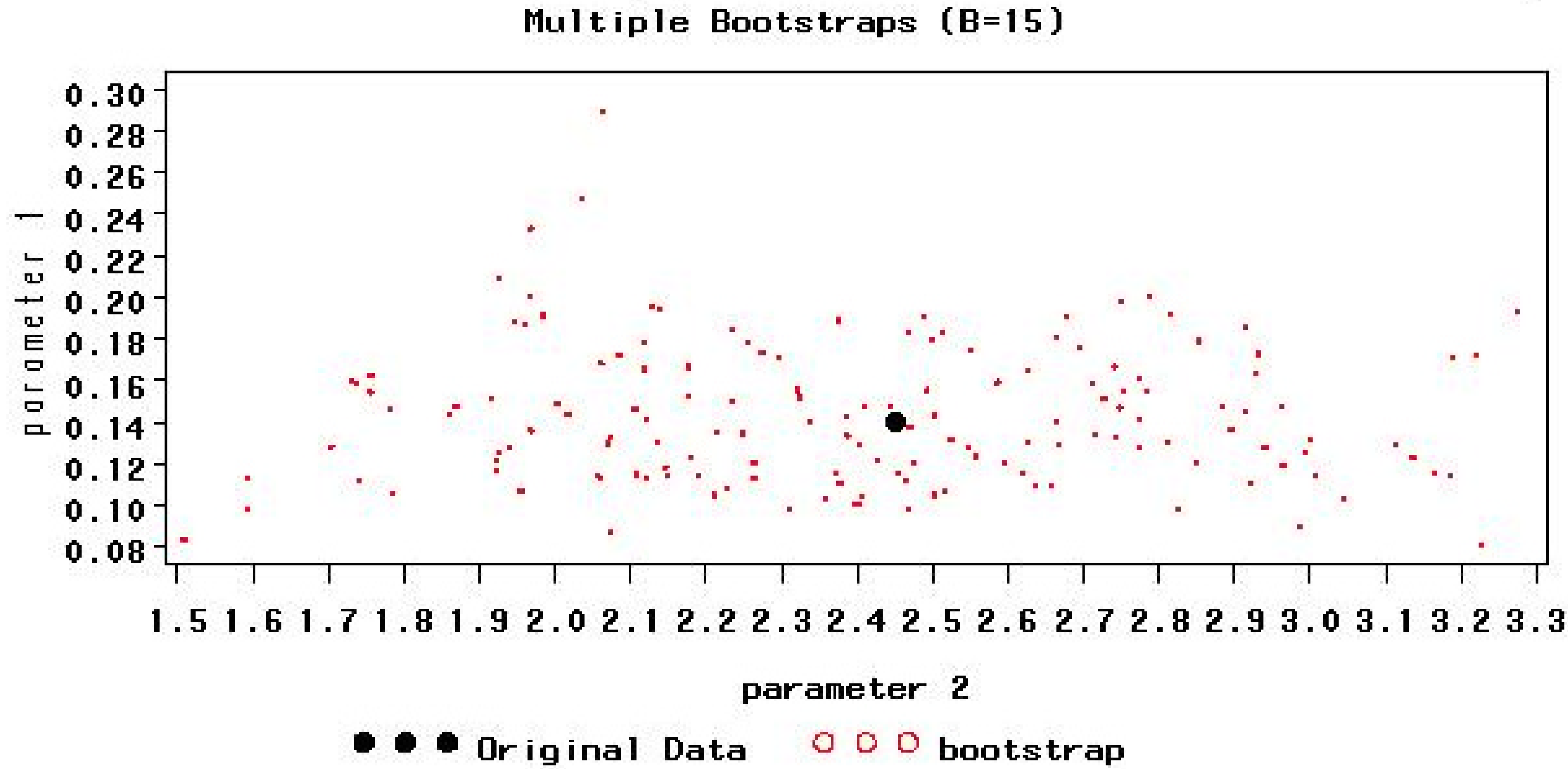



Bathing Removal Efficiency Uncertainty from Multiple Bootstraps (B=5)
parameter 1
200
180
160
140
120
100
80
60
40
20
0
0
10
20
30
40
50
parameter 2
Original
bootstrap

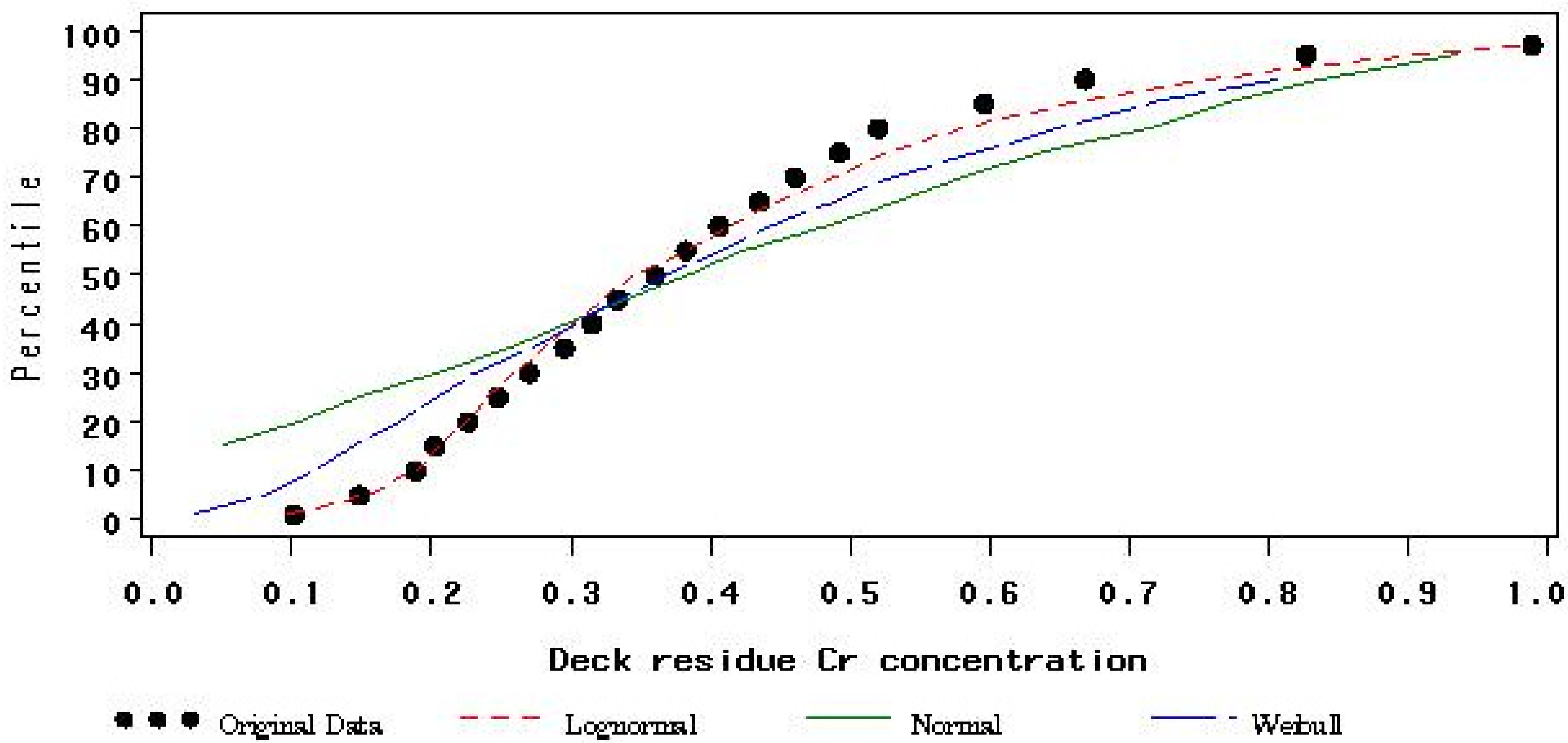
Cr Transfer efficiency – Cold Climate

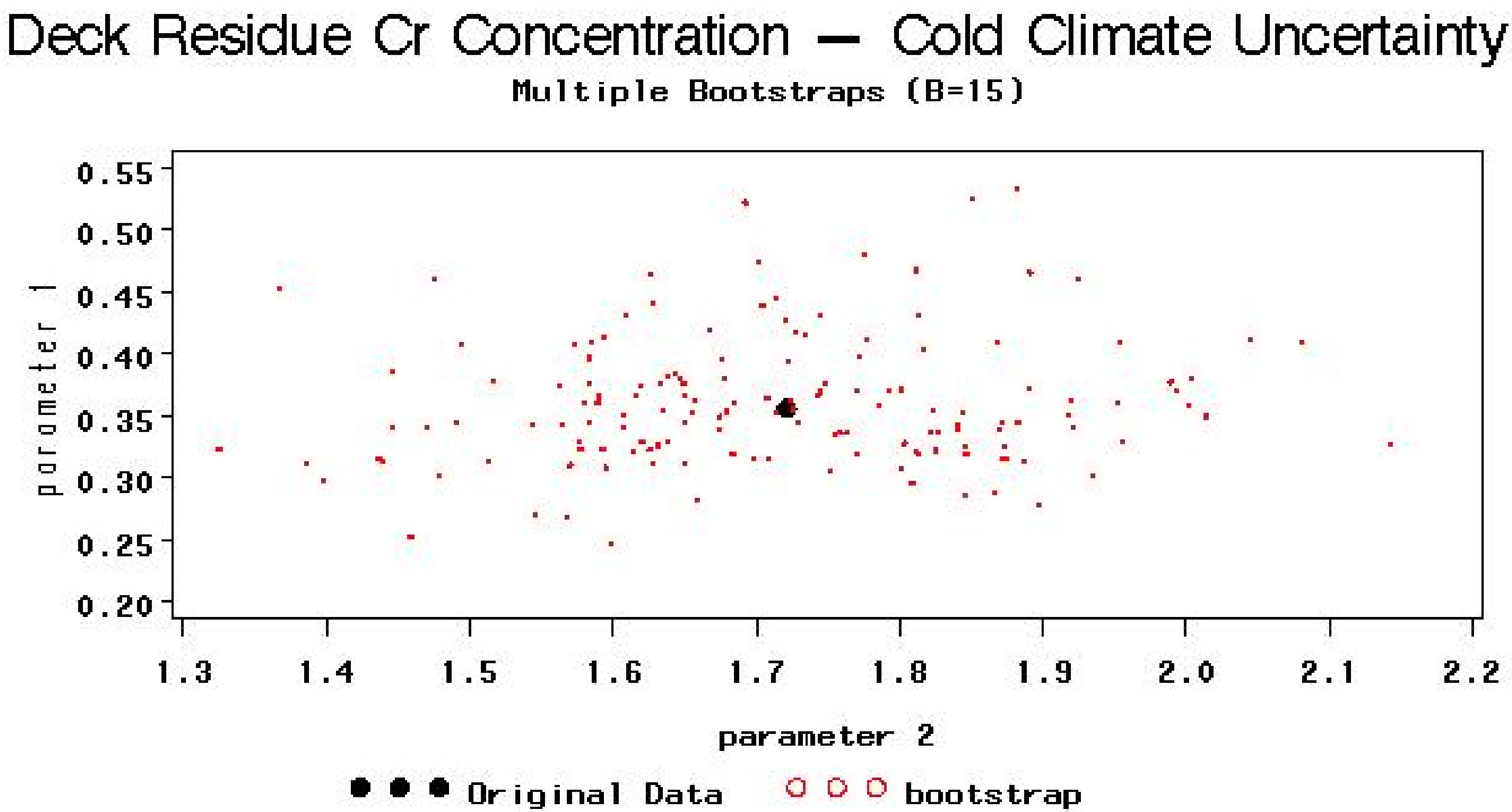


Cr Transfer Efficiency — Cold Climate Uncertainty



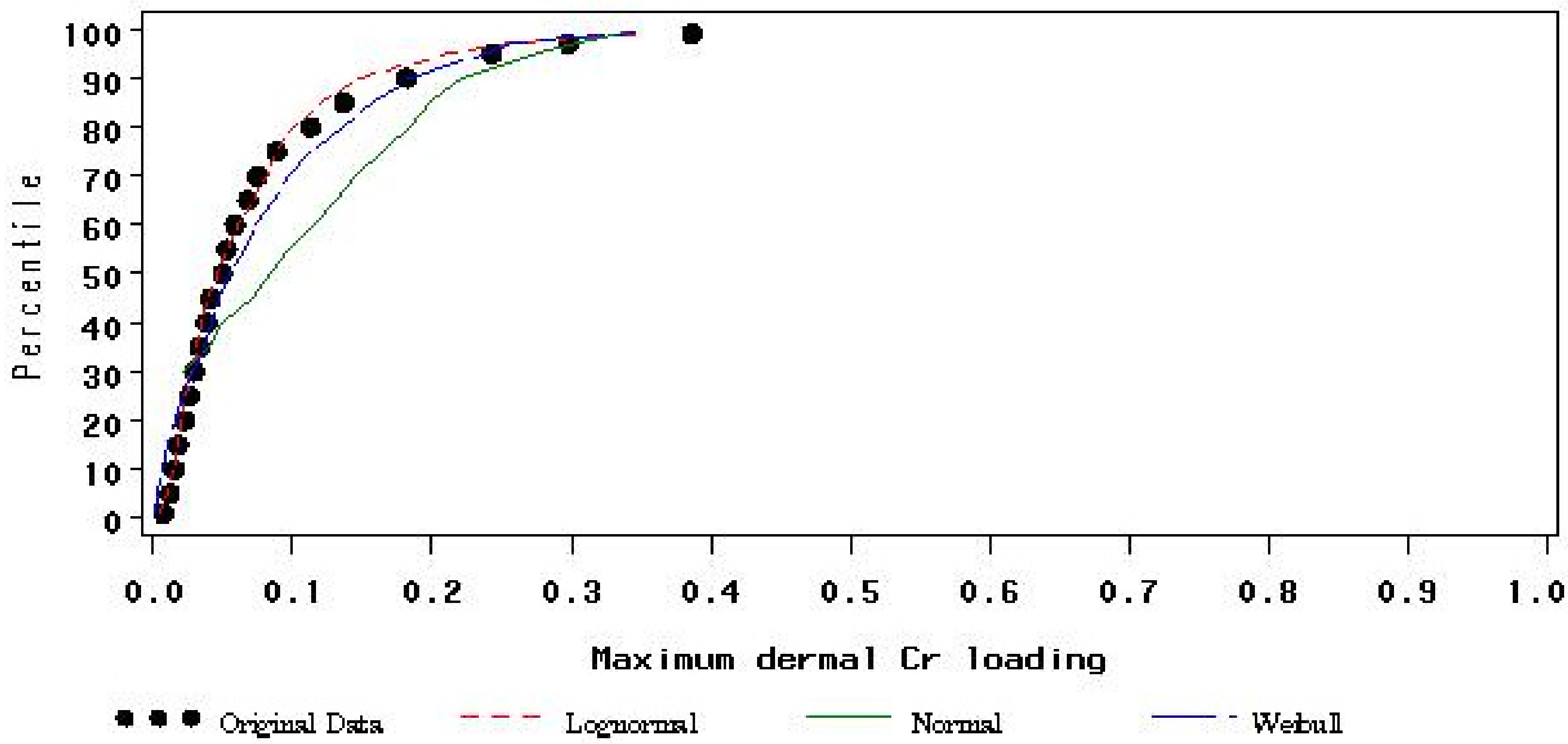
Deck Residue Cr Concentration – Cold Climate

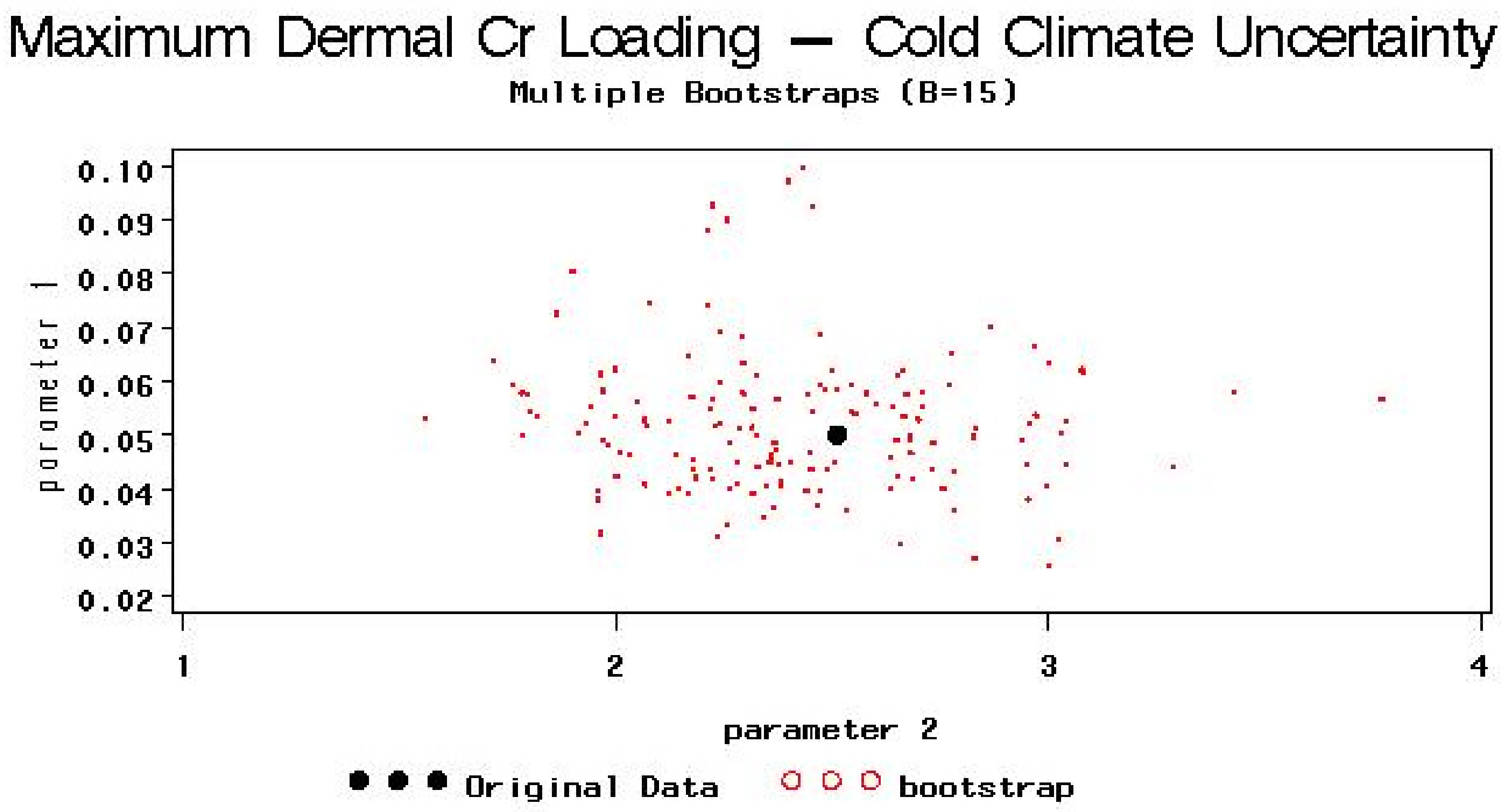




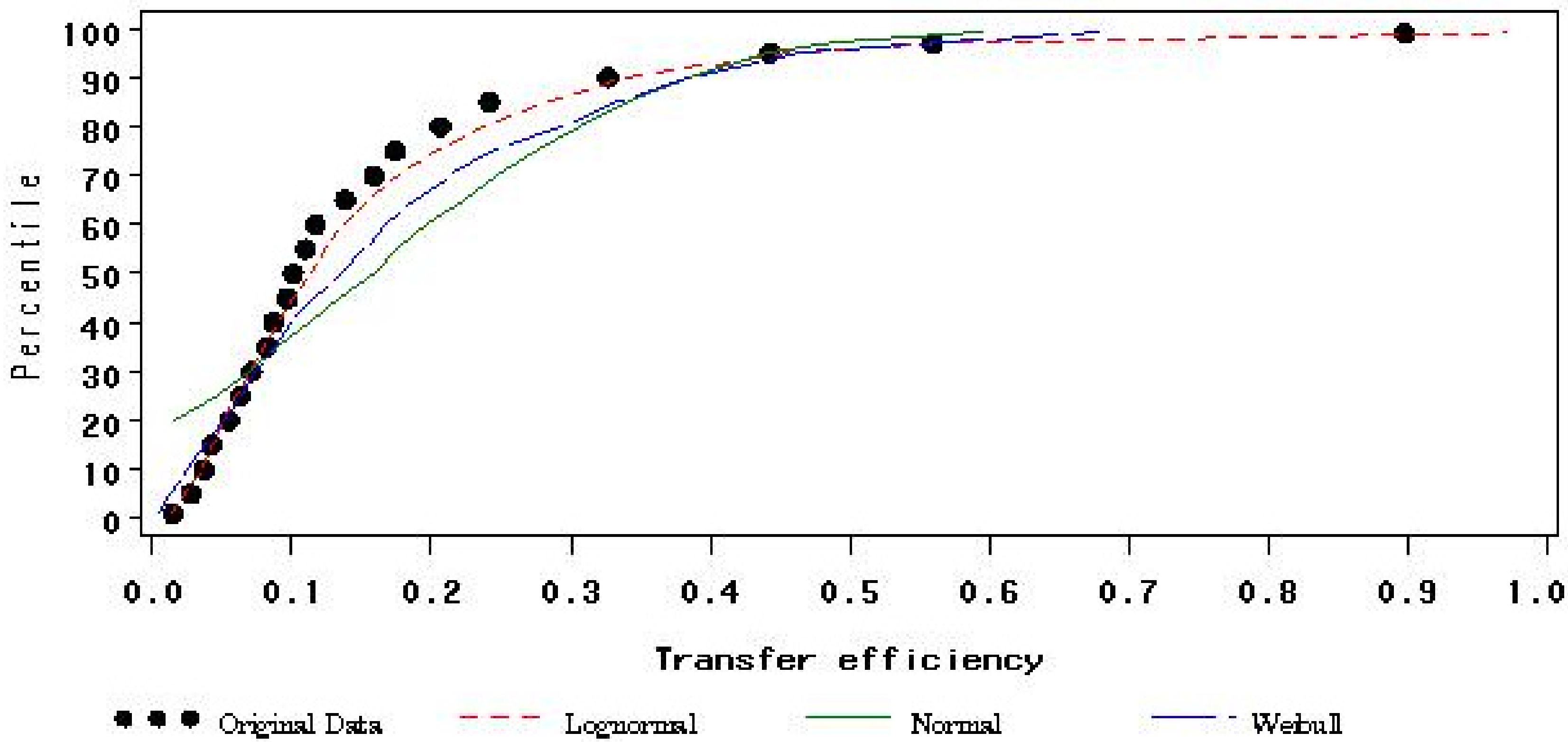
Deck Residue Cr Concentration — Cold Climate Uncertainty
Multiple Bootstraps (B=15)
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
parameter 1
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
parameter 2
Original Data
bootstrap

Maximum Dermal Cr Loading – Cold Climate



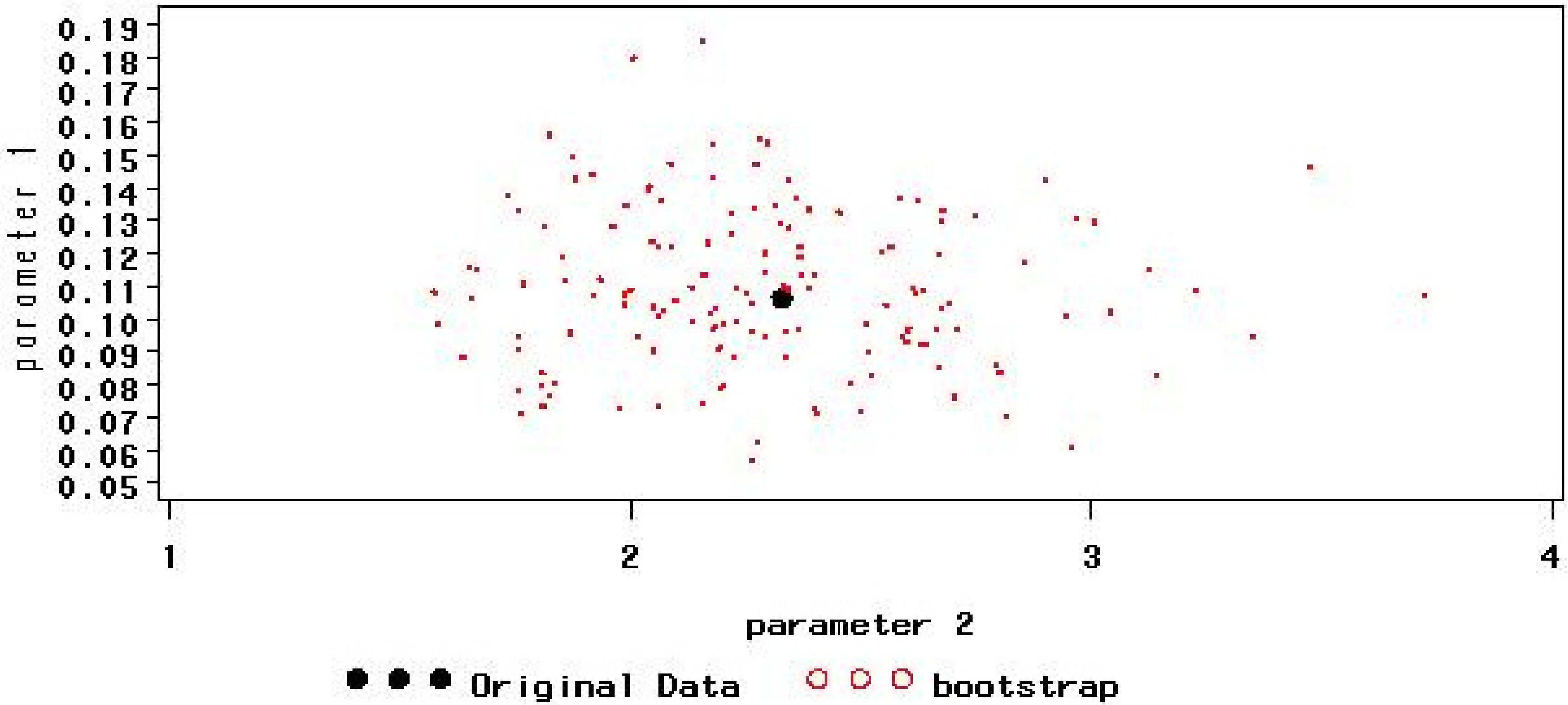

Maximum Dermal Cr Loading – Cold Climate Uncertainty
Multiple Bootstraps (B=15)
parameter 1
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
1
2
3
4
parameter 2
Original Data
bootstrap

Cr Transfer efficiency – Warm Climate

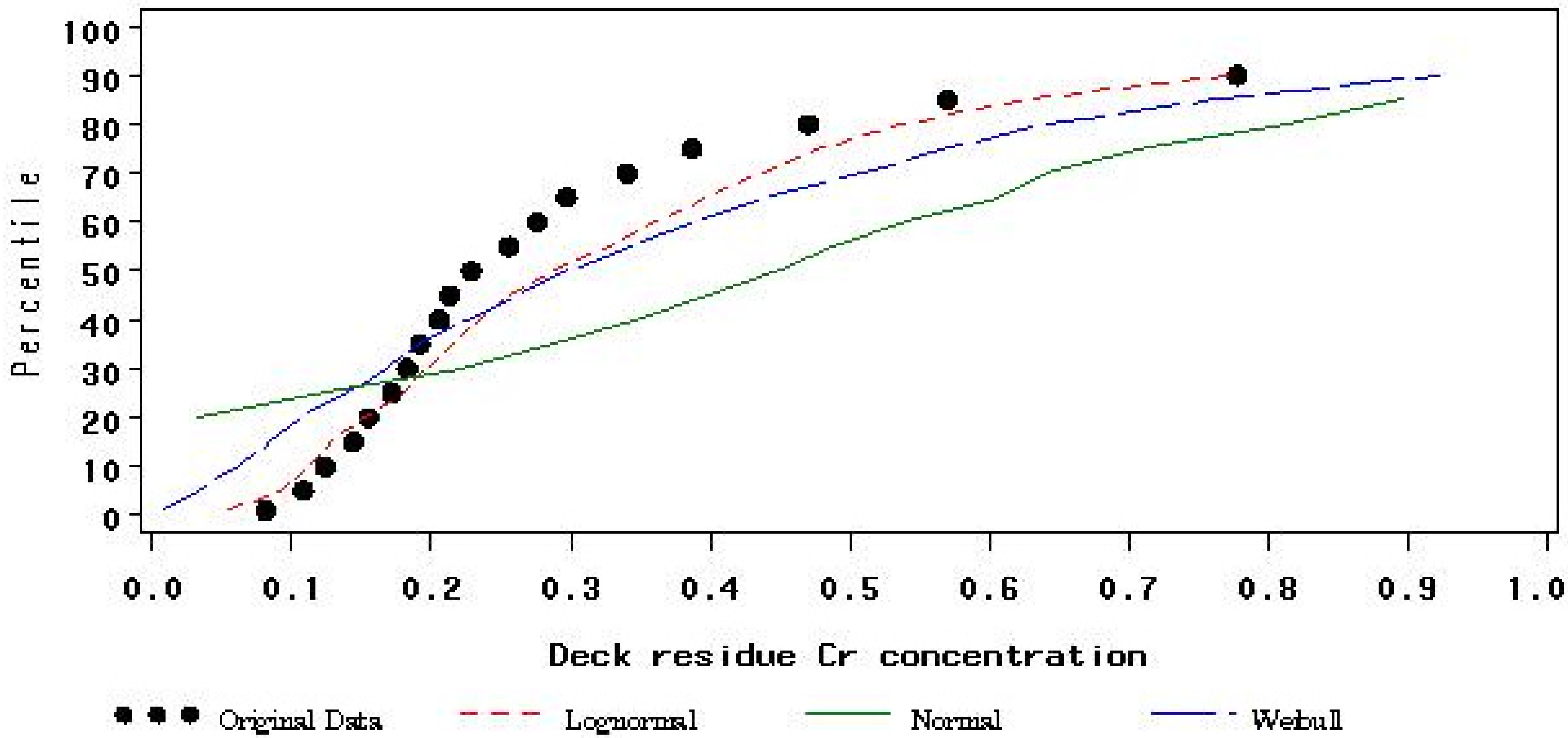


Cr Transfer Efficiency – Warm Climate Uncertainty

Multiple Bootstraps (B=15)

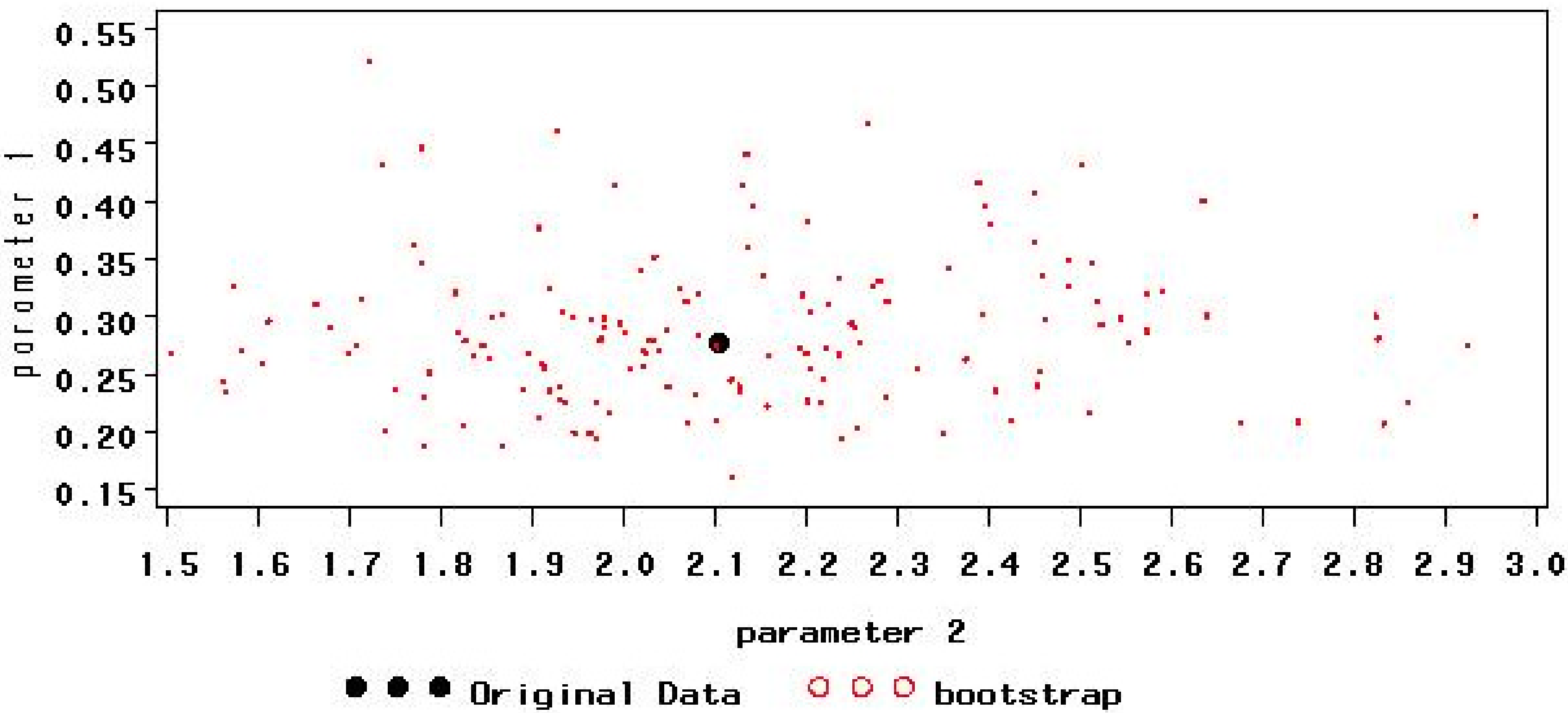


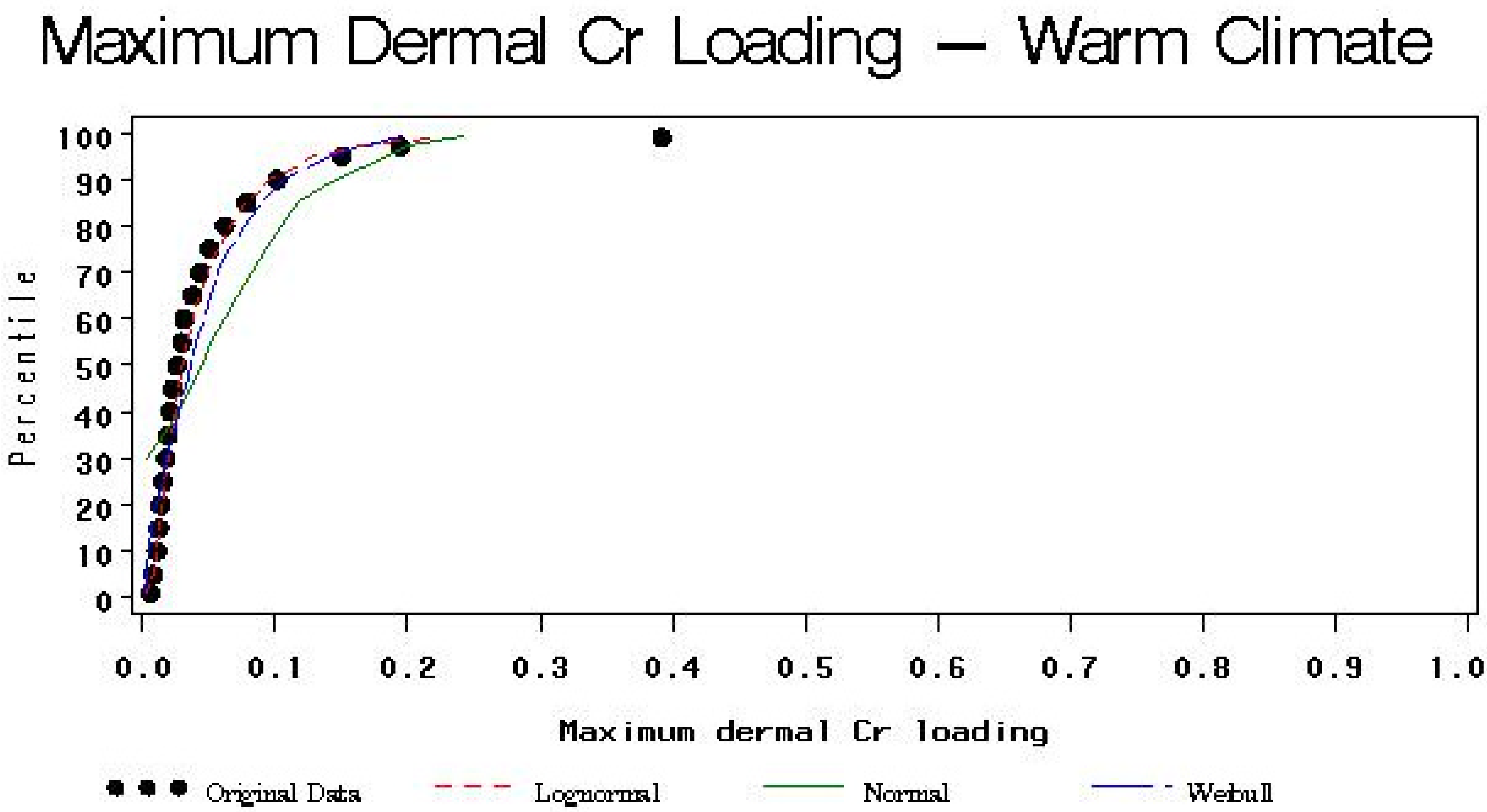
Deck Residue Cr Concentration – Warm Climate



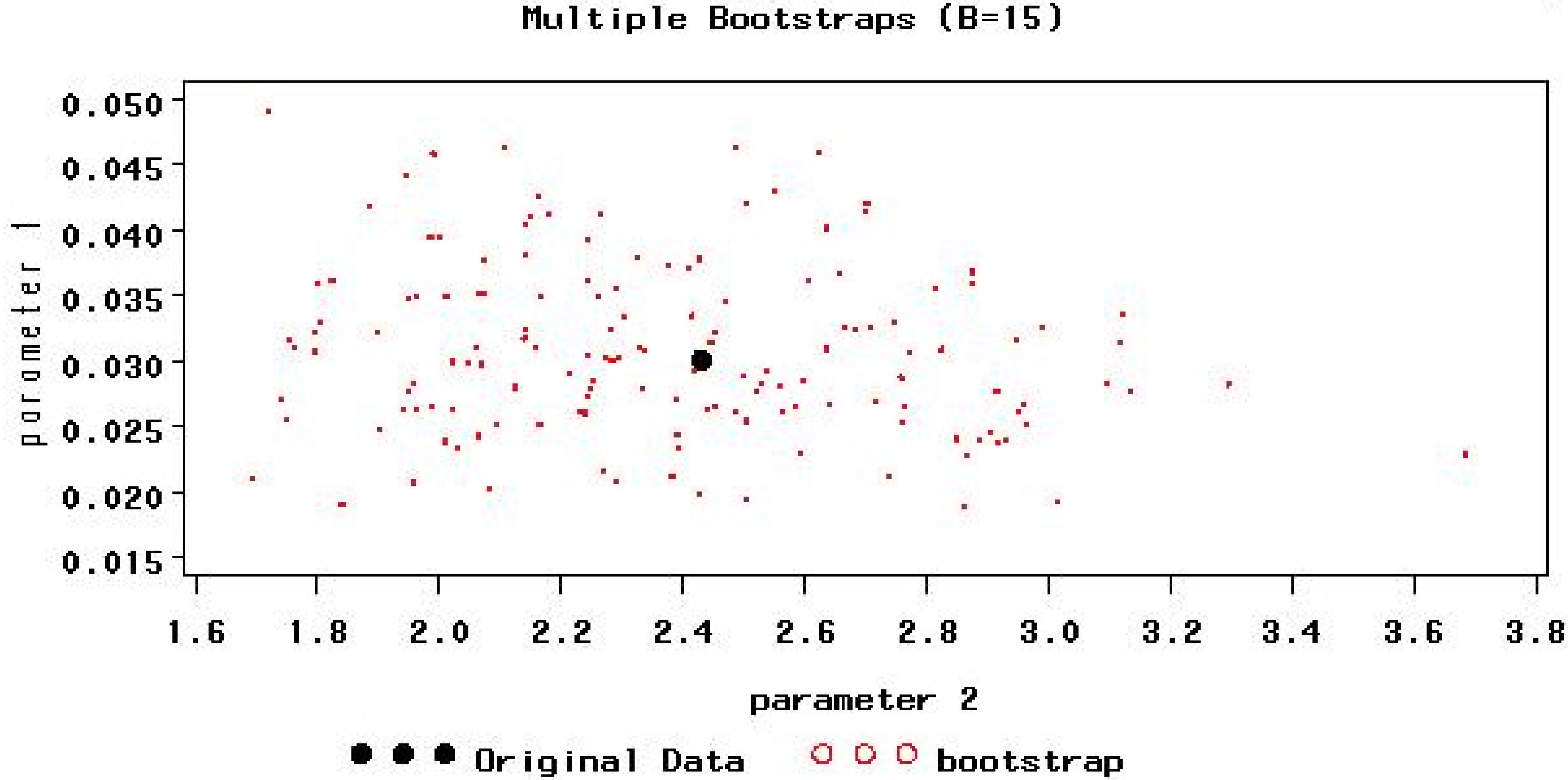
Deck Residue Cr Concentration — Warm Climate Uncertainty

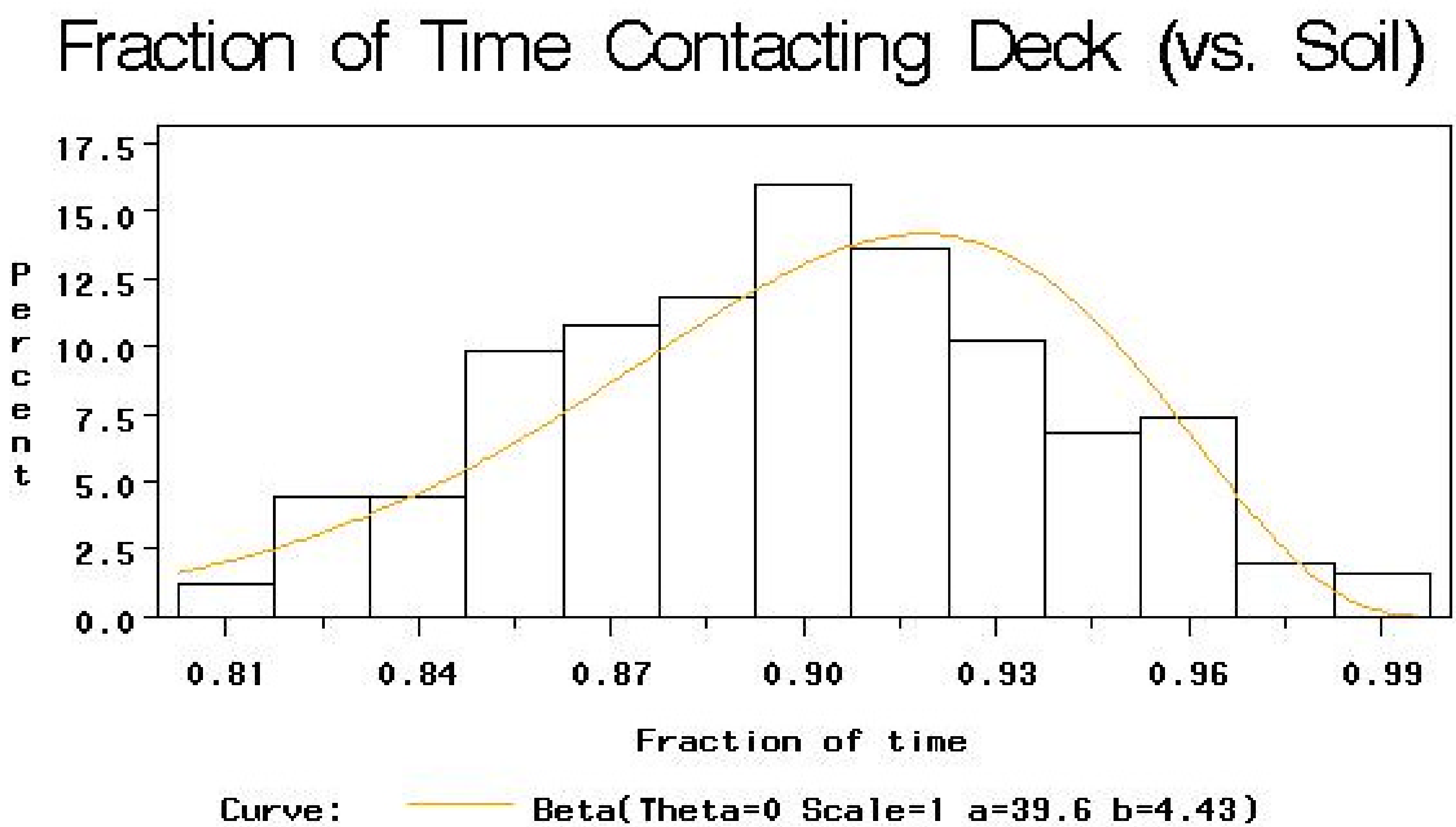
Multiple Bootstraps (B=15)



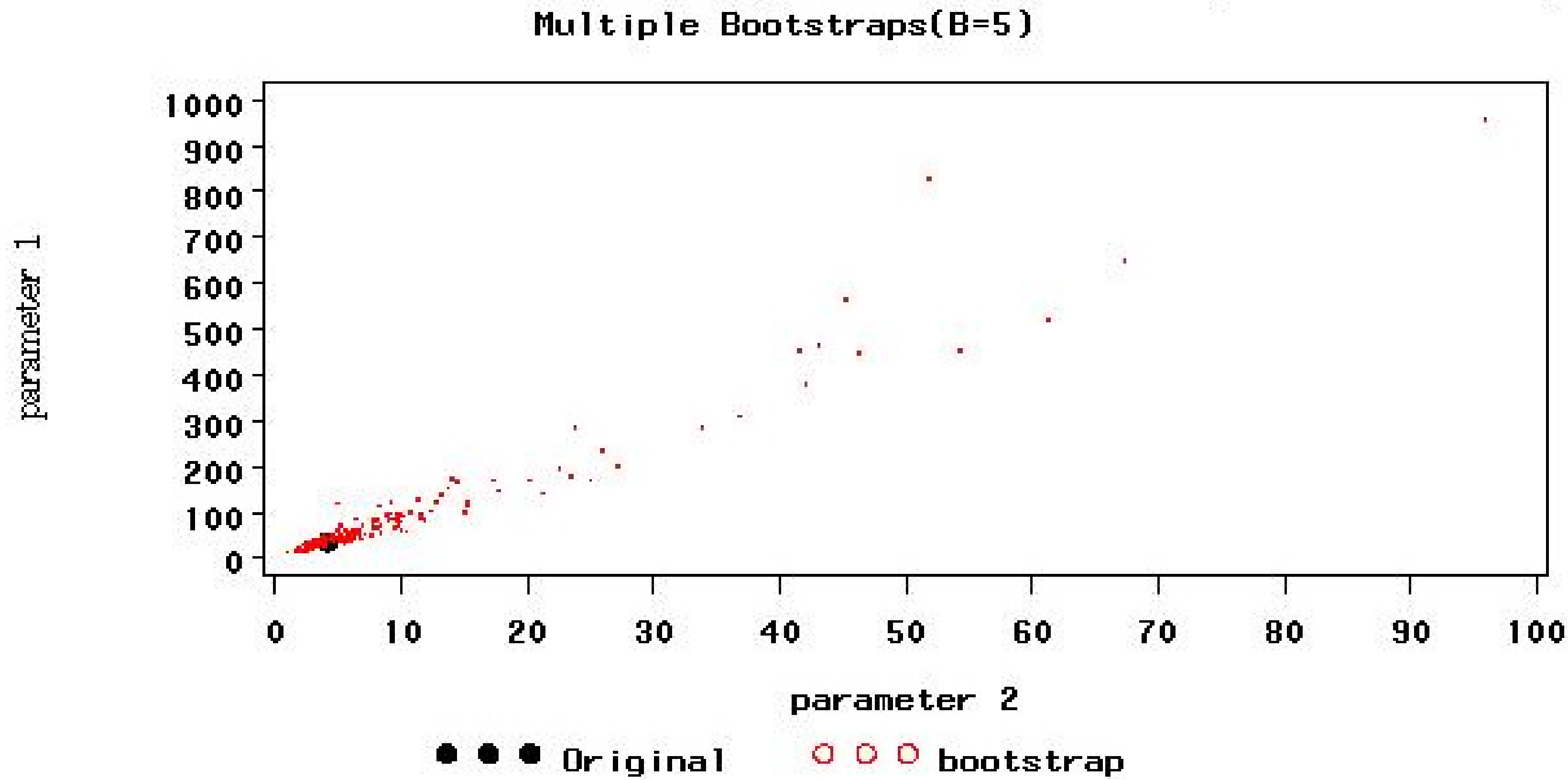

Maximum Dermal Cr Loading – Warm Climate
Percentile
100
90
80
70
60
50
40
30
20
10
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Maximum dermal Cr loading
Original Data
Lognormal
Normal
Weibull

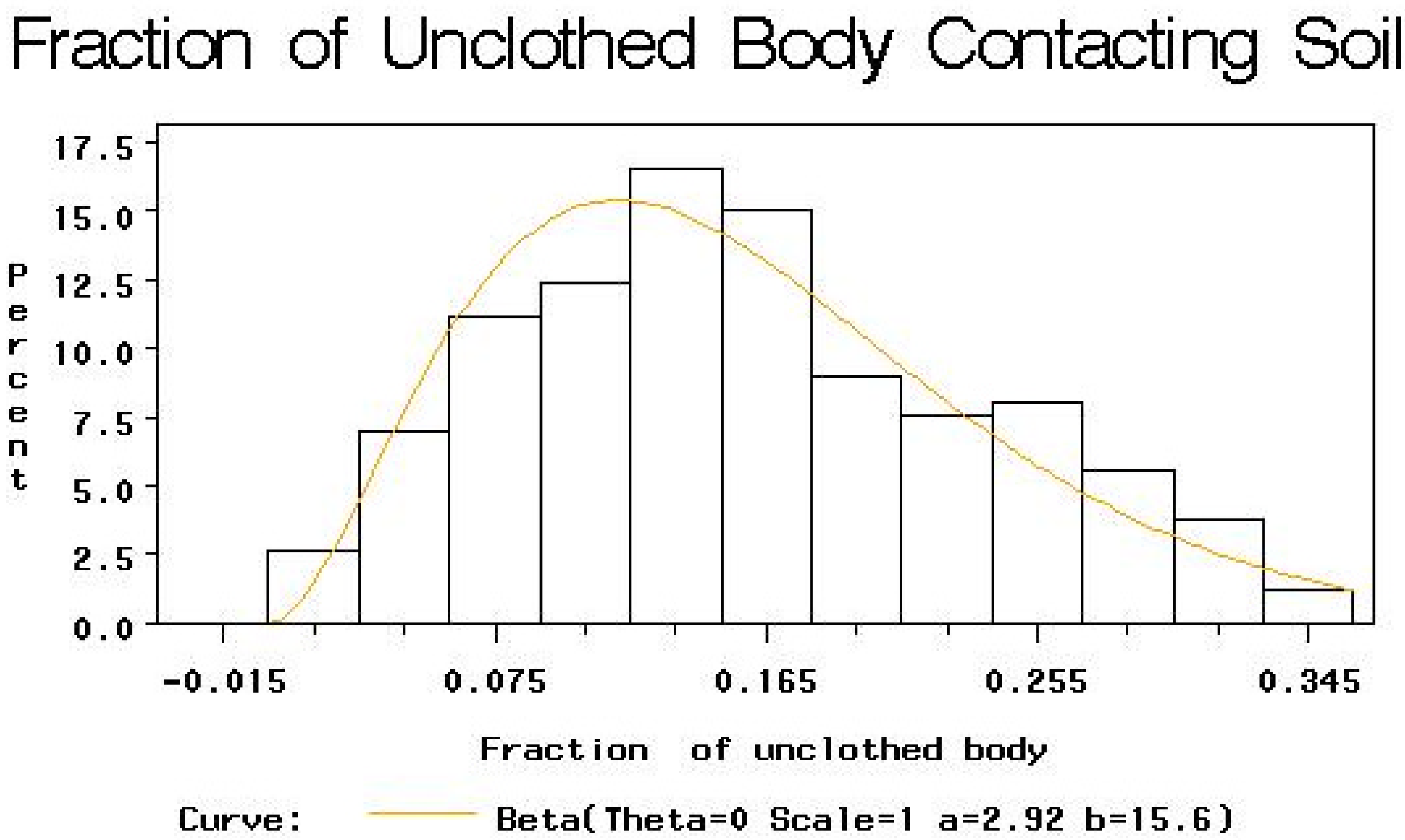
Maximum Dermal Cr Loading — Warm Climate Uncertainty

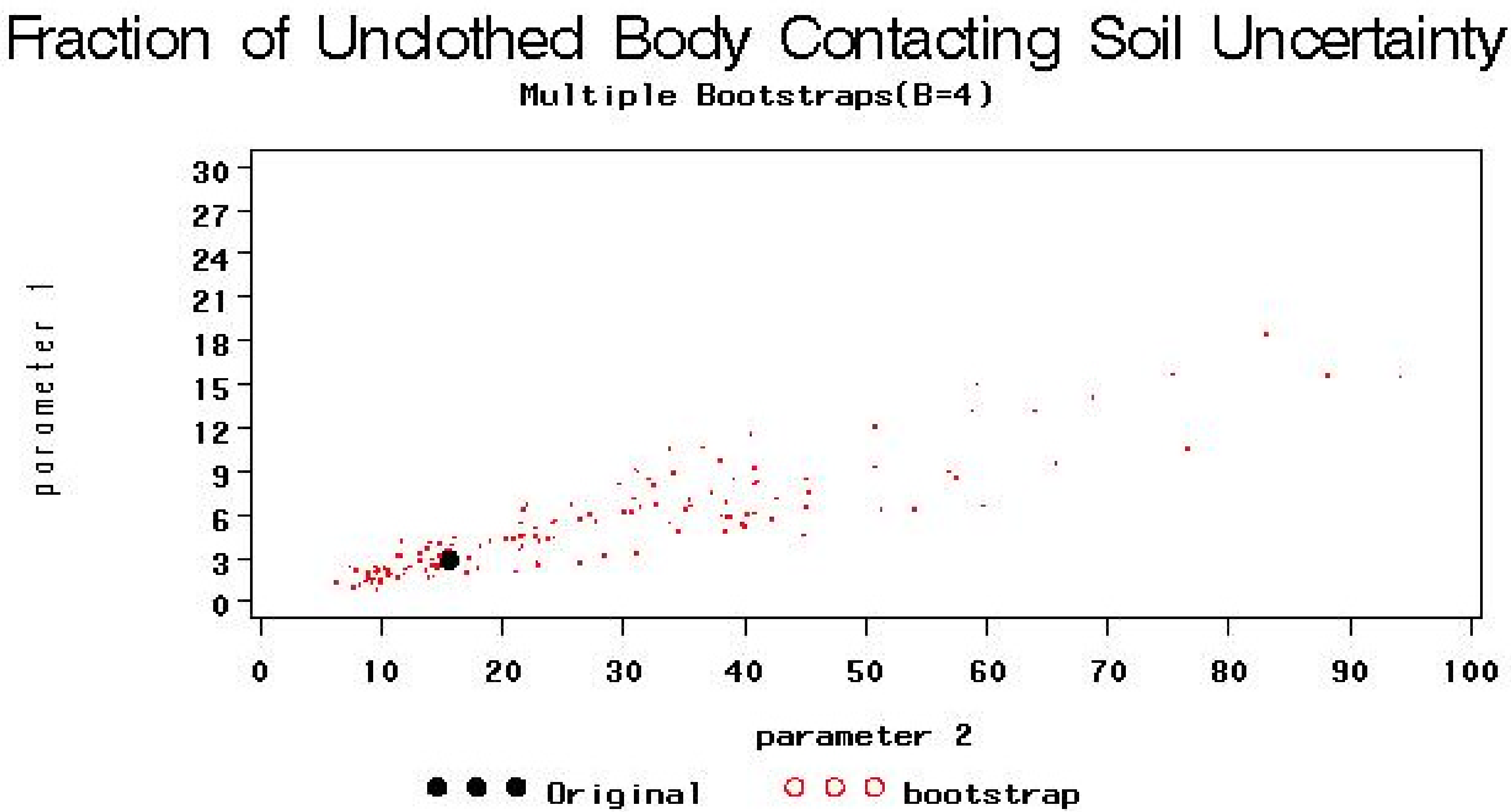


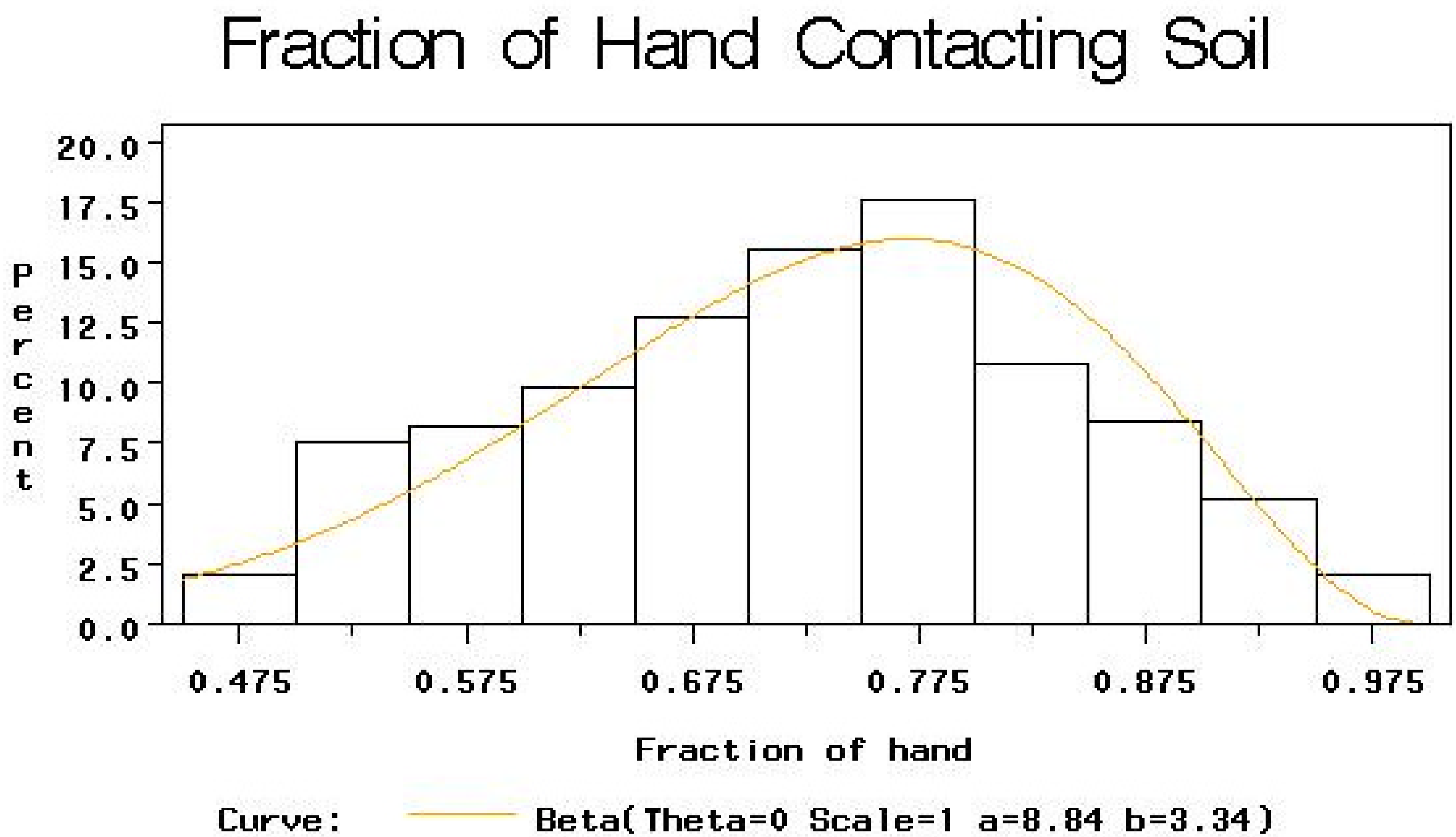

Fraction of Time Contacting Deck (vs. Soil)
Percent
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0.81
0.84
0.87
0.90
0.93
0.96
0.99
Fraction of time
Curve:
Beta(Theta=0 Scale=1 a=39.6 b=4.43)

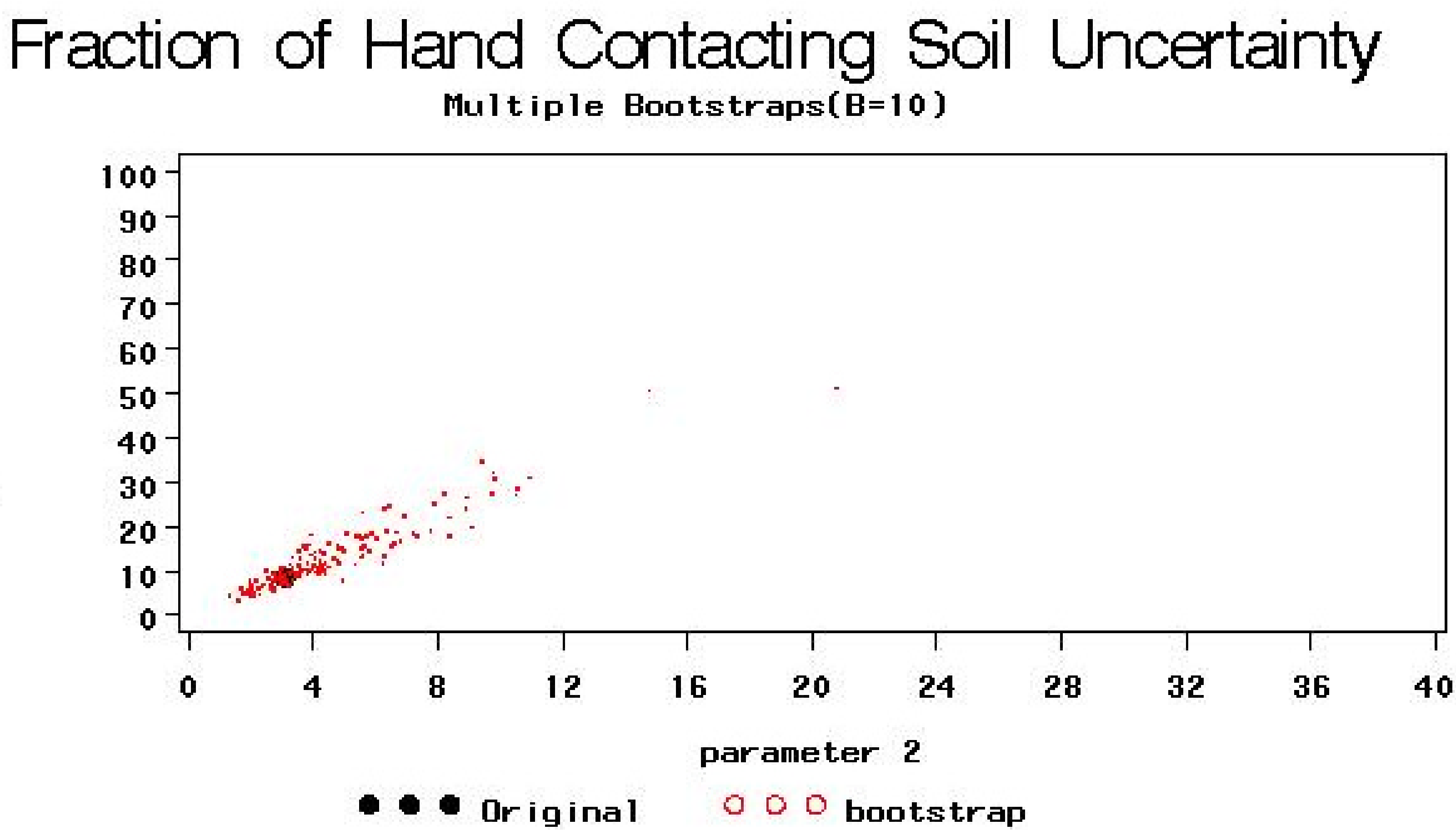
Fraction of Time Contacting Deck (vs. Soil) Uncertainty

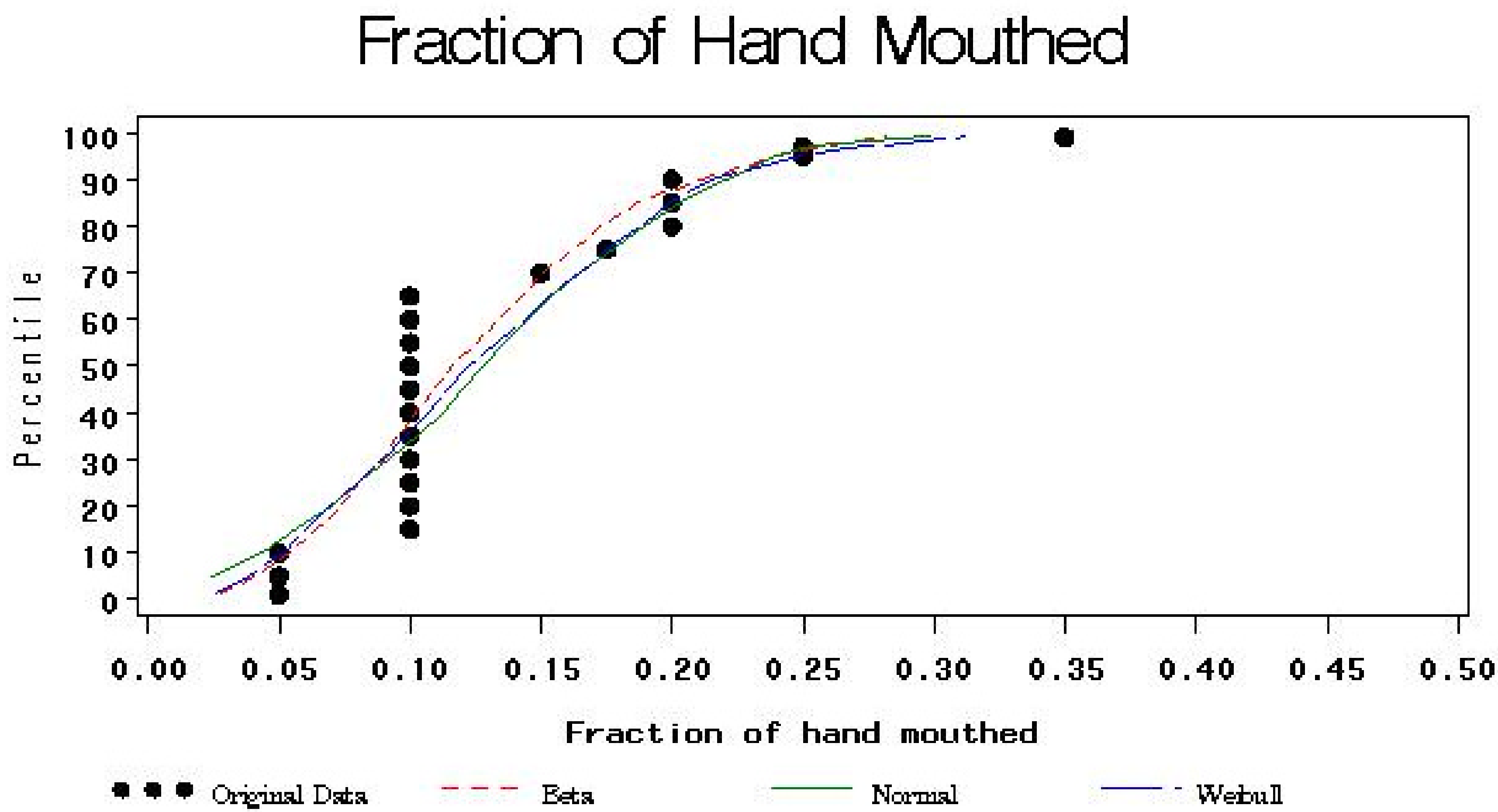



Fraction of Unclothed Body Contacting Soil
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
Percent
-0.015
0.075
0.165
0.255
0.345
Fraction of unclothed body
Curve: Beta(Theta=0 Scale=1 a=2.92 b=15.6)

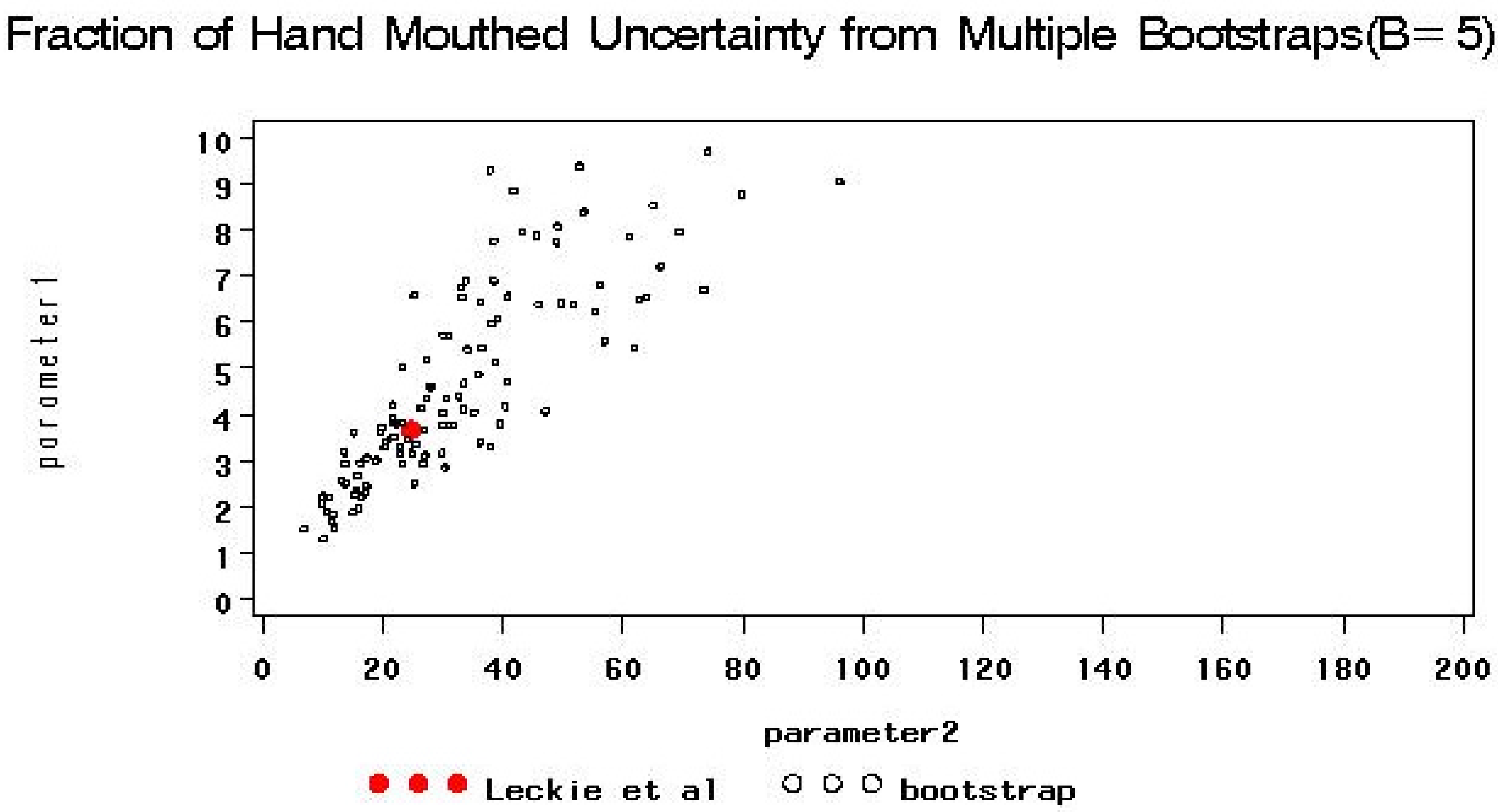

Fraction of Unclothed Body Contacting Soil Uncertainty
Multiple Bootstraps(B=4)
parameter 1
30
27
24
21
18
15
12
9
6
3
0
0
10
20
30
40
50
60
70
80
90
100
parameter 2
Original
bootstrap

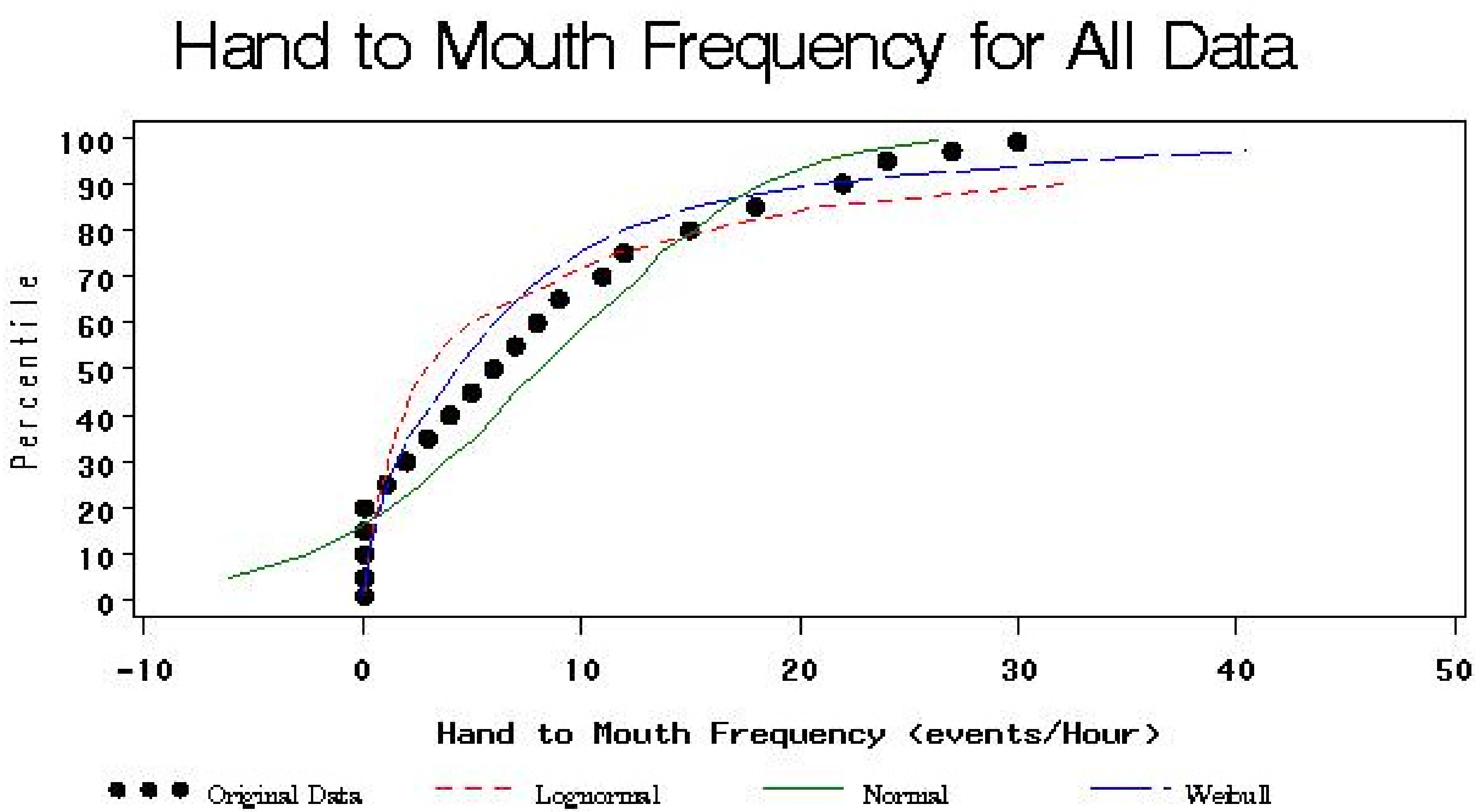

Fraction of Hand Contacting Soil
Percent
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0.475
0.575
0.675
0.775
0.875
0.975
Fraction of hand
Curve:
Beta(Theta=0 Scale=1 a=8.84 b=3.34)

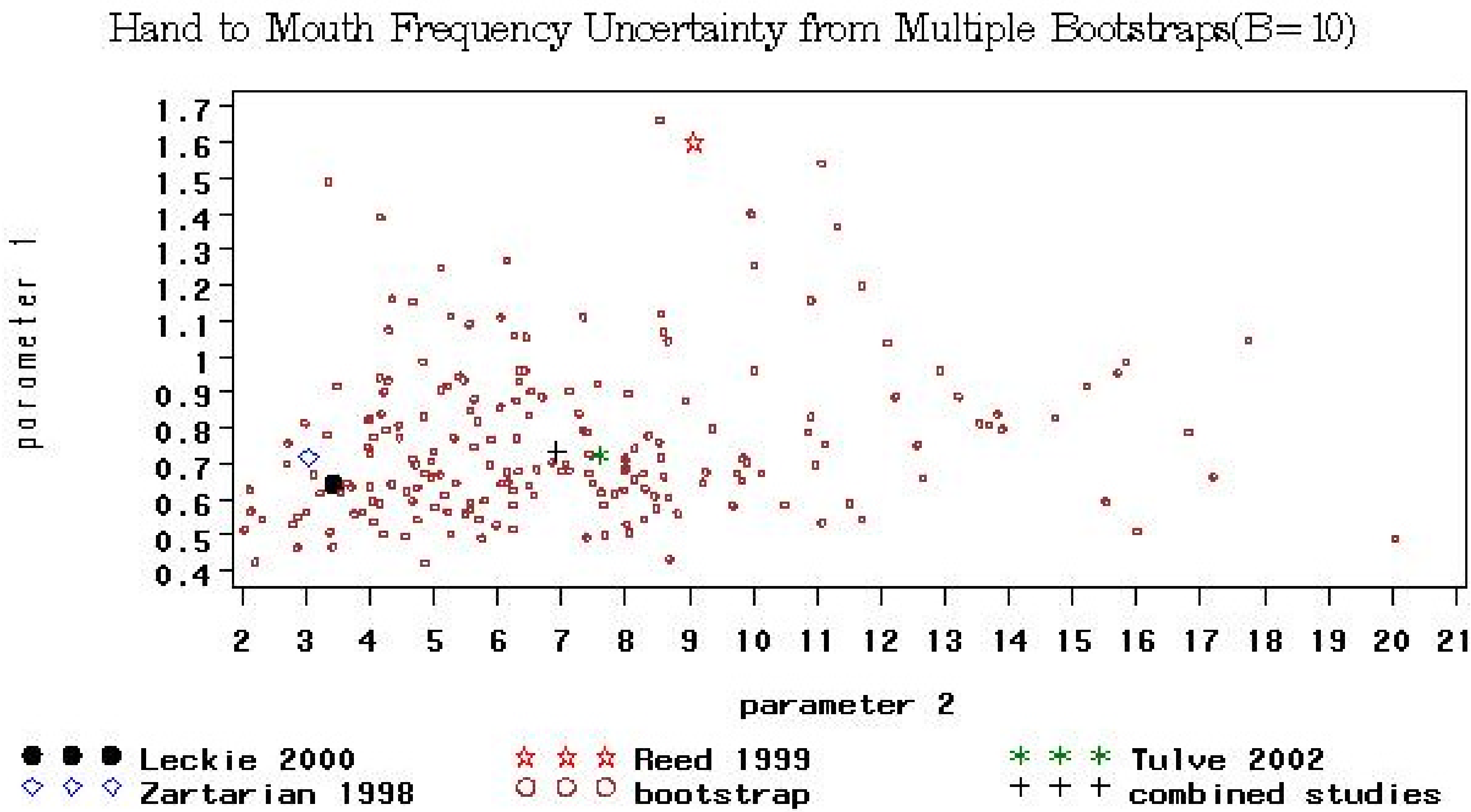

Fraction of Hand Contacting Soil Uncertainty
Multiple Bootstraps(B=10)
porometer 1
0
10
20
30
40
50
60
70
80
90
100
0
4
8
12
16
20
24
28
32
36
40
parameter 2
Original
bootstrap



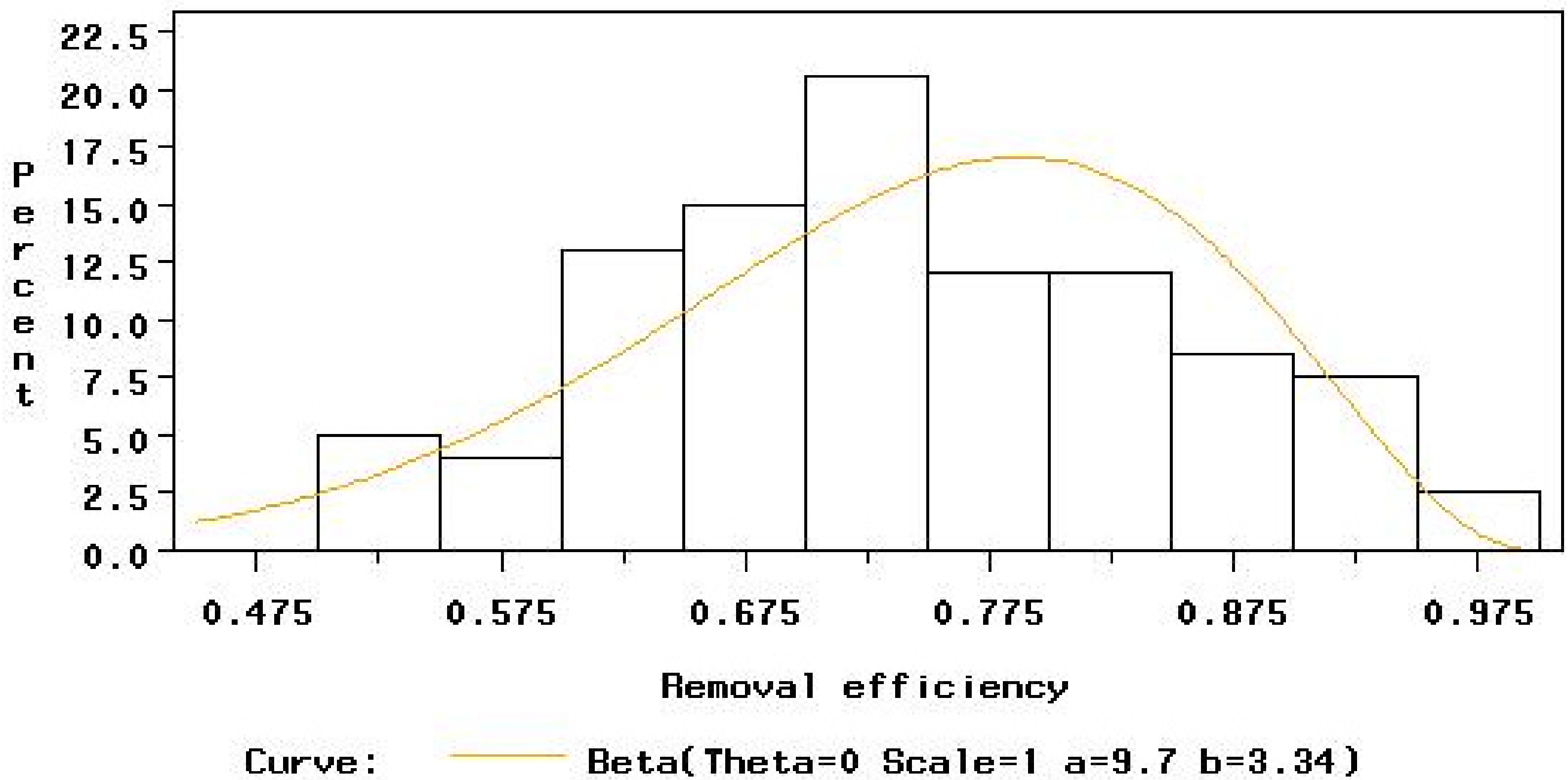
Fraction of Hand Mouthed
Percentile
100
90
80
70
60
50
40
30
20
10
0
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
Fraction of hand mouthed
Original Data
Beta
Normal
Weibull

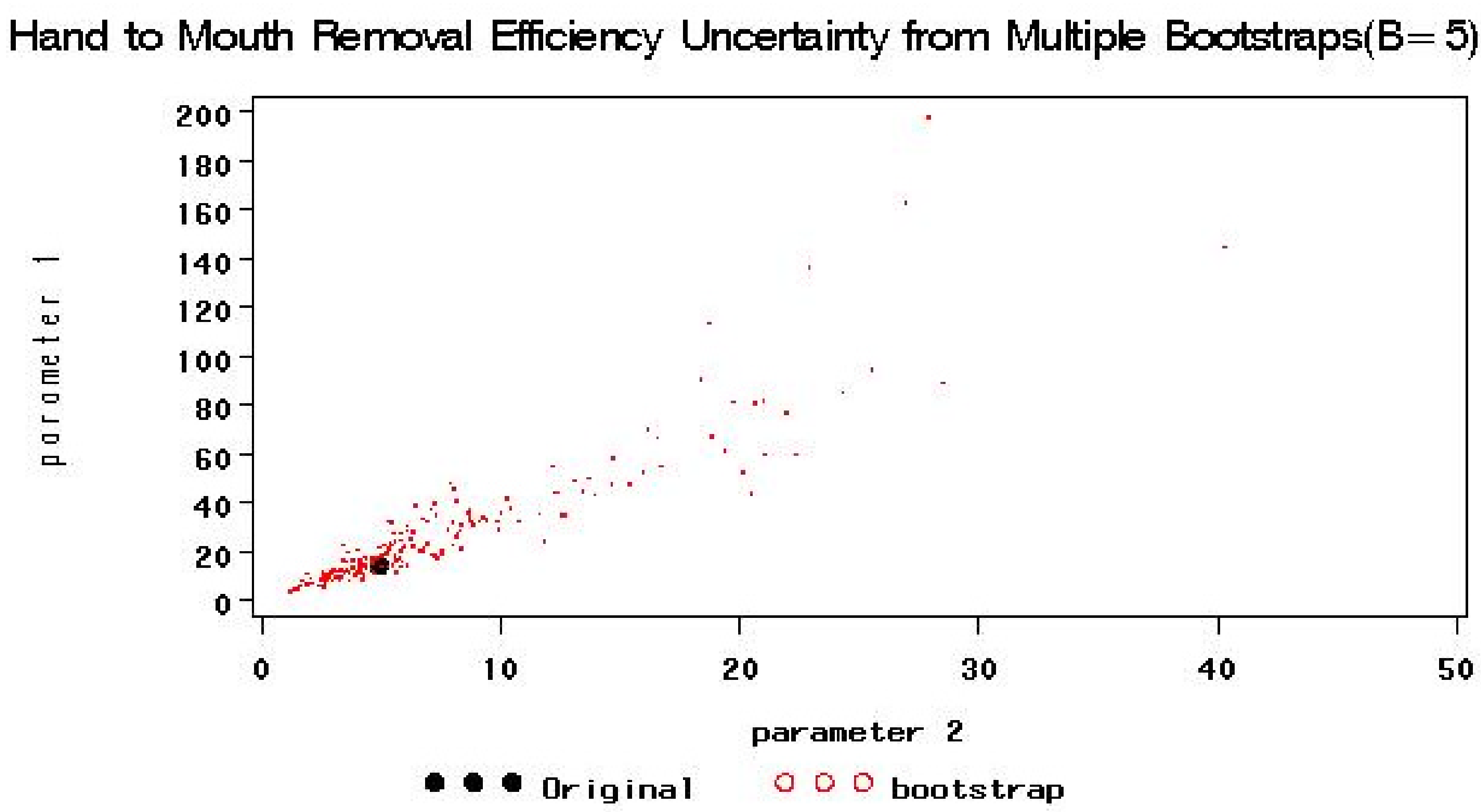

Fraction of Hand Mouthed Uncertainty from Multiple Bootstraps(B= 5)
parameter1
0
1
2
3
4
5
6
7
8
9
10
0
20
40
60
80
100
120
140
160
180
200
parameter2
Leckie et al
bootstrap

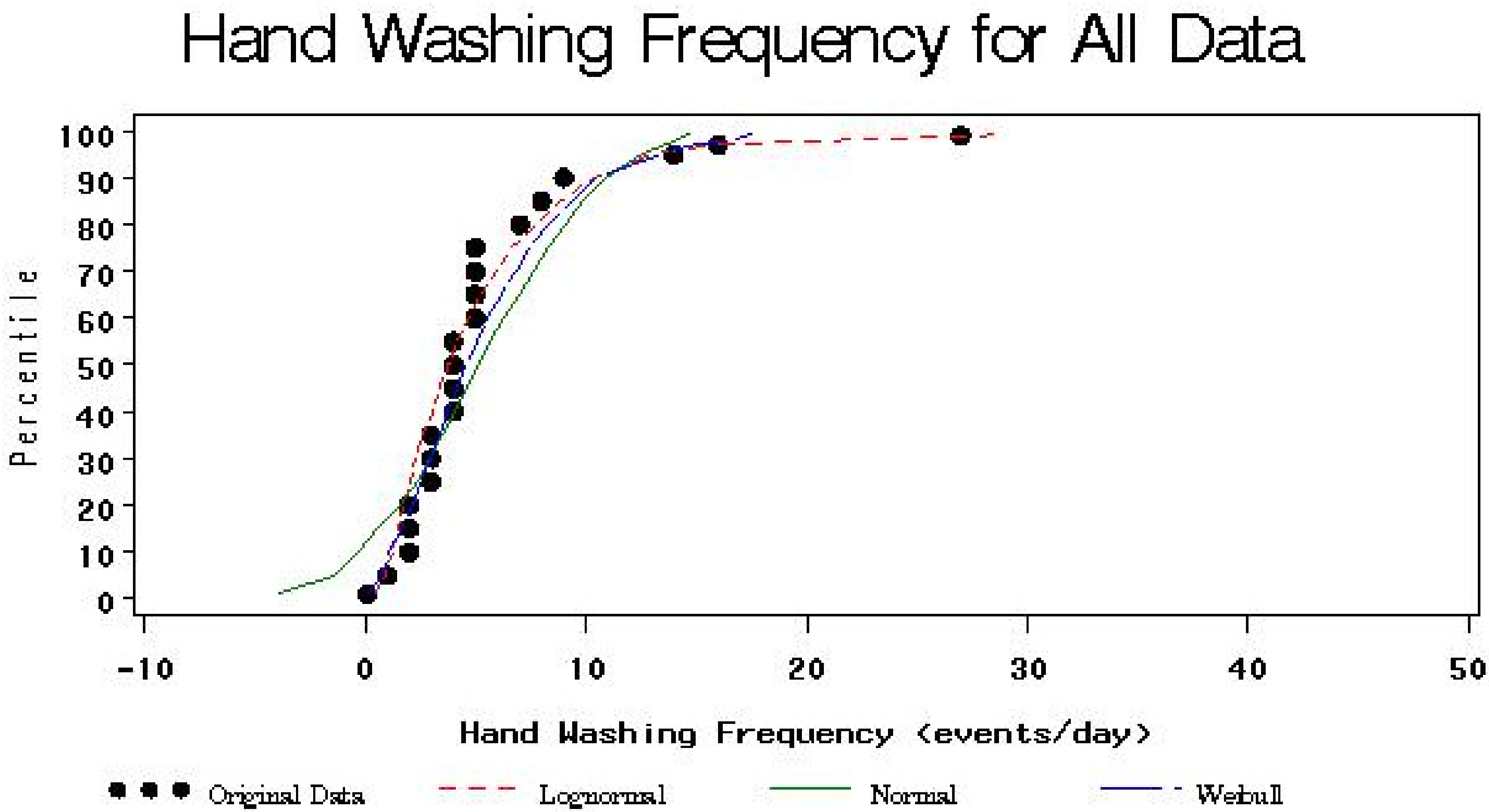

Hand to Mouth Frequency for All Data
Percentile
100
90
80
70
60
50
40
30
20
10
0
-10
0
10
20
30
40
50
Hand to Mouth Frequency (events/Hour)
Original Data
Lognormal
Normal
Weibull


Hand to Mouth Frequency Uncertainty from Multiple Bootstraps(B=10)
parameter 1
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
parameter 2
Leckie 2000
Zartarian 1998
Reed 1999
bootstrap
Tulve 2002
combined studies

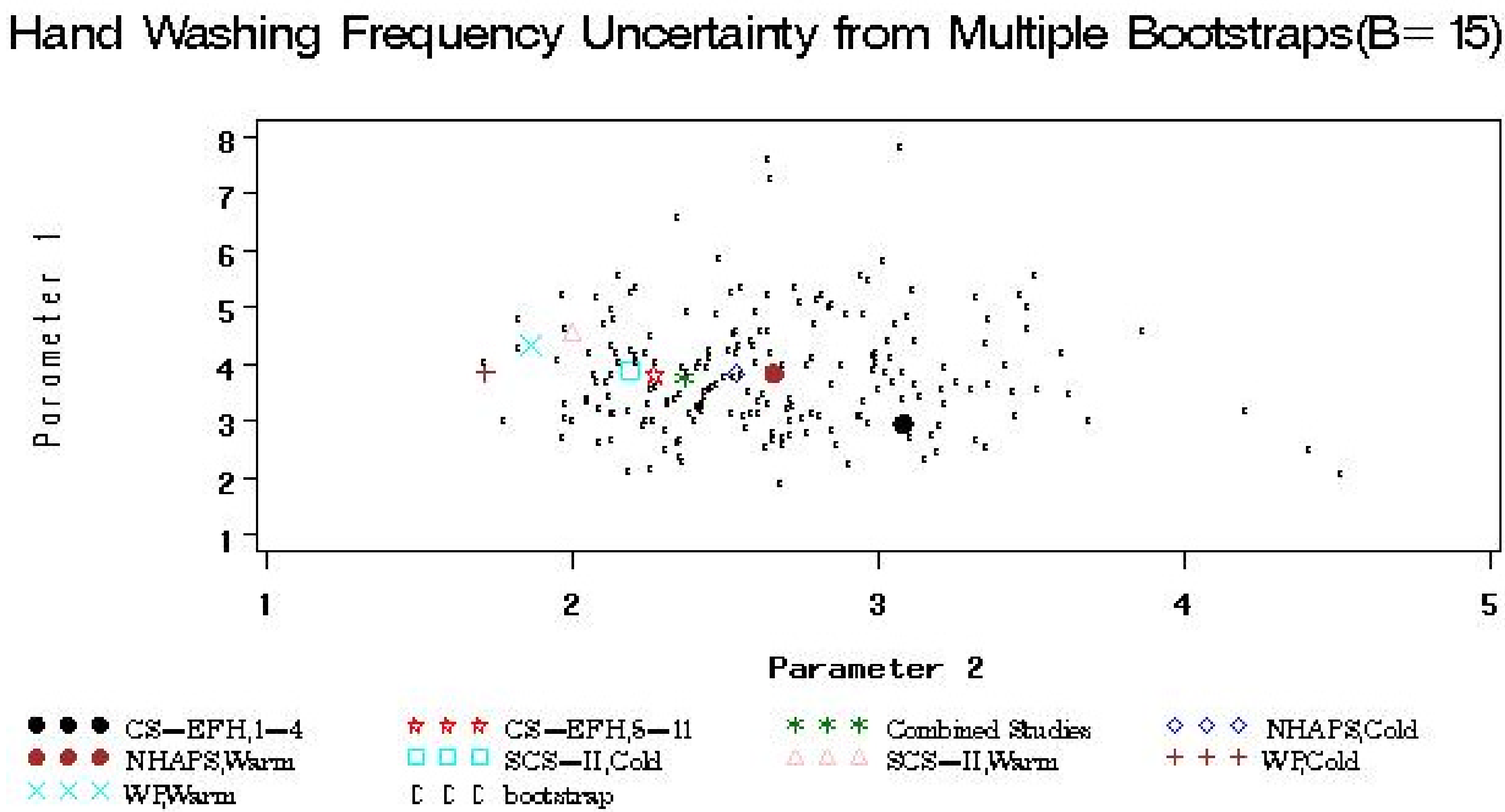
Hand to Mouth Removal Efficiency



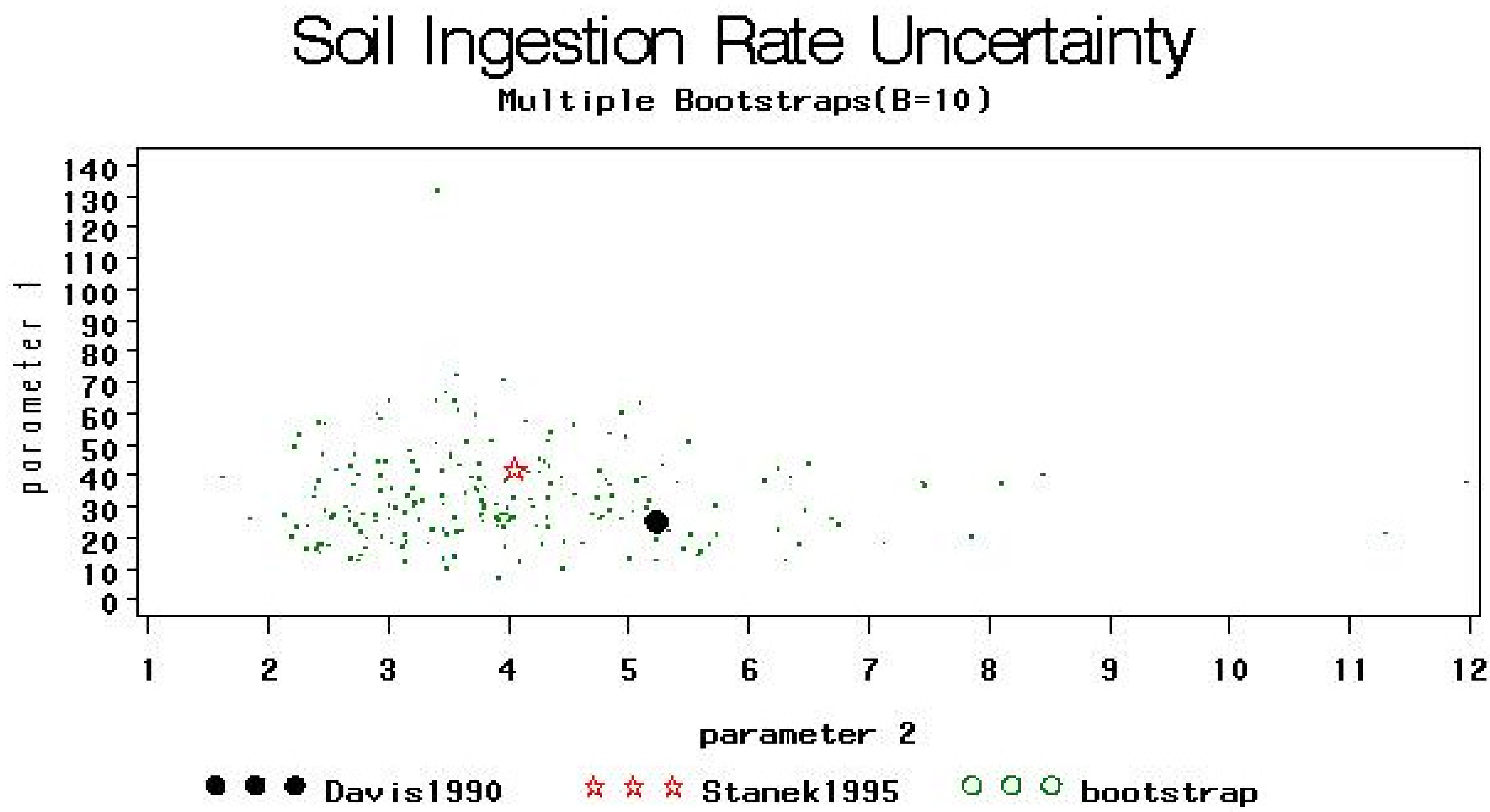

Hand to Mouth Removal Efficiency Uncertainty from Multiple Bootstraps(B=5)
parameter 1
0
20
40
60
80
100
120
140
160
180
200
0
10
20
30
40
50
parameter 2
Original
bootstrap

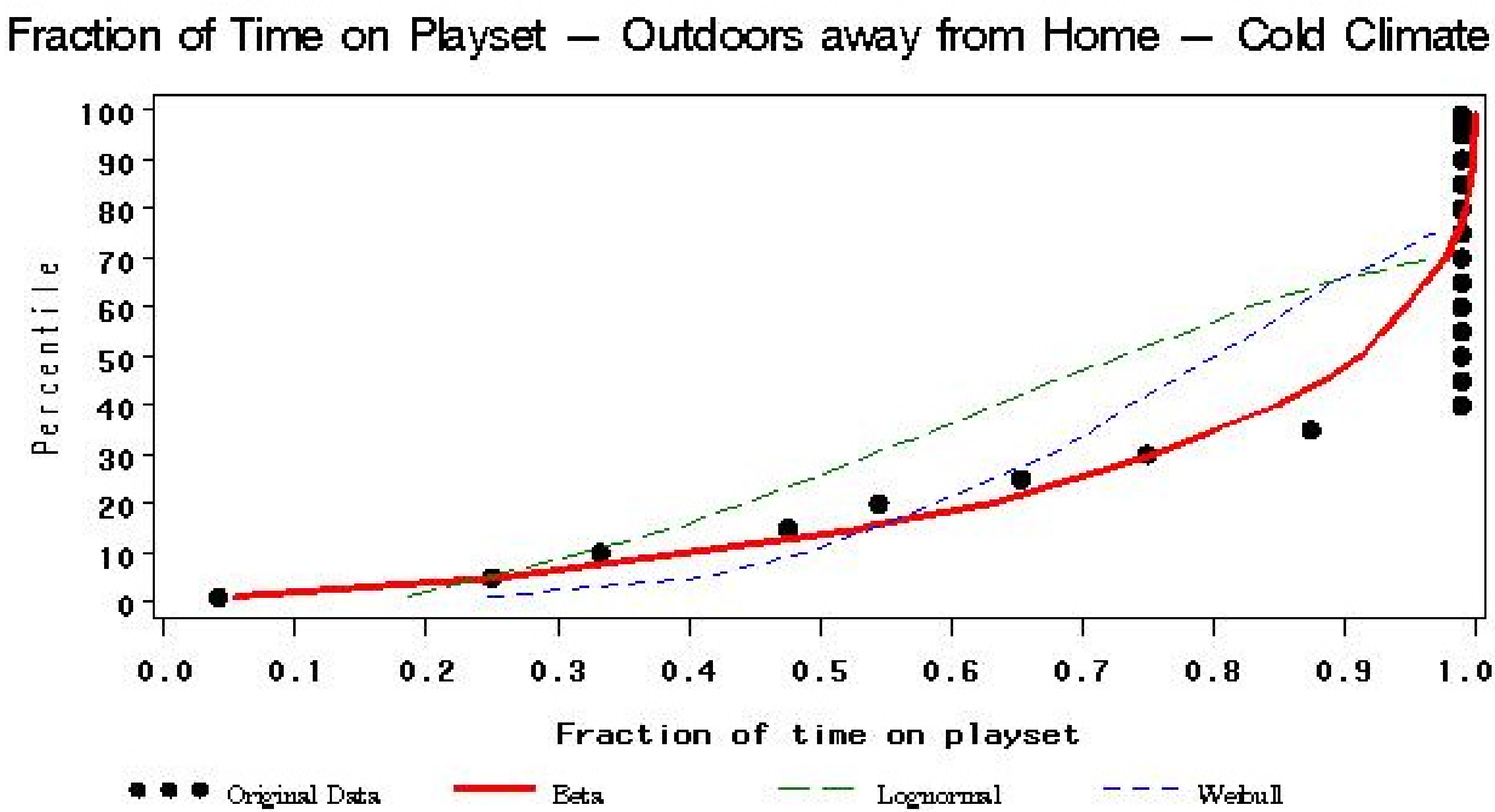


Hand Washing Frequency for All Data
Percentile
100
90
80
70
60
50
40
30
20
10
0
-10
0
10
20
30
40
50
Hand Washing Frequency (events/day)
Original Data
Lognormal
Normal
Weibull



Hand Washing Frequency Uncertainty from Multiple Bootstraps(B= 15)
Parameter 1
Parameter 2
1
2
3
4
5
6
7
8
CS—EFH,1—4
NHAPS,Warm
WF,Warm
CS—EFH,5—11
SCS—II,Cold
bootstrap
Combined Studies
SCS—II,Warm
NHAPS,Cold
WF,Cold

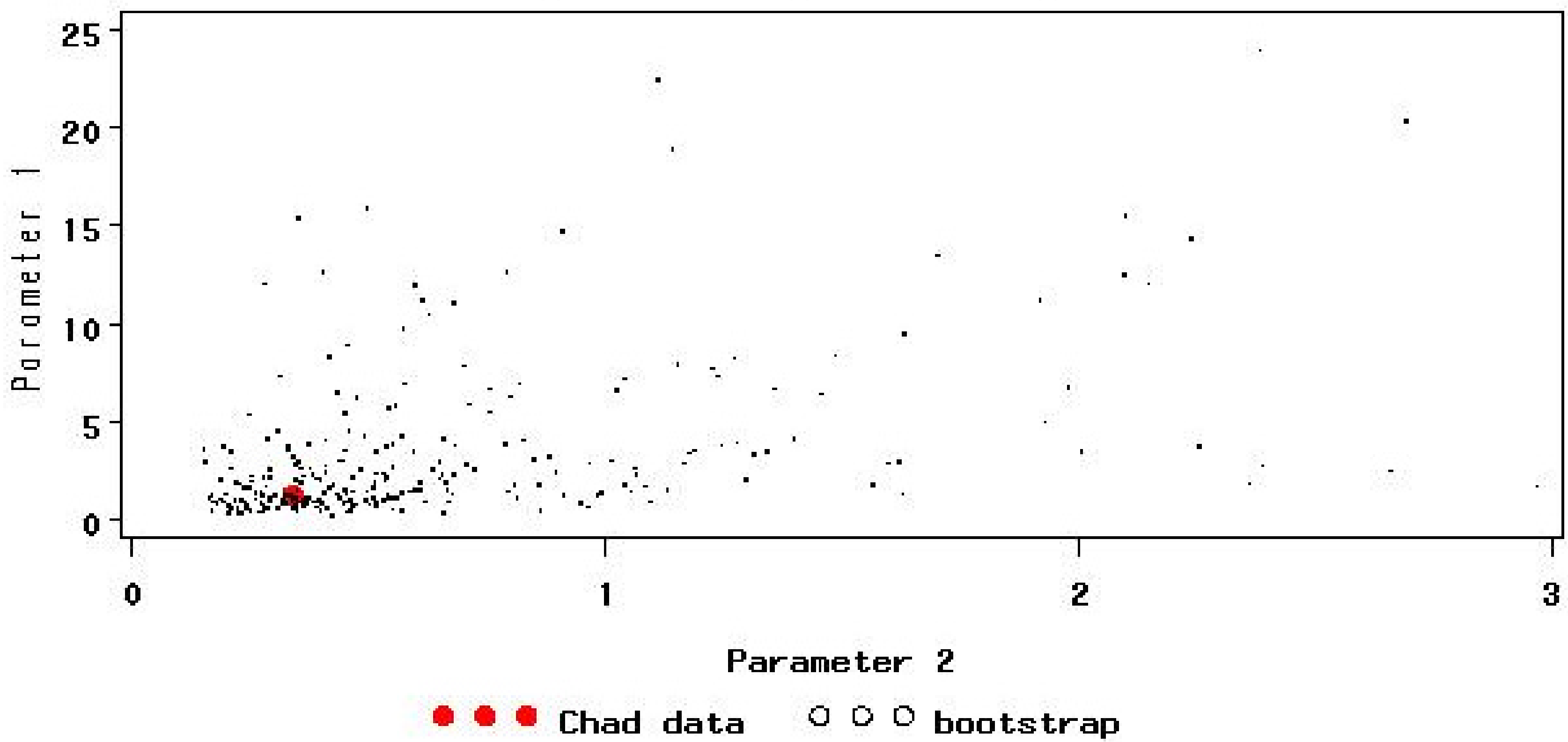

Soil Ingestion Rate Uncertainty
Multiple Bootstraps(B=10)
parameter 1
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
12
parameter 2
Davis1990
Stanek1995
bootstrap

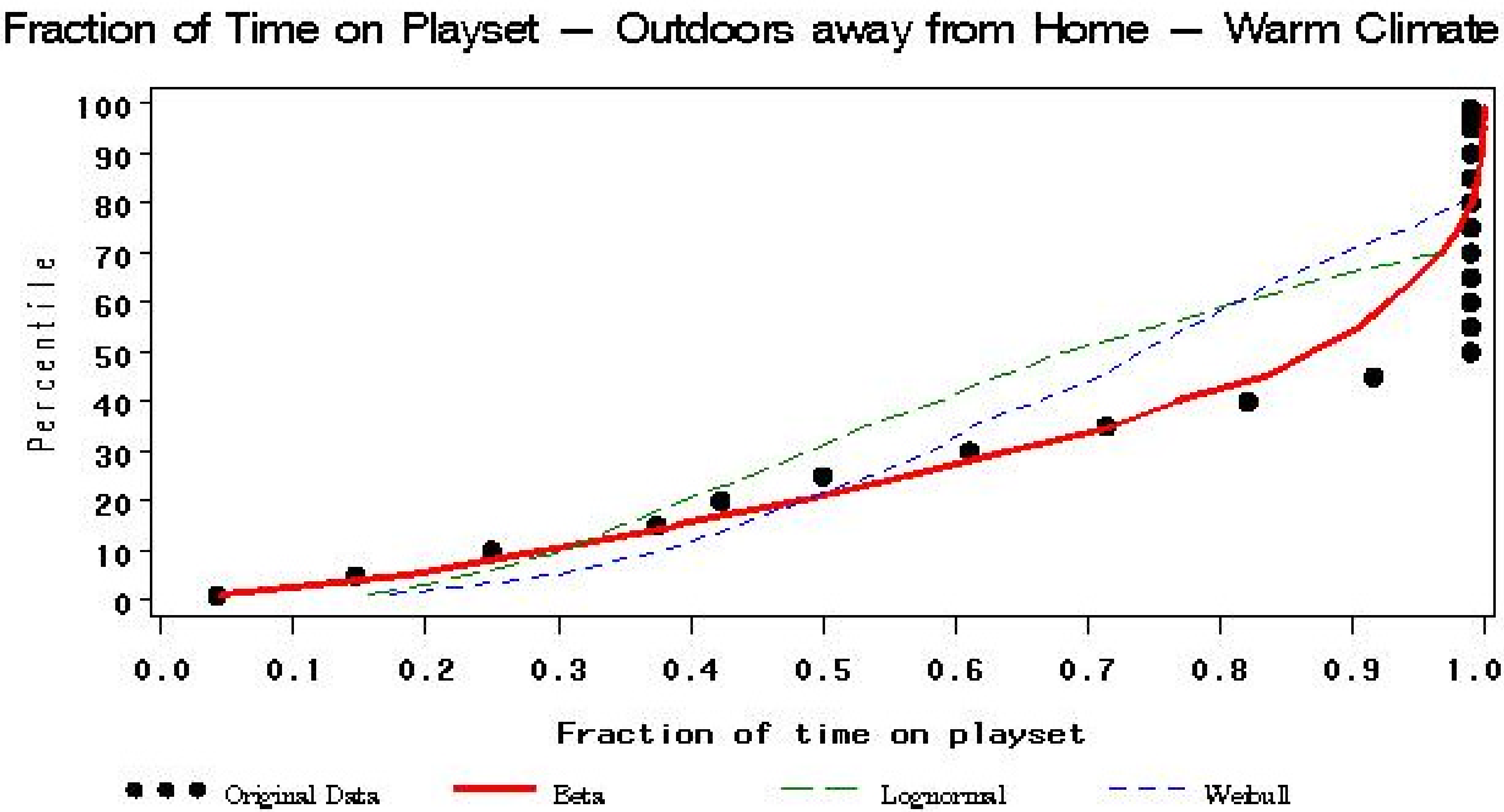


Fraction of Time on Playset – Outdoors away from Home – Cold Climate
Percentile
0
10
20
30
40
50
60
70
80
90
100
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Fraction of time on playset
Original Data
Beta
Lognormal
Weibull

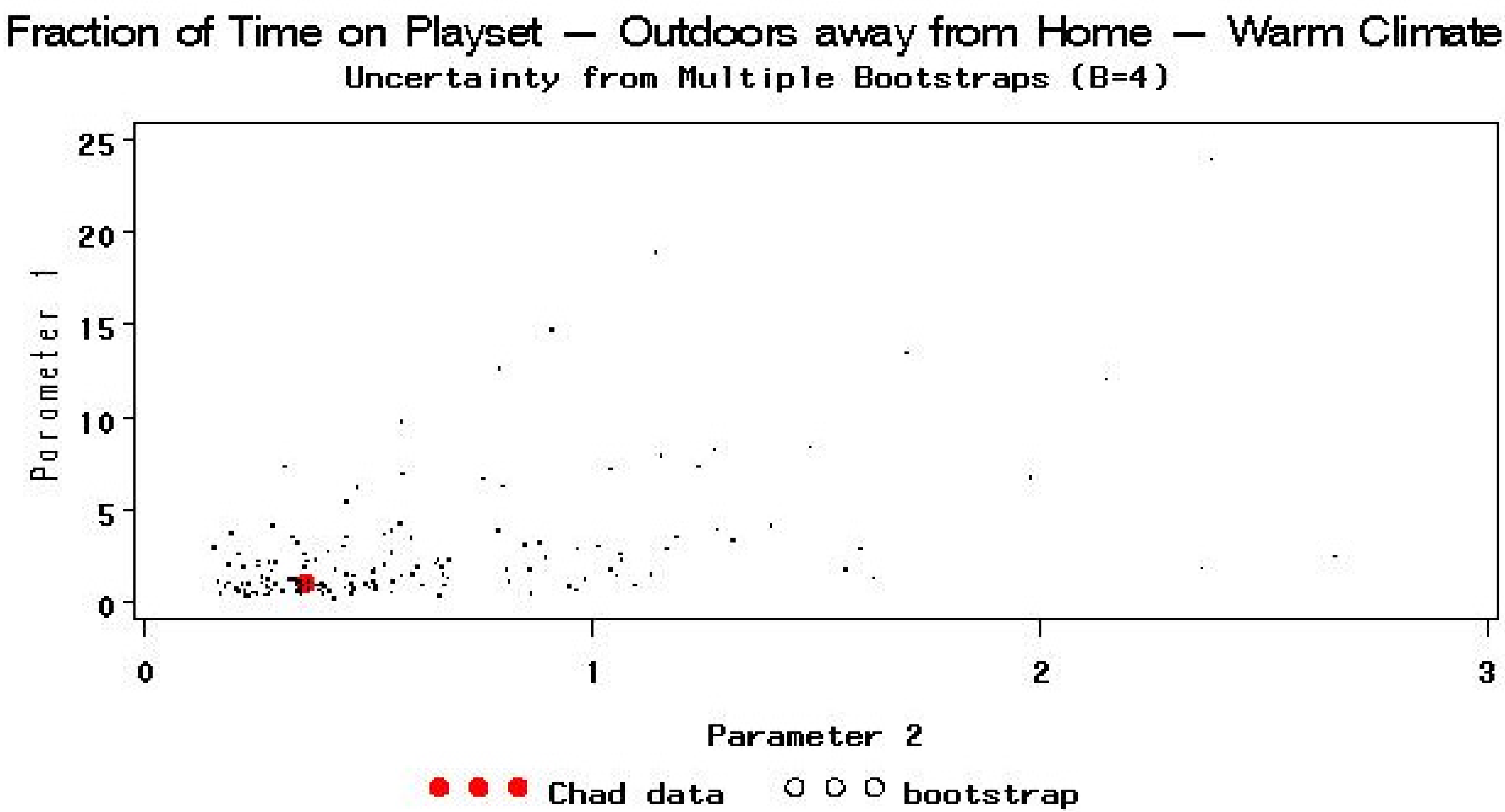
Fraction of Time on Playset – Outdoors away from Home – Cold Climate

Uncertainty from Multiple Bootstraps (B=4)



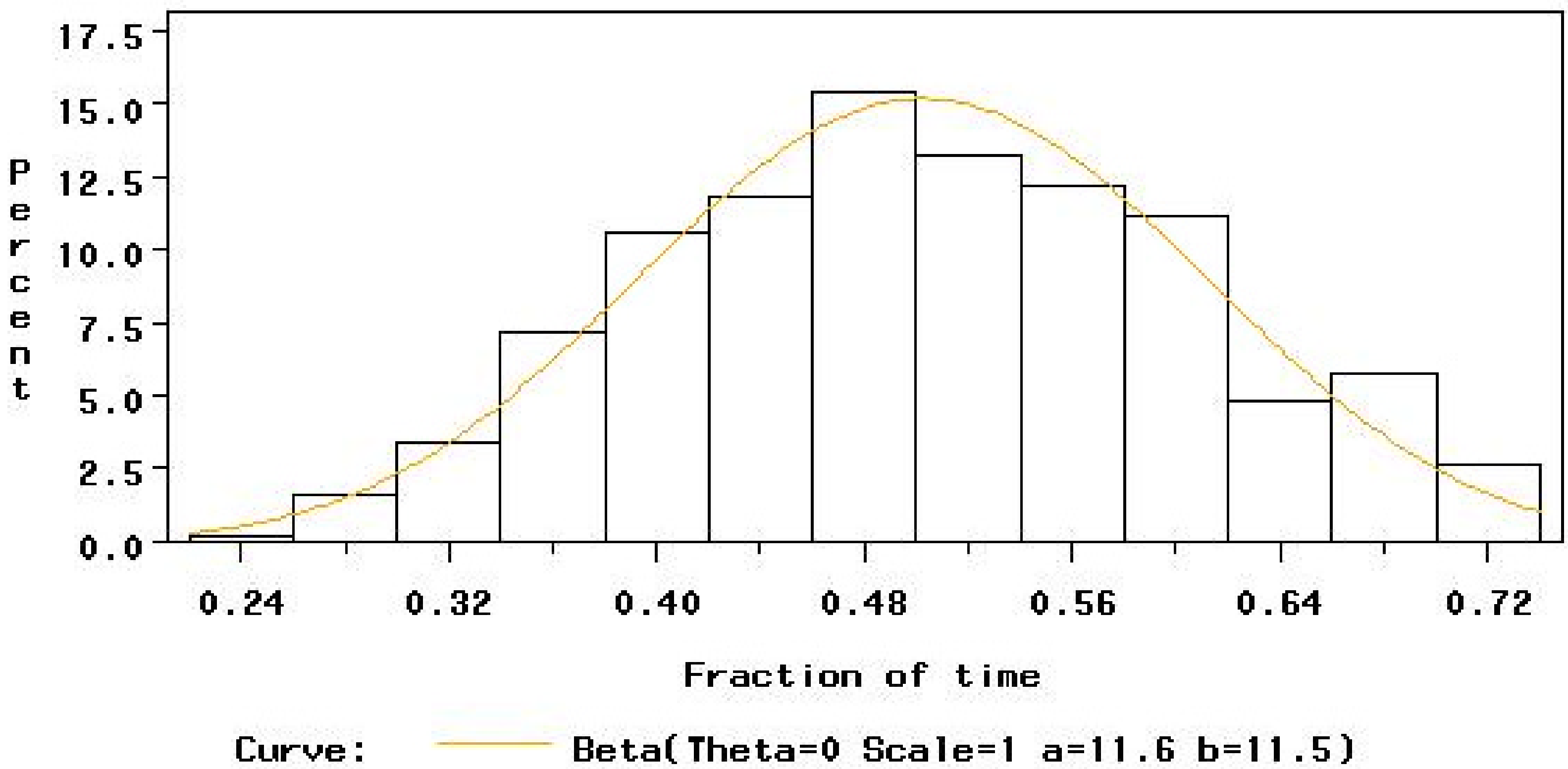


Fraction of Time on Playset – Outdoors away from Home – Warm Climate
Percentile
0
10
20
30
40
50
60
70
80
90
100
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Fraction of time on playset
Original Data
Beta
Lognormal
Weibull



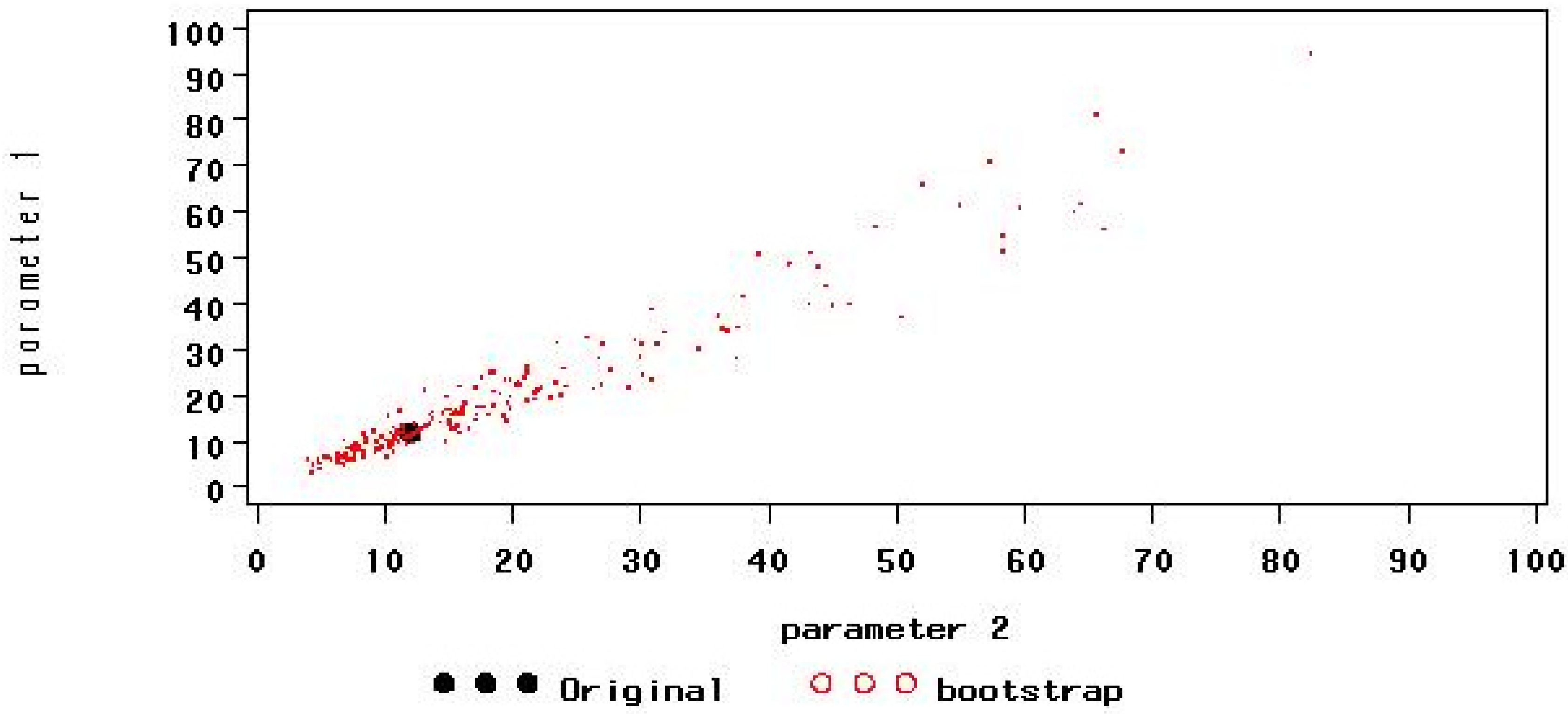
Fraction of Time on Playset — Outdoors away from Home — Warm Climate
Uncertainty from Multiple Bootstraps (B=4)
Parameter 1
25
20
15
10
5
0
0
1
2
3
Parameter 2
Chad data
bootstrap

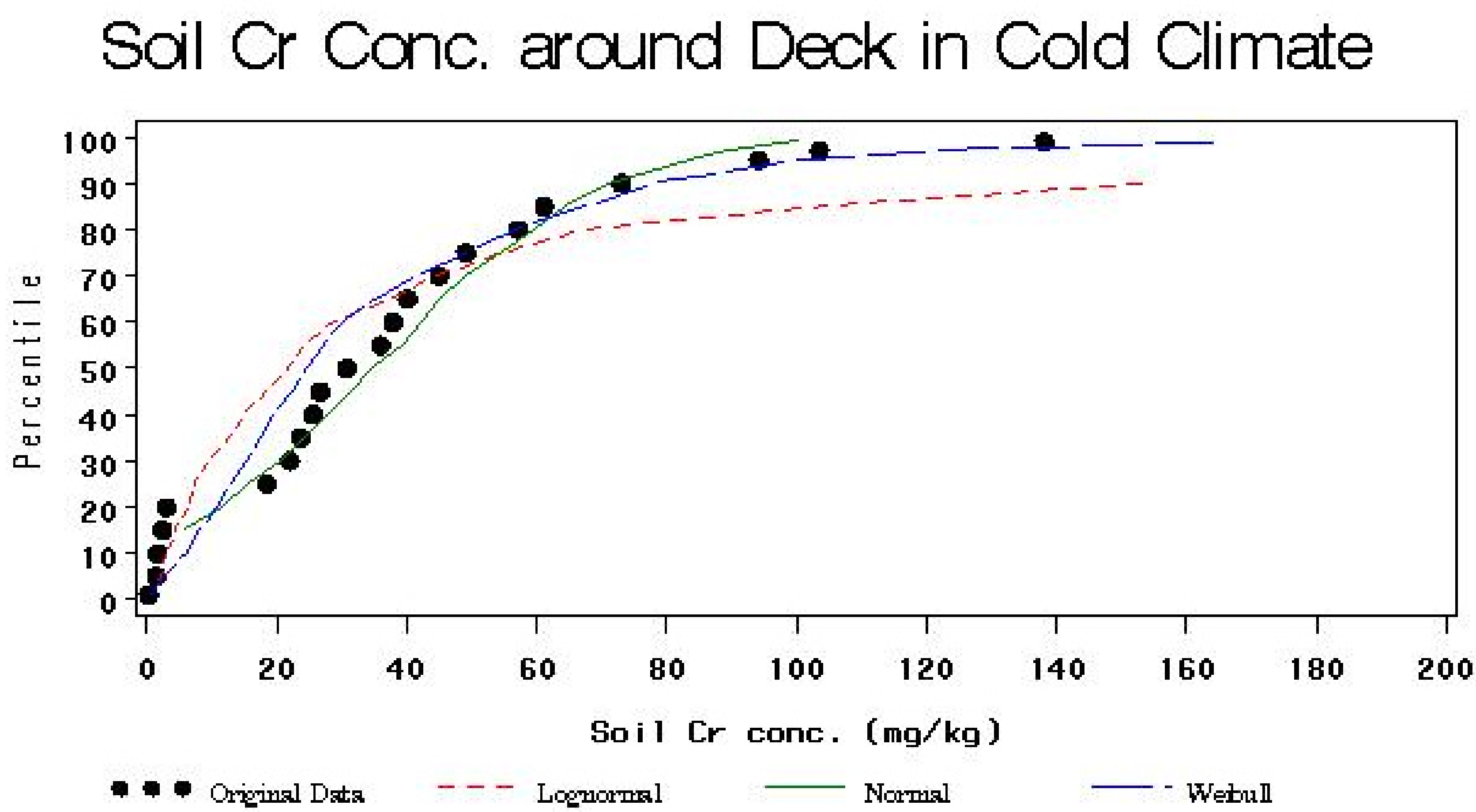
Fraction of Time Contacting Playset (vs. Soil)



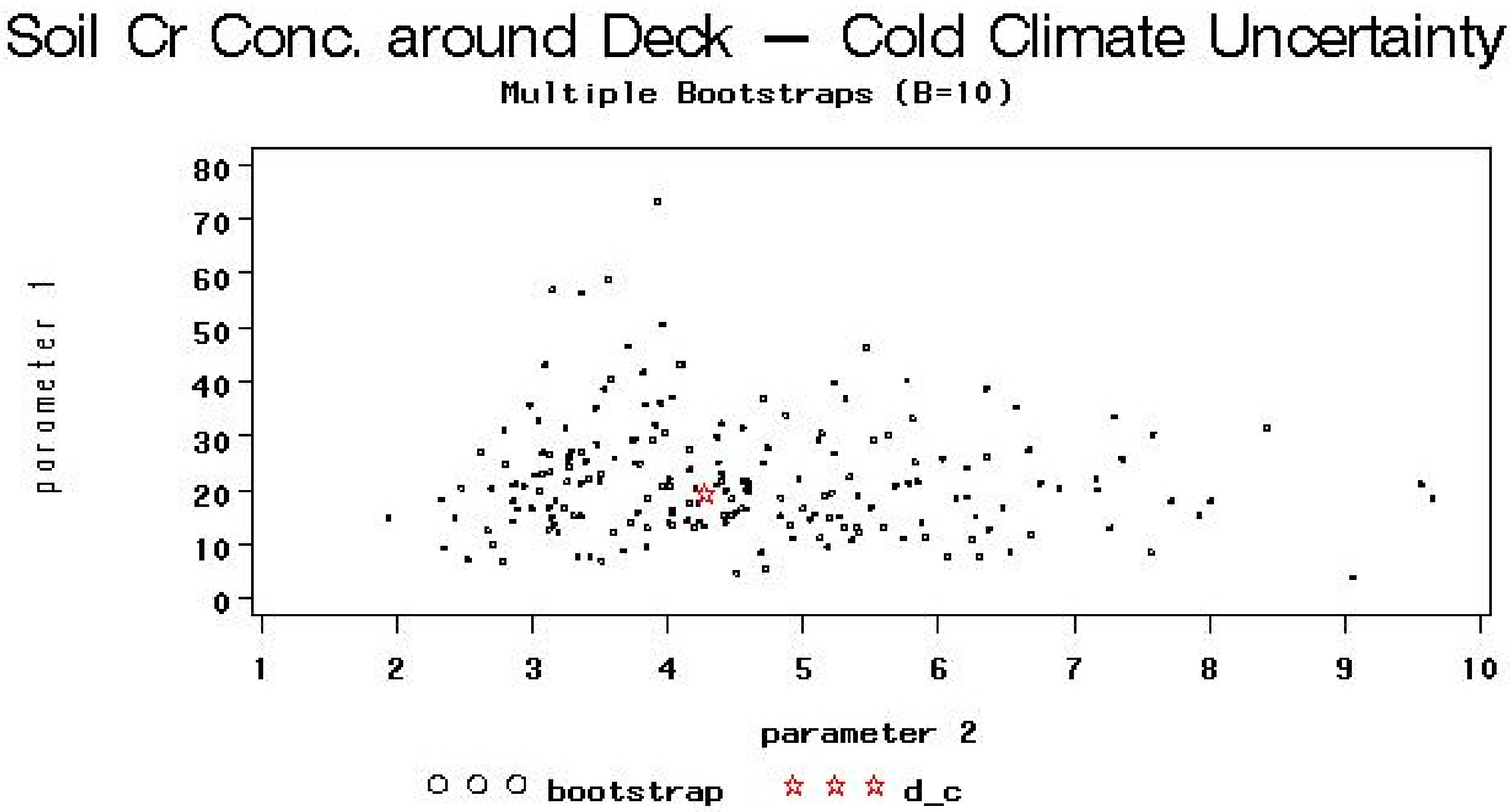
Fraction of Time Contacting Playset (vs. Soil) Uncertainty

Multiple Bootstraps(B=5)



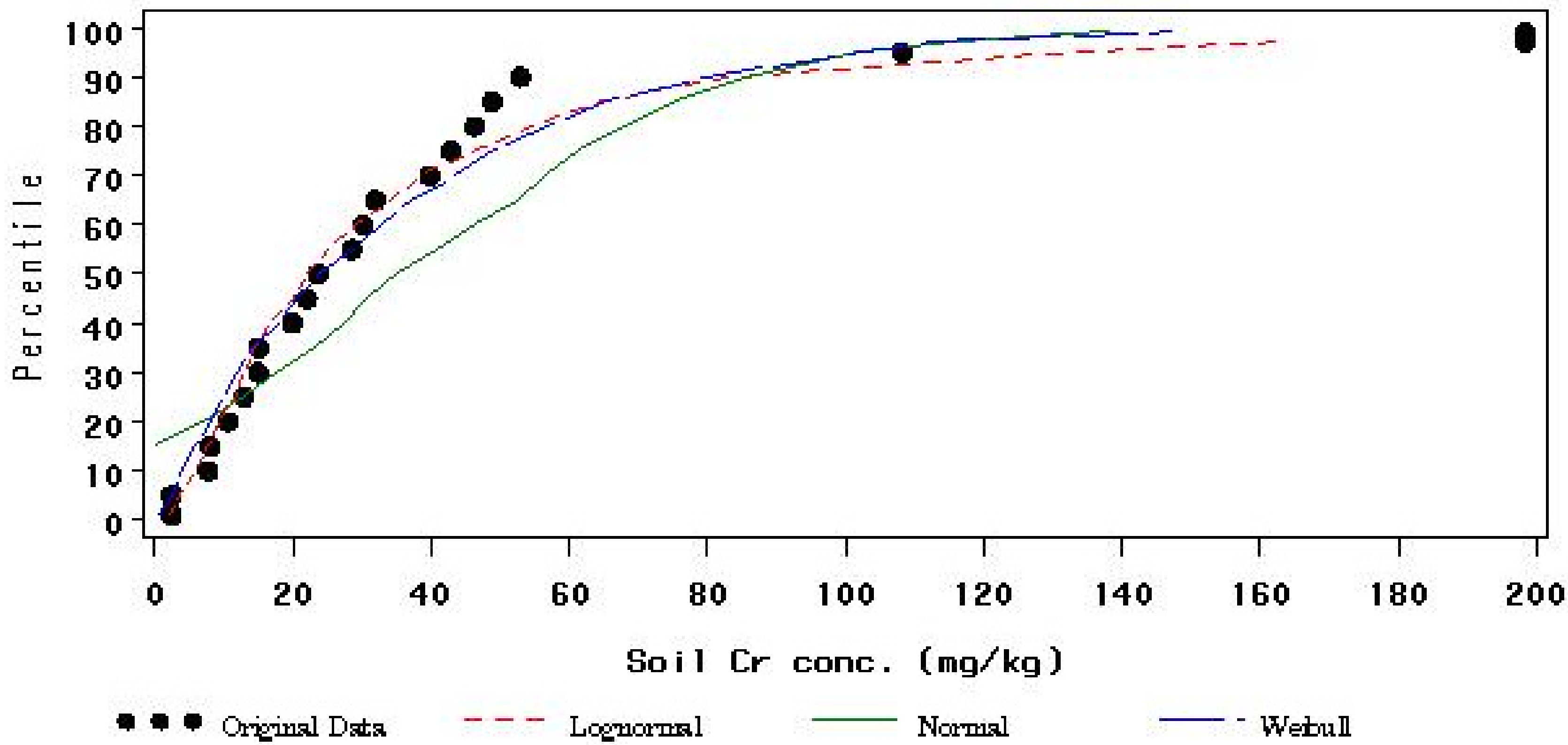


Soil Cr Conc. around Deck in Cold Climate
Percentile
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100
120
140
160
180
200
Soil Cr conc. (mg/kg)
Original Data
Lognormal
Normal
Weibull



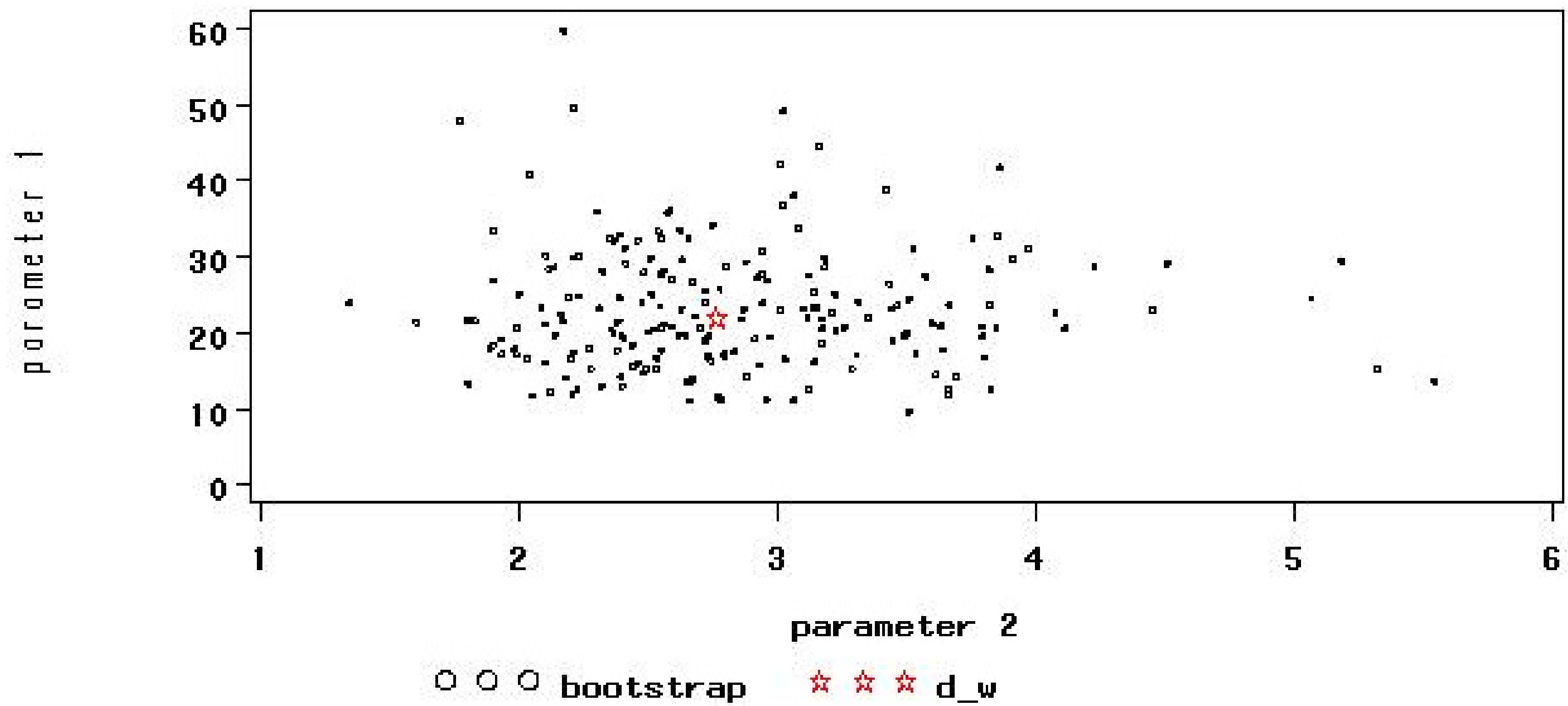
Soil Cr Conc. around Deck — Cold Climate Uncertainty
Multiple Bootstraps (B=10)
parameter 1
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
parameter 2
bootstrap
d_c

Soil Cr Conc. around Deck in Warm Climate

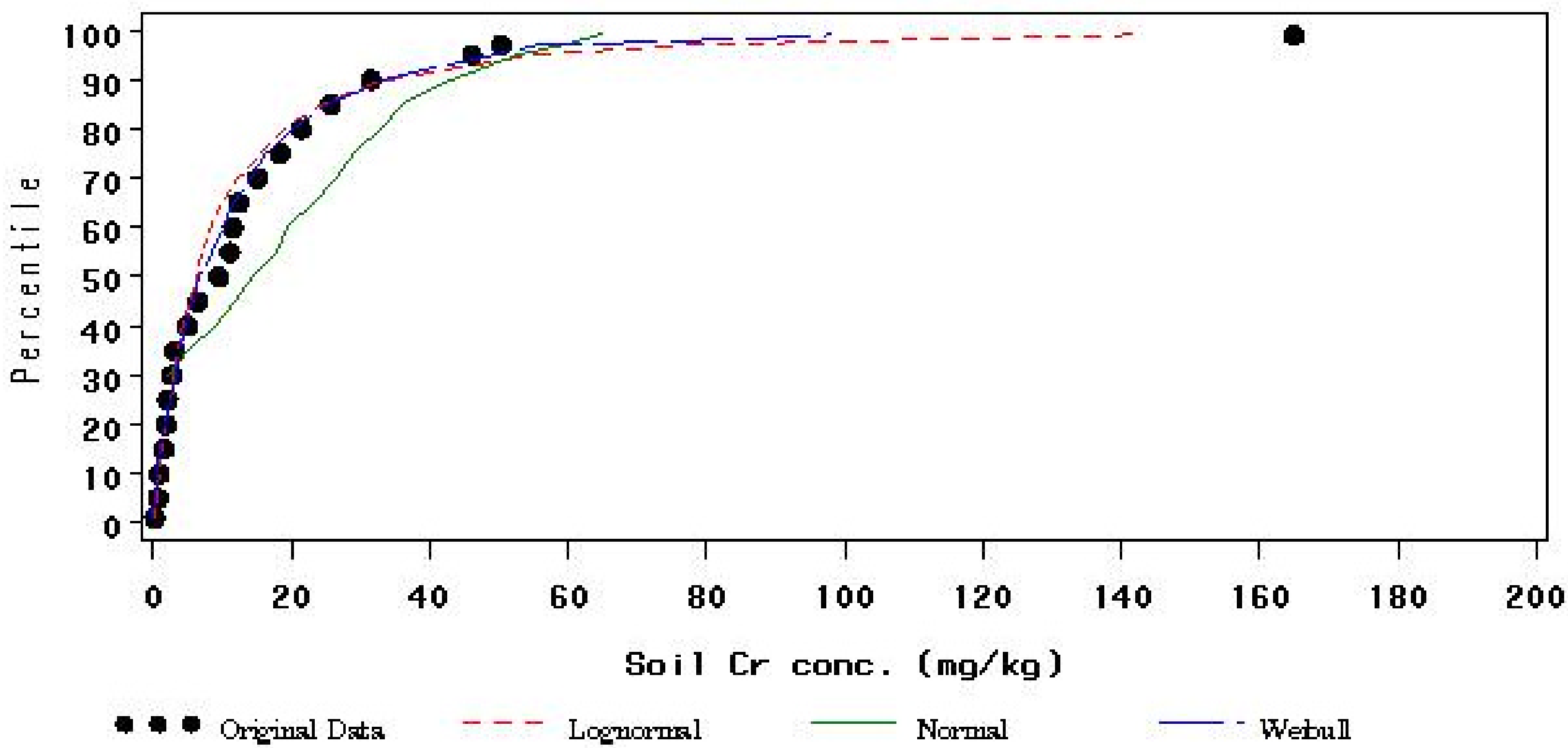


Soil Cr Conc. around Deck – Warm Climate Uncertainty

Multiple Bootstraps (B=10)

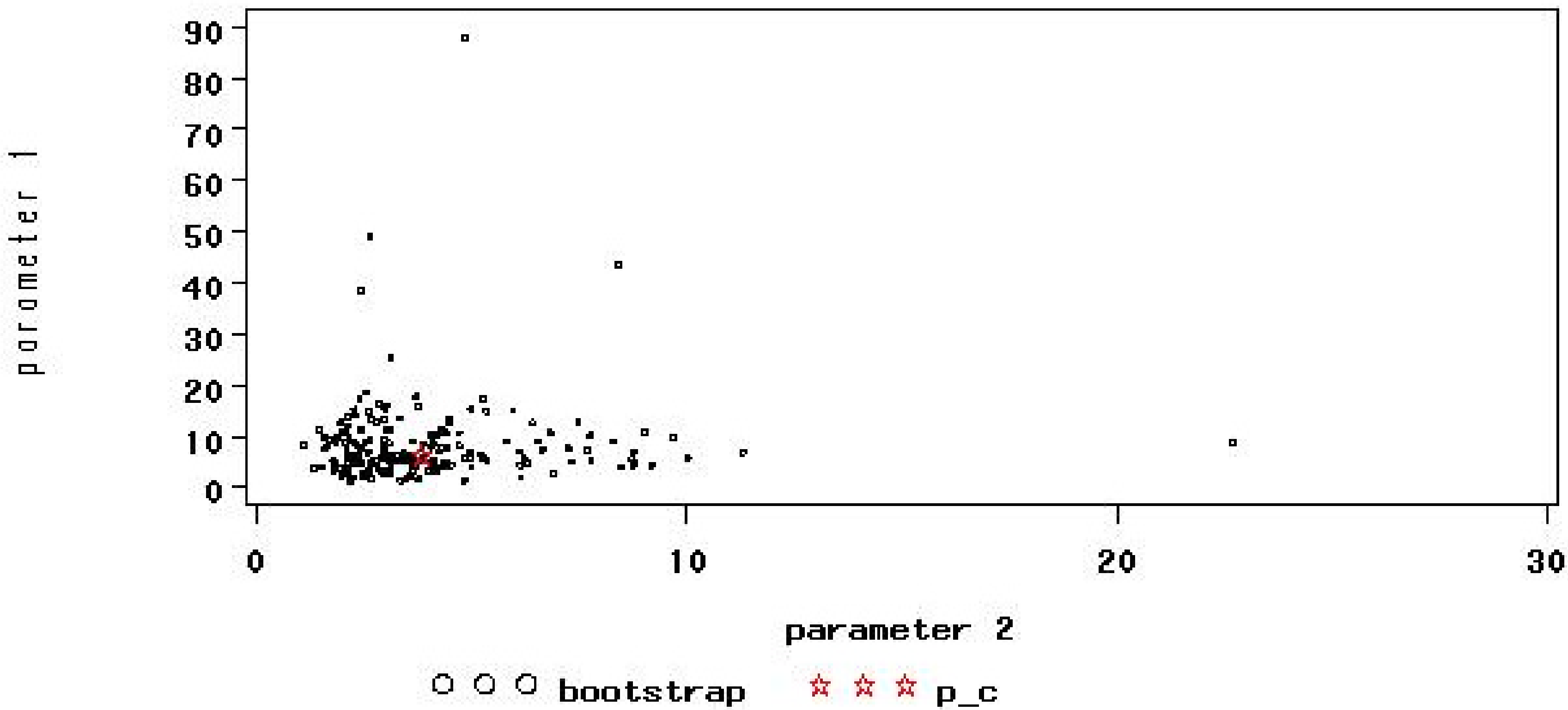


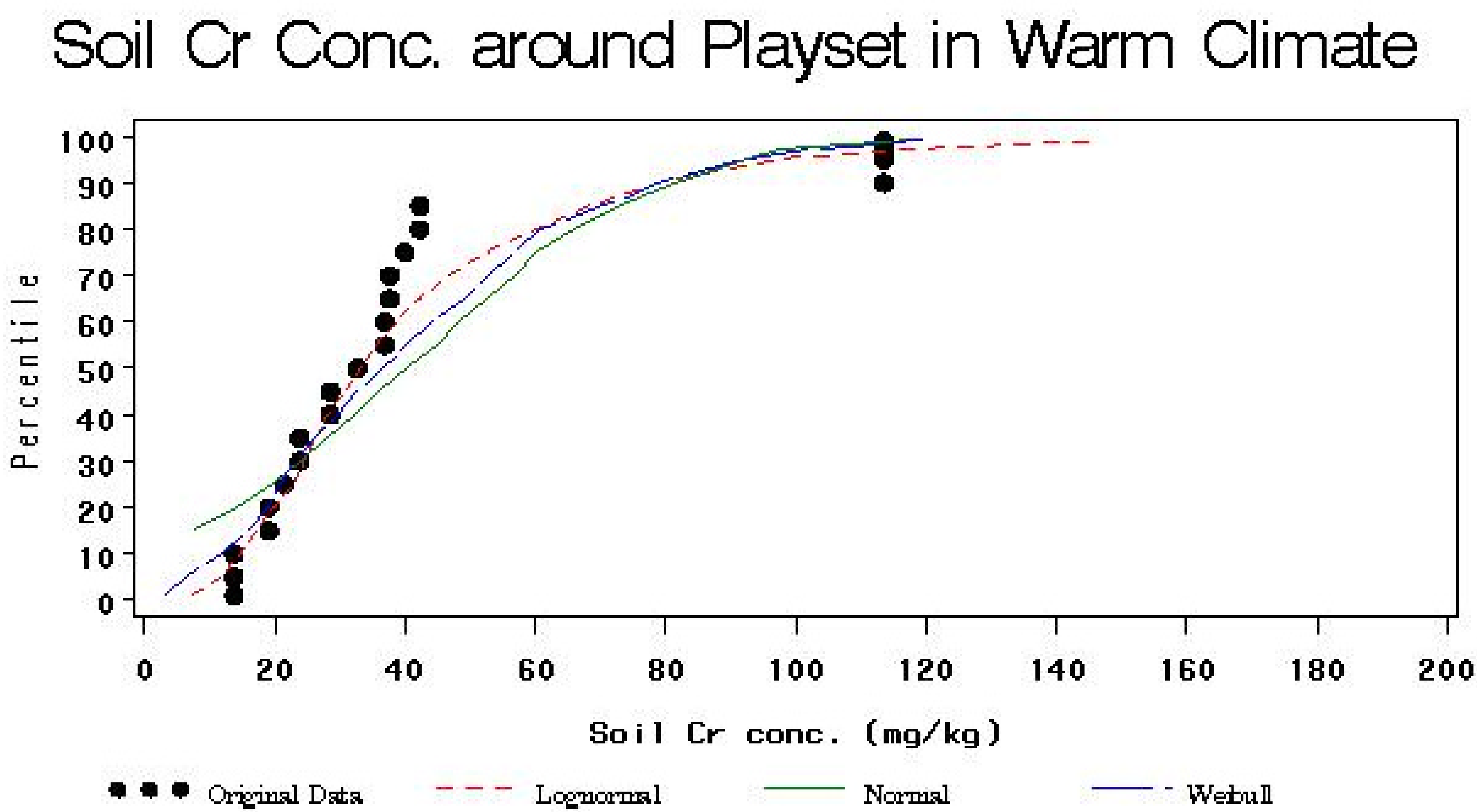
Soil Cr Conc. around Playset in Cold Climate

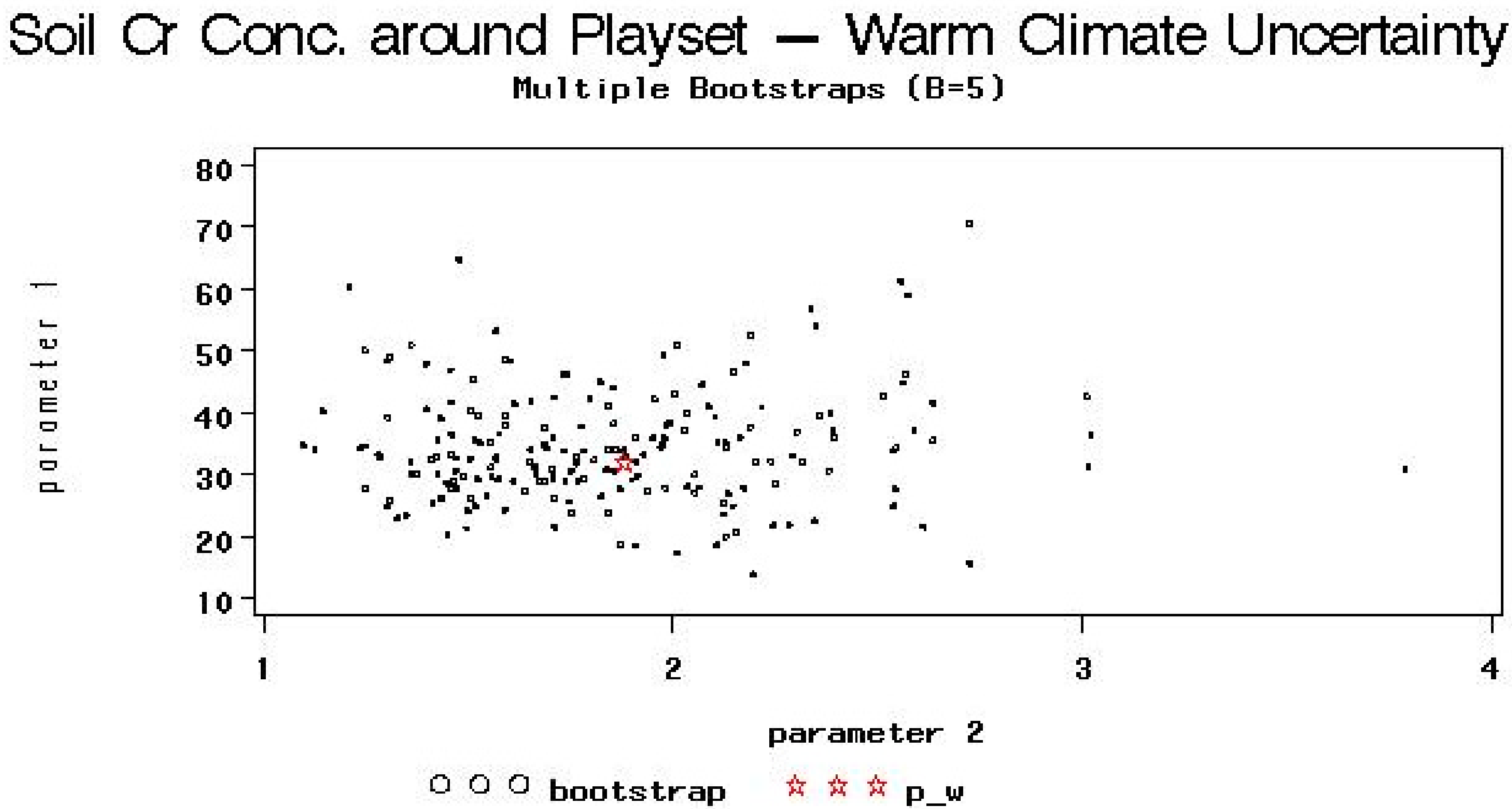


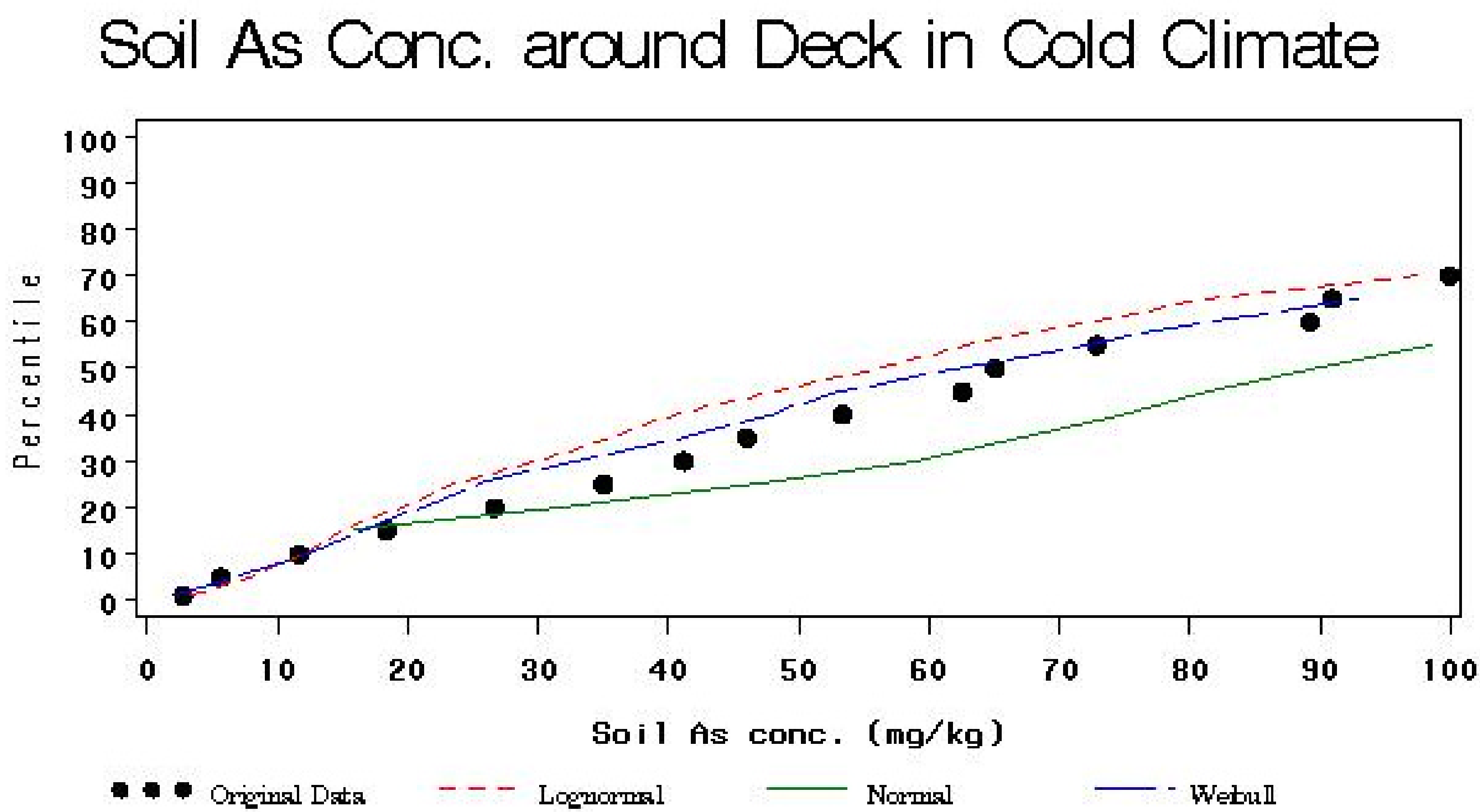
Cr Soil Cr Conc. around Playset — Cold Climate Uncertainty

Multiple Bootstraps (B=5)



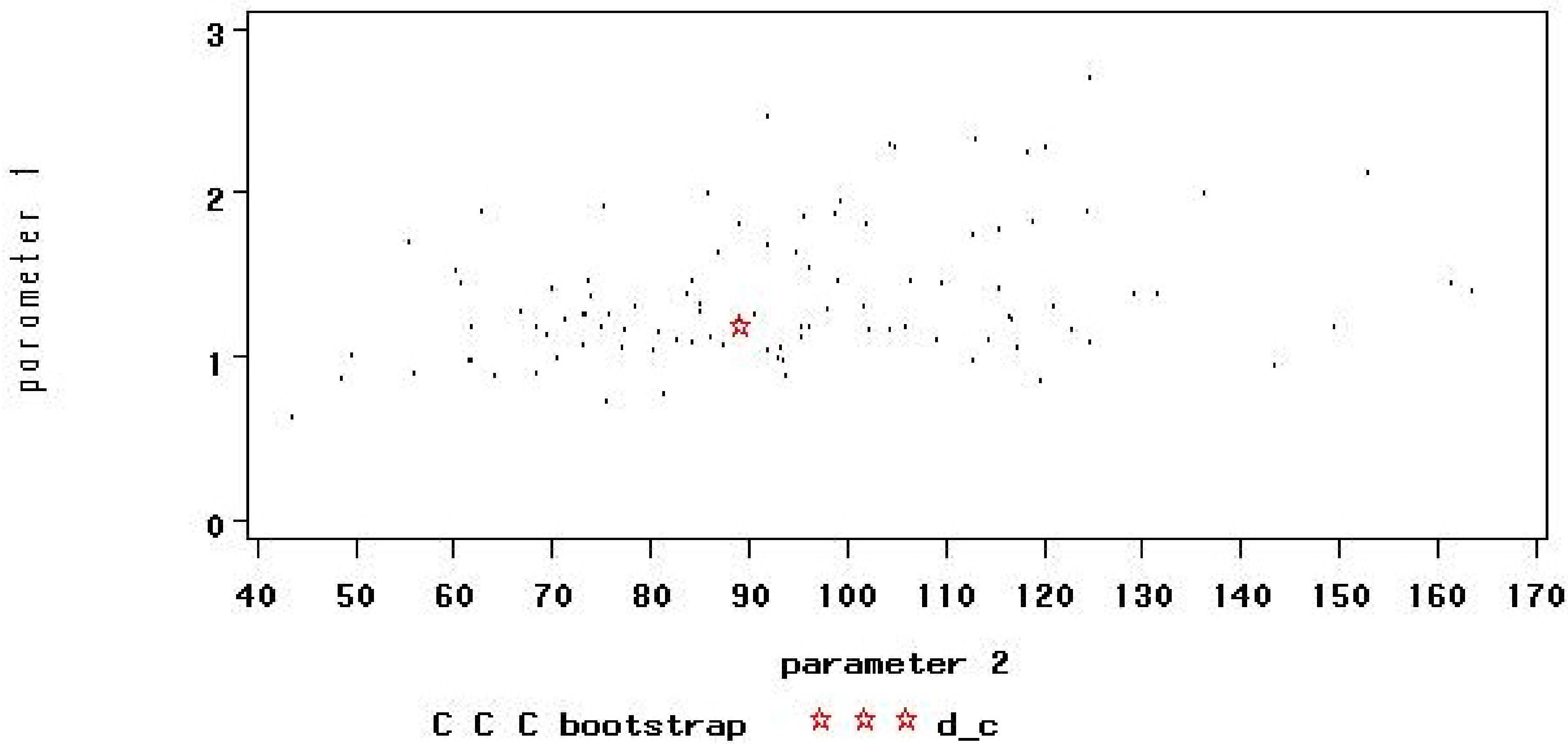

Soil Cr Conc. around Playset in Warm Climate
Percentile
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100
120
140
160
180
200
Soil Cr conc. (mg/kg)
Original Data
Lognormal
Normal
Weibull

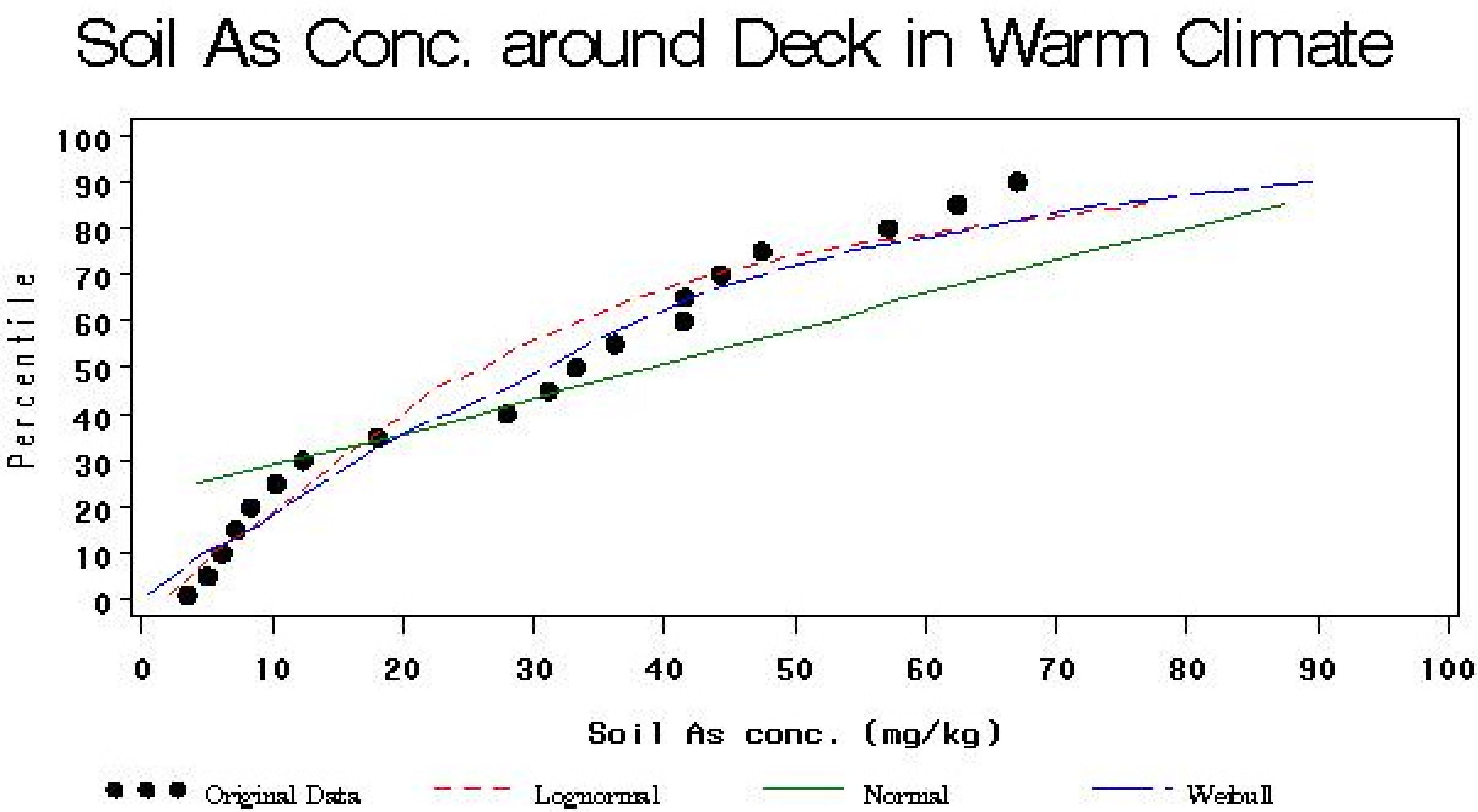

Soil Cr Conc. around Playset — Warm Climate Uncertainty
Multiple Bootstraps (B=5)
80
70
60
50
40
30
20
10
parameter 1
1
2
3
4
parameter 2
bootstrap
p_w



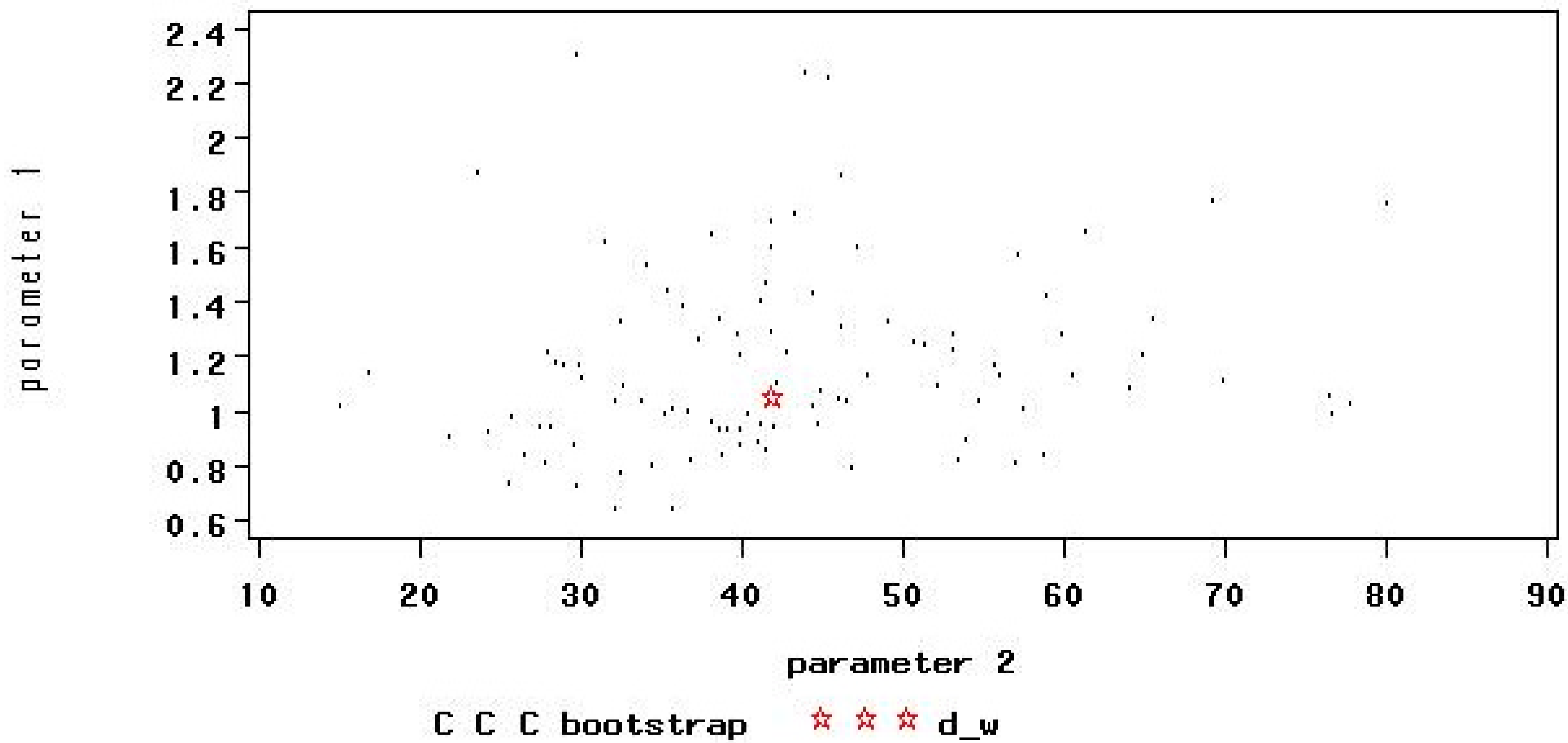
Soil As Conc. around Deck in Cold Climate
Percentile
0
10
20
30
40
50
60
70
80
90
100
Soil As conc. (mg/kg)
Original Data
Lognormal
Normal
Weibull

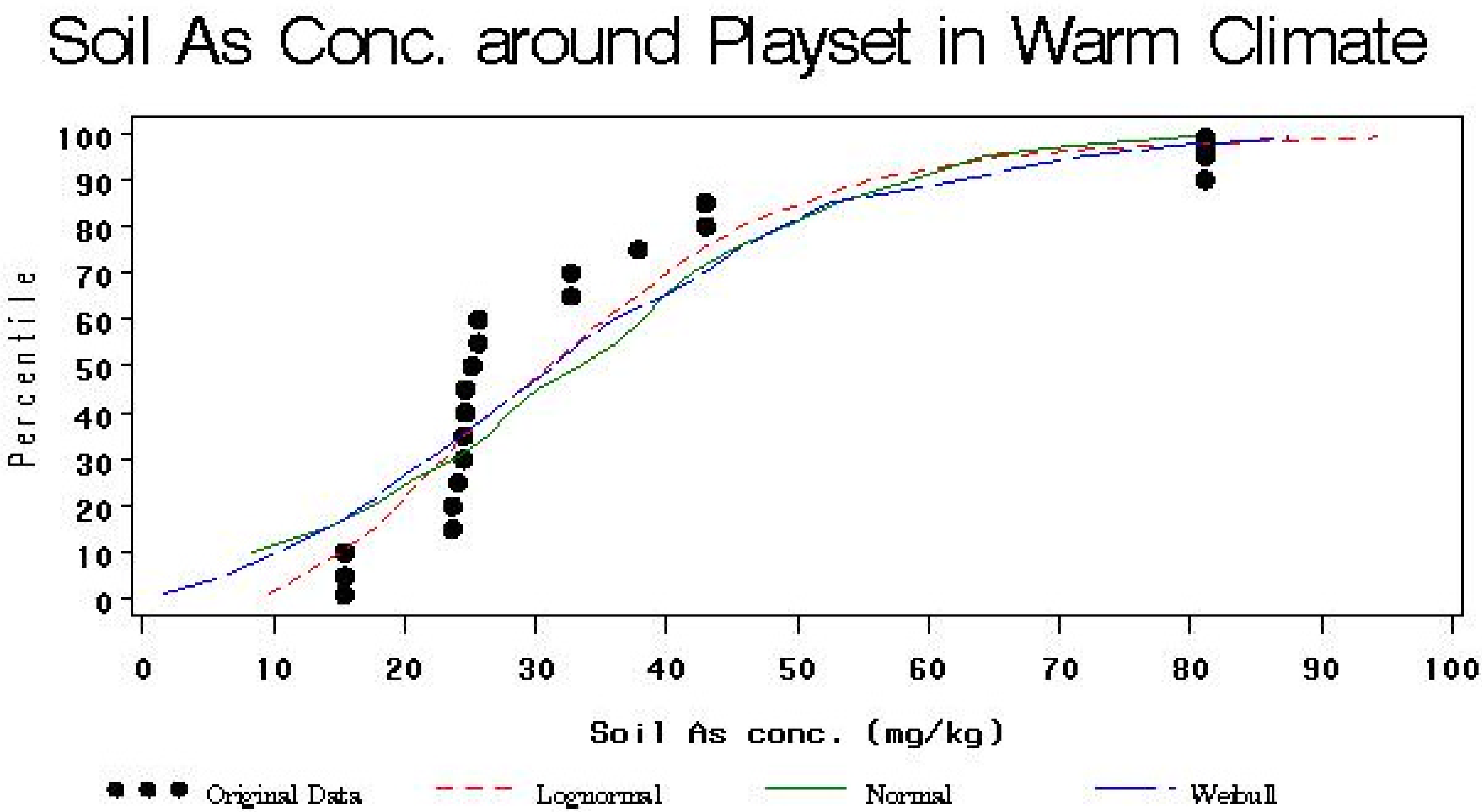
*** As Soil Conc. around Deck in Cold Climate ***



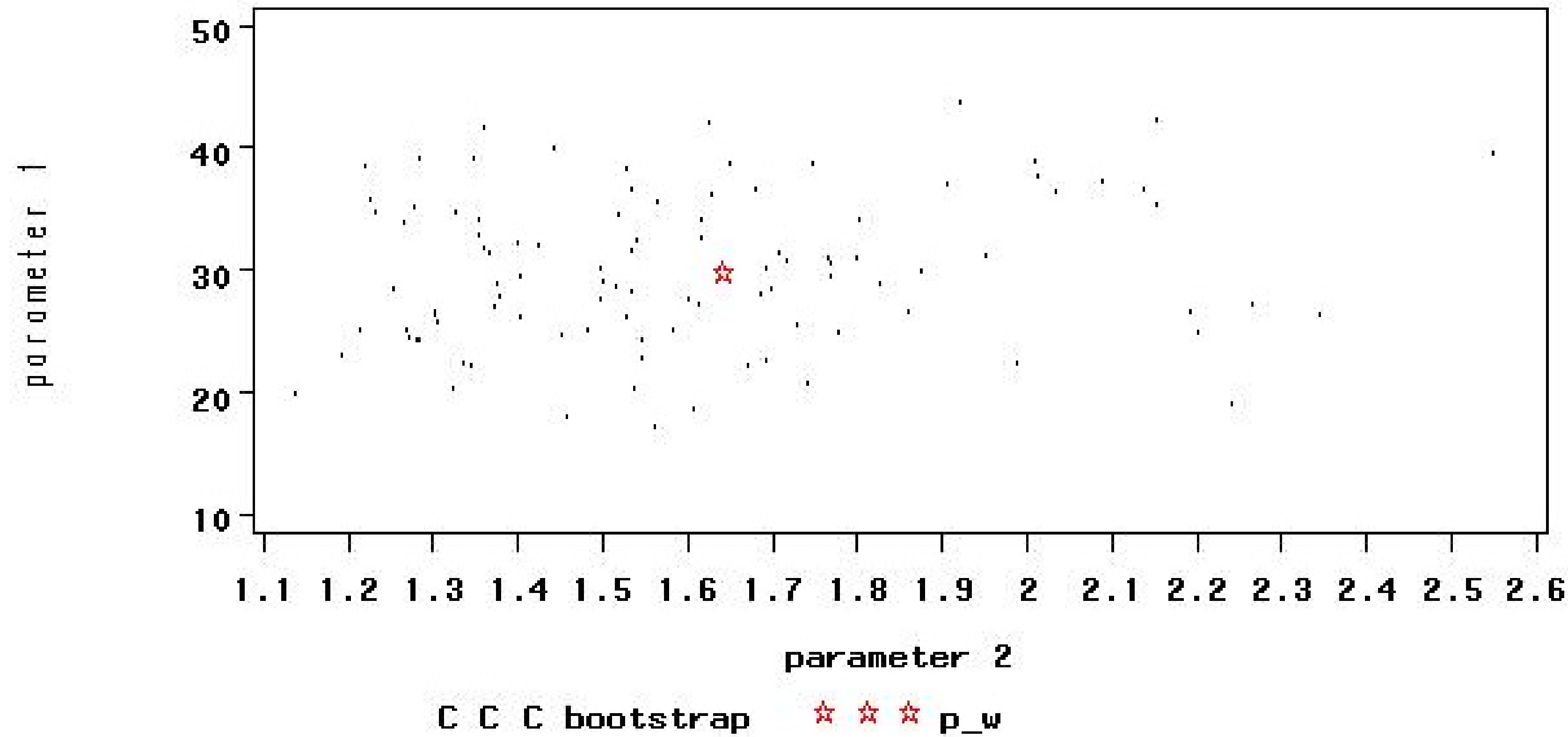

Soil As Conc. around Deck in Warm Climate
Percentile
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Soil As conc. (mg/kg)
Original Data
Lognormal
Normal
Weibull

*** As Soil Conc. around Deck in Warm Climate ***

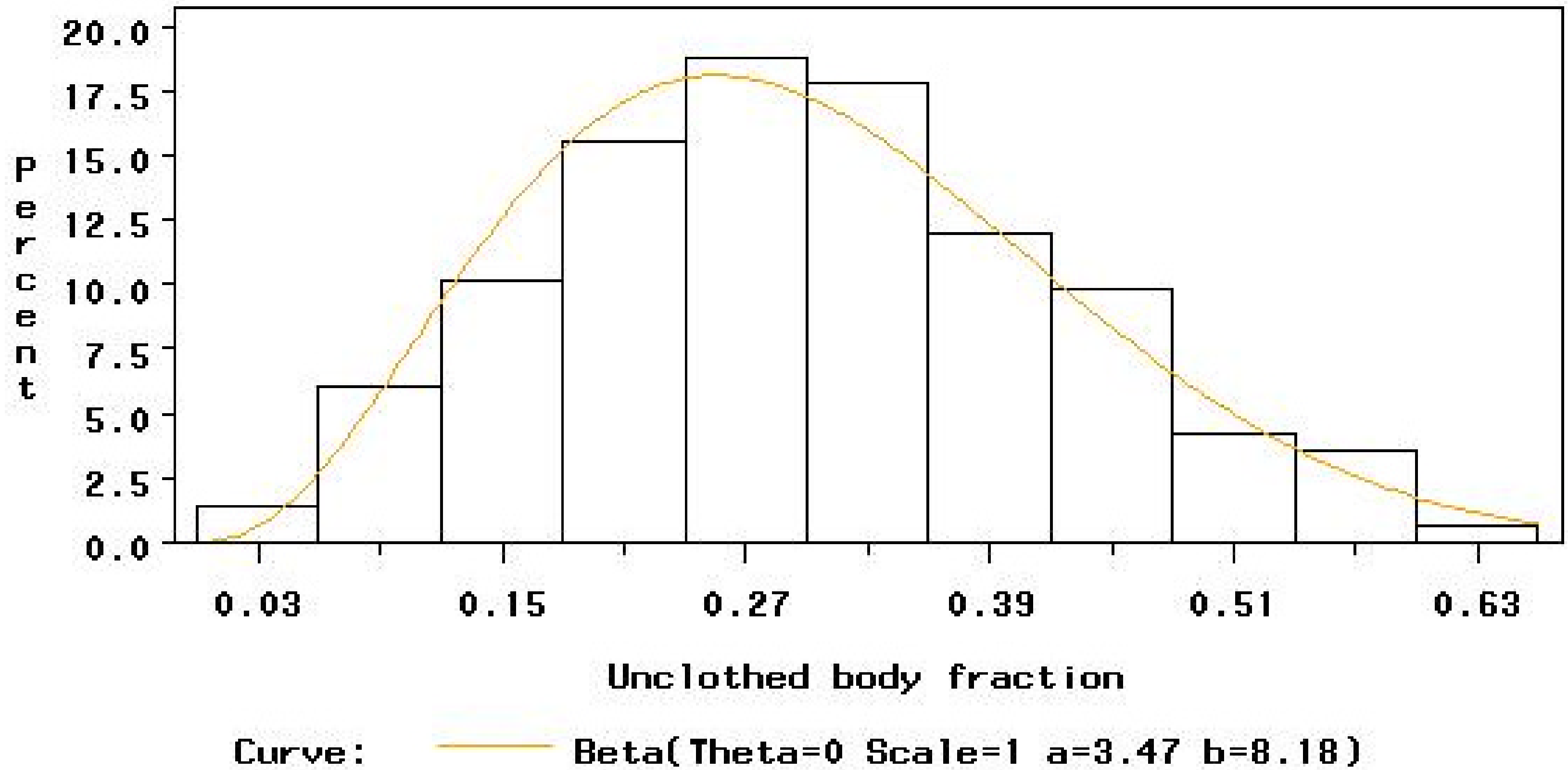



Soil As Conc. around Playset in Warm Climate
Percentile
0
10
20
30
40
50
60
70
80
90
100
Soil As conc. (mg/kg)
Original Data
Lognormal
Normal
Weibull

*** As Soil Conc. around Playset in Warm Climate ***

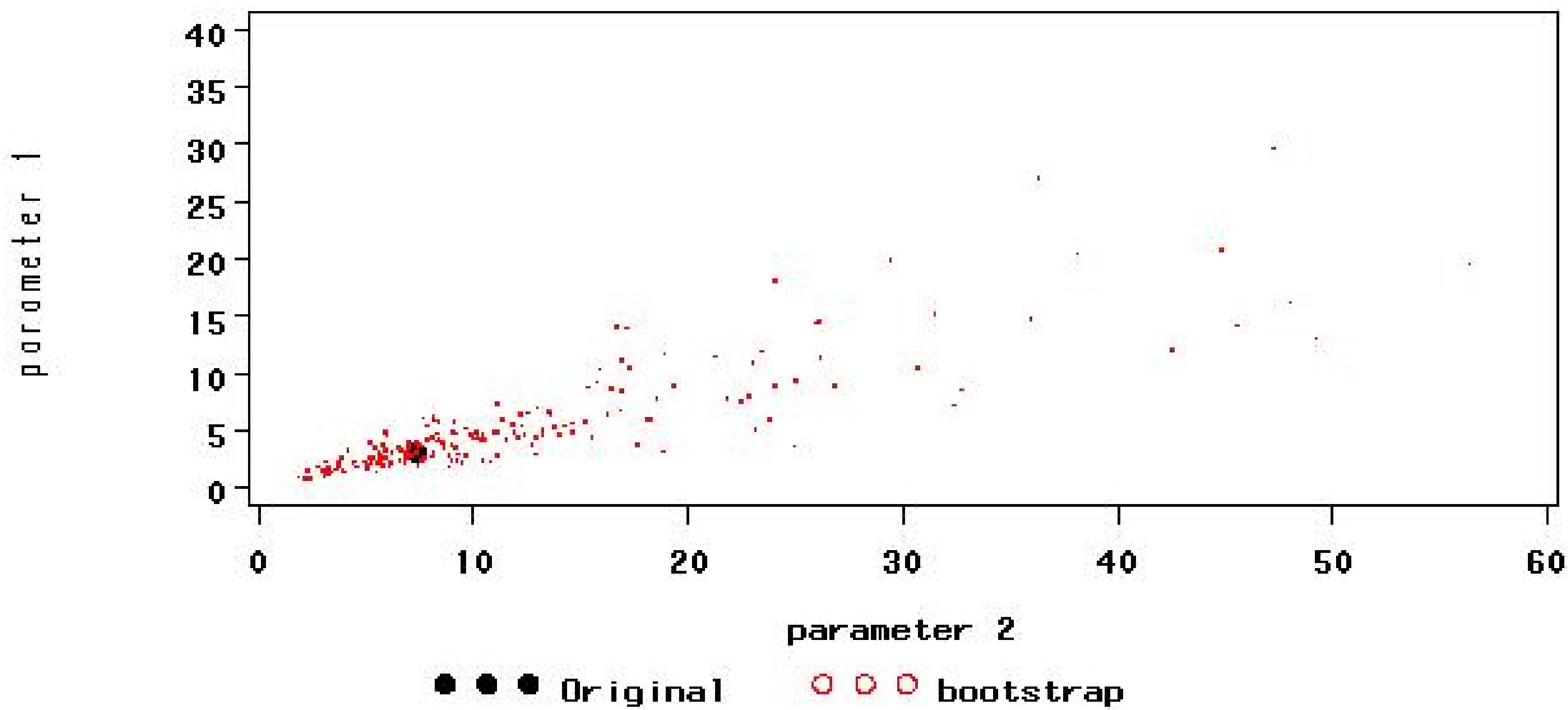


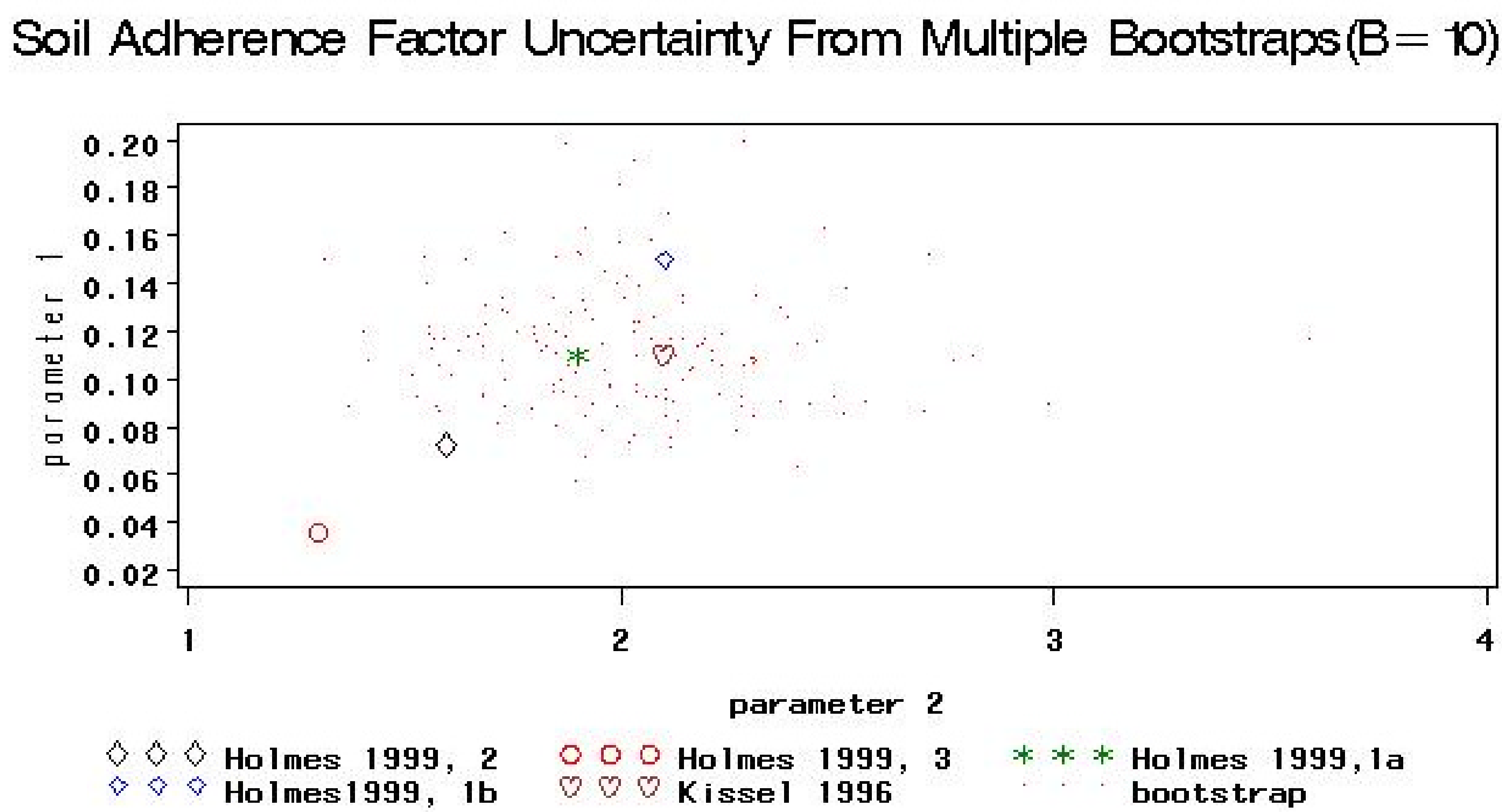
Warm Climate – Unclothed Body Fraction



Warm Climate – Unclothed Body Fraction Uncertainty

Multiple Bootstraps(B=5)





Soil Adherence Factor Uncertainty From Multiple Bootstraps (B = 10)
parameter 1
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
1
2
3
4
parameter 2
Holmes 1999, 2
Holmes 1999, 3
Holmes 1999,1a
Holmes1999, 1b
Kissel 1996
bootstrap

ADDENDUM

A Probabilistic Exposure Assessment for Children Who Contact CCA-Treated Playsets and Decks

Using the Stochastic Human Exposure and Dose Simulation Model for the Wood Preservative Exposure Scenario (SHEDS-Wood)

Draft Final Report

November 4th, 2003

Prepared by

H. Özkaynak[1], J. Xue[1] V.G. Zartarian[1], W. Dang[2]
U.S. Environmental Protection Agency
1 Office of Research and Development, National Exposure Research Laboratory
2 Office of Pesticide Programs, Antimicrobials Division

G. Glen, L. Smith, C. Stallings
ManTech Environmental Technology, Inc.

Introduction

This document is a supplement to "A Probabilistic Exposure Assessment for Children Who Contact CCA-Treated Playsets and Decks: Using the Stochastic Human Exposure and Dose Simulation Model for the Wood Preservative Exposure Scenario (SHEDS-Wood)", released as a Draft Final Report on September 25, 2003. This is EPA's response to the comments received from representatives of CCA registrants through OPP's error review process. Corrections for errors found in the original report are provided here in the Errata (Attachment 1).

Comments were received in the following documents:

Reviewer	Date	Index Symbol	Title
ACTA Group	Oct. 17, 2003	A	Error comments on EPA's draft final report: "A Probabilistic Exposure Assessment for Children Who Contact CCA-Treated Playsets and Decks".
Gradient Corp.	Oct. 16, 2003	G	Comment on EPA's probabilistic assessment of children's exposures to CCA-treated playsets and decks
Exponent	Oct. 20, 2003	E1	Review of the draft probabilistic exposure assessment for children who contact CCA-treated playsets and decks
Exponent	Oct. 30, 2003	E2	Comments on a probabilistic risk assessment for children who contact CCA-treated playsets and decks, draft report, Oct 20, 2003

Conclusions

After review of these comments, EPA staff has concluded that the overall results and conclusions of the September 2003 CCA exposure assessment remain the same. Moreover, most of the comments received on the exposure assessment document pertain to model inputs and not to the model structure. Alteration of inputs as suggested by the reviewers generally has a small impact on the predicted total exposure distributions (as expressed by ADD and LADD measures). Consequently, these comments are not expected to impact the original exposure or dose inputs used by OPP in its assessment of potential health risks to children who contact CCA-treated playsets and decks.

Index to Comments and Responses

This section addresses points raised by reviewers in a comment and response format. Each set is numbered, with the comment number prefixed by 'C' and the response number prefixed by 'R'. Note that the reviewer comments were not originally presented in this format, and have been paraphrased into a more succinct form. Page numbers in the index below refer to the documents supplied by the reviewers. The Subjects as listed here are very brief indicators of the subject matter of the comments.

#	Rev.	page	Subject
C1	E1	2	CHAD activity codes
C2	E1	2	Multiple diaries from same child
C3	E1	2	Re-use of same diary
C4	E1	3	Number of contact days
C5	E1	3	Contact time within events
C6	E1	3	On / near / away from playset
C7	E1	4	Eight diaries
C8	E1	4	Warm / cold scenarios
C9	E1	5	Inputs to uncertainty runs
C10	E1	5	Stability of 1500 persons
C11	E1	5	Age 7-13 results
C12	E1	6	Age dependent input distributions
C13	E1	6	Transfer efficiency > 1
C14	E1	6,12	Fraction of skin contacting residue
C15	E1	7	Fitting beta distributions
C16	E1	7	Conservative assumptions
C17	E1	7	Lack of time variation in certain variables
C18	E1	8	Subpopulation versus entire population
C19	E1	8	Instability of extreme percentiles
C20	E1	8	
	A	1	Mean > 75th percentile
C21	E1	9-12	New research on dermal absorption
C22	E1	12	
	A	2	Instability of maximum
C23	E1	13-14	Model comparisons
C24	E2	11	Truncation limits on inputs
C25	E2	11	TVL_OUT time
C26	E2	12	Deck / no deck differences
C27	E2	12	Losing body weight
C28	E2	13	No data provided for uncertainty runs
C29	G	2-5	Inputs weak on documentation
C30	G	4-5	Professional judgement not emphasized
C31	G	5	Indoor / outdoor hand-to-mouth

C32	G	4	Emphasize uncertainty in results
C33	G	6	Playset soil should be lower than deck soil
C34	G	6	Use of data sources for warm / cold
C35	G	8-12	Soil ingestion
C36	G	11	High contact time fraction
C37	G	11	Near equates to 2 feet
C38	G	13	Hand fraction contacting residue
C39	G	15-20	Criteria for hand-to-mouth contact
C40	G	20-21	Hand-to-mouth transfer fraction too high
C41	G	21-22	Conversion of daily GI absorption rate to hourly
C42	G	23	Differing mechanisms for soil and residue ingestion
C43	G	23-24	Fitting of GI absorption distributions
C44	G	24-25	Motivation for 100% GI absorption analysis
C45	G	27	Data values in Table 53
C46	G	25-31	Model comparisons misleading
C47	G	31-32	Size of modeled population
C48	G	33	Additional percentiles in Table 12
C49	G	33	Body weight
C50	G	33-34	Missing variables in uncertainty
C51	G	34-35	Broader aspects of uncertainty
C52	G	27	Aggregate across pathways
C53	A	1	Total chromium versus Cr(VI)
C54	A	1	Element for LOD
C55	A	1	Pica / non-pica input distributions
C56	A	2	Clarification of reference
C57	A	2	Intermediate term Cr results
C58	A	1-2	Desire to review underlying data

Comments and Responses

C1. *The SHEDS-Wood model examines the CHAD location codes but not the activity codes. In some cases the activity code seems to preclude playset contact. Exclusion of such events would reduce the potential for contact with CCA-treated wood.*

R1. The main issue here is that the CHAD database contains diaries from the entire population, not just the subset being examined in this report. Therefore, CHAD includes many children who do not engage in playset use, at least not on the particular day reported in CHAD. There are not enough diaries from playset users to fully populate all the cohorts required by the model. These cohorts consist of twelve age-gender groupings, four seasons, two day types (weekend and weekday), and three outdoor time groupings (high, medium, and low). This produces 288 combinations, each requiring diaries. The diary pool was expanded to include any child who spent time outdoors in locations that might have playsets, regardless of whether the diary reports actual playset usage. This ensured that all cohorts were represented, but entailed the addition of another input variable to randomly determine what fraction of the events in suitable locations were to be designated as contact events.

C2. *The SHEDS-Wood model draws only one dairy day at a time from CHAD, and therefore does not utilize the cases in CHAD where more than one diary is available from the same child.*

R2. SHEDS-Wood makes use of 2536 diary-days of CHAD data from 1688 different children. There are only 720 children with two diary days (nearly all from the University of Michigan study - usually not consecutive days) and another 64 with three diary days (all from the Cincinnati study). The SHEDS-Wood protocol for assembling a year-long diary from eight single-day diaries from different children would need to be modified, if multiple diaries from the same child were used. Since it is undesirable to eliminate the 904 children with just one dairy day from consideration, due to sample size and other considerations, the model would require three methods for assembling a year-long diary, depending on the number of diaries available from the selected child. These additional methods have not been developed given the limitations (e.g., small sample size and limited geographic representativeness) of available CHAD multi-day diaries.

C3. *SHEDS-Wood re-uses the same activity diary day quite often, yet children do not spend the same amount of time outdoors from day to day.*

R3. The relevant variable for exposure in SHEDS-Wood is the amount of contact time with CCA-treated wood. This is determined using three factors: the activity diary, a daily probability check for contact, and (if contact occurs) a check for each suitable outdoor event to determine contact time. Even if the activity diary happens to be the same, these latter checks produce daily variation in the amount of contact time. This is a better methodology than either extreme: keeping the diary fixed, or selecting a new diary every day.

C4. *The number of contact days per year is a key variable for exposure, yet is based in part on arbitrary assumptions.*

R4. The number of contact days is an important variable, and the data reported in the text require additional assumptions to produce annual totals for contact days. The importance of this variable can be judged from the sensitivity analysis (Table 28, page 106). When the average number of contact days per year with a playset was reduced from 126 to 63, the ADD was reduced by a factor of 1.45 (or 31%). The true number of contact days will vary not only from child to child, but from place to place as well. The warm and cold scenarios are not intended to apply to all children, they are illustrative examples, referred to as 'bounding scenarios' (although they are not strict upper and lower bounds). It is appropriate to say that, given a group of children in a warm climate who use CCA-treated playsets on average for 126 days per year, then the warm weather results should apply. There may be specific communities or specific groups of children where the actual playset use is higher or lower than this figure. In such cases, the sensitivity analysis indicates the size of the adjustment in ADD that should result.

C5. *The rules in SHEDS-Wood for allocating which portions of suitable outdoor events are to be designated as contact time are arbitrary.*

R5. The main concern is that the average amount of contact time should match the amount requested by the user via the relevant input variable. The distribution of this amount over the suitable diary events is a secondary consideration, as it has a very minor influence on measures such as ADD or LADD. For the relatively few cases where there are many suitable diary events (say, ten, for example), and given that 50% of possible contact time becomes actual contact time, it was considered more likely that the entire duration of five of the ten suitable events would be on playsets, as compared to one-half of the duration for each of the ten suitable events. This was built in as a modeling assumption, but it is one that has a negligible influence on the results.

C6. *SHEDS-Wood effectively allows a child to move from 'on' a playset to 'near' it (and back), but does not allow the child to stray further away during play.*

R6. SHEDS-Wood defines 'contact time' as the time spent close enough to a playset to be affected by either the residues on the wood or by the chemicals leached into the nearby soil. Time spent elsewhere in a playground is not 'contact time'. As mentioned above, the amount of contact time is controlled by a model input variable, and is often less than the full duration of a given diary event.

C7. *SHEDS-Wood uses eight diaries to construct a year-long activity pattern. This may inflate the variability of exposure, by the repeated use of diary with an unusually high (or low) amount of outdoor time.*

R7. A journal article that has recently been accepted for publication indicates that eight is sufficient. However, a special SHEDS-Wood analysis has recently been conducted (not included in the main report) using 16 diaries to construct a year. For a run of the Arsenic warm climate scenario, for 1500 children for one year each, the results showed no difference in the mean exposures (both had mean ADD = 1.10E-4 mg/kg/day), and the run using 16 diaries had 10% higher values for the 95^{th} percentile of exposure (4.25E-4 mg/kg/day, compared to 3.86E-4 mg/kg/day). For a lifetime run, the use of 16 diaries lowered the mean LADD by 7% and the 95^{th} percentile of LADD by 8%. These shifts are comparable to the size of expected stochastic variation from run to run.

C8. *The warm and cold scenarios are not necessarily representative, and they do not include any seasonal variation in weather within them.*

R8. This is correct. These scenarios are described as 'bounding scenarios' and it is likely that most (but not all) of the target population should have exposures that lie between these two cases. The motivation for running these bounding scenarios is explained in the text on page 17.

C9. *It is not clear if the uncertainty fitting allowed the distributional shapes to be altered between uncertainty runs, or only the parameters within a single shape.*

R9. It is the latter case. The shape of the 'parent distribution' is the same as for a standard run. The 'uncertainty distributions' are sets of parameter pairs. See the section 'Modifications to the bootstrap approach' for details.

C10. *It is not clear if the sample size of 1500 used to achieve stable results referred to each scenario or to a combination.*

R10. Each model run consisted of 1500 children (except for a few of the special analyses). Since the probability of having a deck was 50%, roughly 750 children had a deck in each run, and the rest did not. However, some of the children in each run turned out to be pica children, meaning that they exhibited soil ingestion rates over 500 mg/day. Such children were excluded from the summary tables in the report, resulting in typically 730-740 children with decks and a similar number without decks in each run.

In any probabilistic model like SHEDS-Wood, the model results are more stable (meaning less stochastic variation when re-run with identical inputs) with increasing sample size. There is no special threshold at which results become 'stable'. In practice, the choice for the sample size depends on the both the acceptable stability tolerance and on practical considerations of computing. With the given size of 1500 children per run, for lifetime runs the reported results for the means and medians usually vary less than 5% from run to run, and the 95th percentiles usually vary less than 10% from run to run. For short-term and intermediate-term runs the stochastic variation is larger, with the means usually within 10% from run to run, and the 95th percentile usually within 20% from run to run.

C11. *The results for children aged 7-13 are projections based on the age 1-6 results, rather than being independently modeled.*

R11. This is correct, and was done this way because of lack of data on older children. This is why the results are included only as a 'special analysis', rather than being reported with the main set of results for 1-6 year old children. Without new age-specific data, it was assumed that exposure rates should be lower for older children, due to reduced hand mouthing behavior (which is part of the dominant exposure pathway). In addition, older children have higher body weights, leading to lower ADD values. The analysis quantifies the relationship between assumed exposure rates and LADD.

C12. *Certain inputs should have age-dependent distributions, especially for hand-to-mouth behavior and soil ingestion rates.*

R12. The SHEDS-Wood code allows age-specific distributions for hand-to-mouth contact frequency and hand washing frequency. However, there were insufficient data to justify fitting such age-specific distributions. For the lifetime runs used to produce LADD estimates, the effective assumption is that these variables are age independent from 1 to 6 years, but then fall abruptly to zero. Other models may have a more gradual decline starting at age four, but do not abruptly stop at age six. It was decided that data were not sufficient to support age-dependent distributions. This is not likely to have a significant effect on the exposure distribution. For example, in the sensitivity analysis, when the soil ingestion rate was cut in half, the net effect was a 6% reduction in mean exposure. For hand-to-mouth frequency the effect was even smaller. The effect of using age-dependent distributions should be substantially less than the effect of cutting the distribution in half at all ages, which is what happens in the sensitivity analysis.

C13. *The transfer efficiency was modeled using a lognormal distribution which can exceed unity on occasion.*

R13. SHEDS-Wood permits any input distribution to be truncated, if desired. Thus, a lognormal distribution truncated at one can be used for 'fractions'. However, the 'transfer efficiency' in SHEDS-Wood is not strictly a fraction. It represents a ratio of concentration on the skin to the concentration on the wood surface. For a single touch, this ratio cannot logically exceed one. But SHEDS-Wood does not model single touches, it models the combined effect of a series of touches over a time interval. Note that the duration of contact appears explicitly in the equation for new dermal exposure (Appendix 2, page A2-5). By repeatedly touching the same portion of skin to different parts of the wood surface, it is possible to build up a concentration on that piece of skin that is higher than the concentration on the wood surface. The experimental data show that this is rare, as the mean value for this ratio is only 20% (warm scenario).

C14. *The fraction of skin contacting residues is too high in SHEDS-Wood.*

R14. The reviewer cites new research that results in only 4%-15% of skin coming into contact with residue for a single touch, increasing to about 40% for multiple touches. The SHEDS-Wood variable for skin contact rate has a mean of 78%, for a 20-minute interval. Note that this does represent the actual portion of the skin that contacts residues. For example, a value of 80% could mean that 20% of the skin surface touches the residue a total of four times (in 20 minutes). Note that this variable does not apply to a single touch, but to the combined effects of 20 minutes of play. As the equations in Appendix 2 indicate, this term is multiplied by a duration to determine new exposure. The product of skin contact rate and contact duration is dimensionless, and has a mean value of 4% for a one minute contact, and a mean value of 39% for a ten minute contact. These numbers are consistent with the new data.

C15. *The discussion on the use of the beta distribution to fit uniform or triangular inputs obscures the fact that these latter shapes might not be appropriate for particular inputs.*

R15. Beta distributions were used for parameters that are logically bounded to be between zero and one, such as proper fractions or probabilities. As discussed in the text, the 'foundational triangular distributions' capture most of the range of experimental data. Studies involving human subjects usually have very small sample sizes (often no more than 10 or 20), so the sample is unlikely to capture the tails of the distribution. In addition, many studies only report summary statistics such as mean and standard deviation. The beta distribution fits reasonably well to triangular shapes, while permitting some small but non-zero area in the tails extending out to zero and one. This two-stage fitting procedure worked better than direct fitting of a beta distribution to the raw data in cases where there were very few data points. Beta distributions were not fit to uniform distributions.

C16. *SHEDS-Wood uses conservative assumptions for some input distributions.*

R16. This is correct. However, the number of such conservative assumptions has been reduced as new data became available. Wherever possible, realistic estimates were used. When there was little reliable data, best professional judgement was used.

C17. *Some modeling variables (for example, the climate) are assumed to show no variation in time for a given child, which would inflate the variability in long-time averages such as LADD.*

R17. For the example of the climate, the warm and cold scenarios are only intended to be bounding scenarios. In general, there will be some children who experience changing conditions over time, resulting in a mix of high and low rates of exposure. Such children will have LADD levels below those of children who experience consistently high rates of exposure.

C18. *The focus on subpopulations will result in exposures that apply only to a (high-end) fraction of the entire population. A larger target population would entail a shift towards lower values for the resulting exposure distribution.*

R18. The model results are only intended to apply to the defined target population.

C19. *The high-end percentiles are subject to both uncertainty and numerical instability.*

R19. The numerical instability is addressed in R10 above. The tails of the exposure distribution often reflect values selected from the tails of one or more of the input distributions. Input distributions derived from studies with small sample size have better characterization of the center of the distribution than of the tails. Hence, the uncertainty in the SHEDS-Wood results increases as one moves away from the center of the exposure distribution.

C20. *For some input distributions and at least one output, the mean value exceeds the 75th percentile.*

R20. For skew distributions with long tails to the right (larger values), the mean is larger than the median (50th percentile) and may even exceed the 75th percentile in some cases. The data are correct for the specific cases identified in the report.

C21. *New research on dermal absorption of arsenic shows lower rates than those used in the SHEDS-Wood report.*

R21. This new research was not available when the main set of model runs was made. An extra model run was subsequently performed using a dermal absorption rate of 0.01% per day, and included in the section on special analyses. The effect was roughly a 30% reduction in LADD in each scenario. Further consideration of these new data for inclusion in the baseline scenario will be sought from the SAP.

C22. *The "Max" estimates in the tables of results are unstable.*

R22. In any probabilistic model, the maximum value obtained across a set of individuals is not a reproducible statistic, and will vary greatly from one model run to another. As mentioned in both R10 and R19, uncertainty and instability increase as one moves from the center of the exposure distribution out to the tails. The maximum value is subject to these effects more than any other part of the distribution.

C23. *The comparisons to earlier exposure assessments for CCA are inappropriate, as these studies have since been superceded.*

R23. The SHEDS-Wood model is very different in nature from the other models, so a direct comparison is not strictly appropriate. It neither validates nor invalidates any of the models. Several of the inputs are not even expressed in compatible units. The report provides comparison tables of both input and results, in order to assist the reader in identifying similarities and differences between the models.

Some of the other models have recently been updated with the use of new input distributions. The reviewers suggest that these new results would remove some of the apparent 'agreement' of the SHEDS-Wood results with the other models. Even if this is so, the statement that strict comparisons are not appropriate still remains in force.

C24. *The SHEDS-Wood model checks truncation limits on input distributions, and 'piles up' values beyond the limits by resetting them to the limit. For soil ingestion rates in non-pica children, this leads to many children being at the 500 mg/day limit.*

R24. This point was realized at the time the model runs were conducted. Therefore, instead of running the pica and non-pica cases separately, a single run contained both cases. The soil ingestion distribution was not truncated, instead a flag was set to (pica=1) if the generated value was over 500, and set to (pica=0) otherwise. This is why the tables in the report have sample sizes somewhat less than 1500 (since the pica children are not included). No variables were explicitly truncated in the standard model runs.

Regarding the relative merits of resampling versus resetting values to the truncation limit, it should be noted that resampling results in a greater reduction in the standard deviation, and for one-sided truncation, also a greater reduction in the mean. Resampling would produce more probability near the distributional mode than is produced by resetting values.

C25. *The use of CHAD diary time in the TVL_OUT category can result in a mis-classification of activity into the high, medium, and low groupings.*

R25. The TVL_OUT category only accounts for a mean of 2.1 minutes per child (out of a mean of 164.2 outdoor minutes per child). The elimination of TVL_OUT time would have a minimal effect on activity classification. Given that the model probabilistically determines whether a high, medium, or low diary is chosen, any diary can be assigned to any child.

Of the 2536 diaries used in SHED-Wood, 47 have TVL_OUT time but no other outdoor time. If one of these diaries is assigned, no exposure can occur on any day that this diary is used. The elimination of TVL_OUT time would mean the removal of these 47 from the diary pool, which might increase overall exposure.

C26. *The LADD results for the playset component of exposure (Tables 14 and 15) show differences between the children with decks and those without decks.*

R26. The results for children without decks are up to 20% higher than for children with decks (for the playset component of exposure). The main reason for this is the maximum dermal loading. Children with decks reach this limit more frequently and then cannot acquire further exposure from playsets until some is removed. In addition, there is stochastic variability, so the results will differ somewhat if the run is repeated.

C27. *SHEDS-Wood allows children to lose weight from month to month. This may result in a relatively high exposure in a month when weight loss occurs.*

R27. Body weight is varied monthly in SHEDS-Wood, and may increase or decrease. Children can in fact lose weight over short time periods. We were unable to reproduce the extreme weight changes reported by the reviewers using the stated sample size of 100. We found that it was very rare (about 1% of the time) to lose as much as 2 kg over 12 months. Average annual body weight increases from one year of age to the next in nearly all cases (998 times out of 1000 cases in a test run).

Although there is a possibility of a high exposure during a month with unusually low weight, other combinations are possible (e.g., high exposure/high weight, low exposure/high weight, low exposure/low weight). The results are presented as averages over time such as ADD or LADD, so these effects tend to average out.

C28. *The version of the model distributed to interested parties did not include data for uncertainty runs.*

R28. This will be provided for the SAP review.

C29. *The report does not provide adequate documentation for the selection of input distributions, neither for data sources nor the distributions.*

R29. Justification and sources for the model inputs are provided in the text. EPA examined relevant literature on the model input parameters and consulted with experts; the data sources and distributions judged to be most appropriate were utilized.

C30. *The report, especially the summary in Table 12, does not convey the extent to which professional judgment was used to establish input distributions. One example cited is the playset contact time fraction.*

R30. Table 12 is merely a summary; the accompanying text provides the detail. In the example cited, the text was sufficiently detailed for the reviewer to ascertain what was done. The specific assumption that playground time was equivalent to playset contact time is conservative and was made in the absence of direct observational data.

C31. *The hand-to-mouth contact frequency does not distinguish between indoor and outdoor activity.*

R31. A subsequent analysis was undertaken, separating this variable into indoor and outdoor distributions. The net effect on the exposure distribution was small, a 6% decrease in the mean and a 3% decrease in the 95th percentile.

C32. *The report does not sufficiently emphasize the uncertainty in the results.*

R32. There are three general types of uncertainty that contribute to the overall uncertainty in the results: uncertainty in input variables, stochastic uncertainty, and uncertainty related to model structure and assumptions. The first of these is explicitly addressed in the report. The stochastic uncertainty refers to the fact that reported summary statistics (for example, the mean or the 95th percentile of exposure) would vary if the model is re-run with identical inputs. Response R10 addresses this point. All models entail certain amount of simplifying assumptions to make the problem of interest tractable; there is no consensus on how to quantify the model formulation uncertainty arising from assumptions regarding model structure.

C33. *The soil concentrations near playsets should generally be lower than near decks. The data used in the assessment were from decks, but were used for playsets as well.*

R33. For lack of data specific to playsets, the same data were used for both. Soil exposure was a minor pathway in all but the special analyses in which the residues were greatly reduced.

C34. *Concentration data from Stilwell (1998) were inappropriately used in both warm and cold scenarios. Hand wipe data from Washington, D.C. were assigned to the cold scenario.*

R34. The reference to Stilwell in Table 12 was in error and is corrected in the Errata. The text accompanying this table was correct. See response R8 regarding the interpretation of the climate scenarios. The hand wipe data from Washington D.C. were collected in April.

C35. *The method of deriving an input distribution for the soil ingestion rate has deficiencies. Specifically, the main objections concern: the pica/non-pica distinction, the method of combining data from two studies, the use of short term data for long term modeling, differences among age groups, the contribution of indoor dust, and direct soil ingestion versus transfer from the hands.*

R35. The available information on soil ingestion rate by young children is highly limited. There is no agreed upon methodology to interpret and analyze these data for modeling use. The approach used in SHEDS-Wood incorporates the essential features of the limited information available. The sensitivity analysis shows that a reduction in soil ingestion rate by a factor of two results in a reduction of 6% in the mean total exposure. To answer the concerns raised by the reviewer, a modified version of the model was run specifically comparing soil ingestion exposure to the amount of hand-mouth soil transfer exposure; it showed that these two quantities were comparable (the latter is roughly 30% lower). This suggests that the hand-mouth transfer for residues is not unduly high. Another set of new model runs was made, dividing the soil ingestion into equal indoor and outdoor portions. The results for the baseline case was a small reduction in both the mean and 95th percentile of total dose (no more than 5%). For the special analyses with residue concentrations reduced by the application of a sealant, the reductions in total dose ranged from 10% to 45%.

C36**.** *The contact time is a very high fraction of the outdoor time, leading to high exposure estimates.*

R36. As remarked earlier in response R30, this is a conservative assumption made in lieu of appropriate data. The sensitivity analysis shows that a 50% reduction in playset contact time results in a 29% reduction in total exposure. For a 50% reduction in deck contact time, the total exposure was only reduced by about 10%. These reductions are less than 50% due to competing influences in the model, particularly the maximum dermal loading. The deck result also reflects the fact that many children do not have decks, so their exposure is unaffected.

C37. *The model assumes that 'near' a playset or deck refers to being within 2 feet of the structure. The literature citation for this distance is incorrect and inadequate.*

R37. The model structure and results do not depend on this value. The reference in the text is corrected in the Errata.

C38. *The hand fraction contacting residues is too high.*

R38. See response R14.

C39. *The criteria for designating hand-to-mouth contact frequency and contact area come from different studies that might be using different standards for defining a mouthing event. Indoor versus outdoor hand mouthing frequencies should be distinguished, and should be age-dependent.*

R39. SHEDS-Wood defines a mouthing event as including at least partial insertion (half of one finger). This is consistent with Leckie et al. (2000) and the data used from Zartarian et al. (1998). Some of the other studies report a mix of insertion and casual hand-to-mouth contacts.

Note that the sensitivity analysis indicates that the effect of altering this input variable is minimal: a halving of its value resulted in a reduction of only 3% in mean total exposure.
Response R31 reports on a new model run using the indoor/outdoor distinction. Response R12 covers age dependency.

C40. *The hand-to-mouth dermal transfer fraction is too high; it is significantly higher than the hand washing removal efficiency.*

R40. The effect of this variable is not large. The sensitivity analysis shows that lowering the hand-to-mouth transfer fraction by 50% results in a 10% decrease in mean total exposure. A new model run was conducted using a triangular distribution (min=0.24, mode=0.48, max=0.72) for hand-to-mouth transfer fraction; this resulting in a reduction in mean LADD of 7% and a reduction in 95th percentile LADD of 10%, for the Arsenic warm climate scenario.

C41. *The daily GI absorption fraction is converted to an hourly rate by dividing by 12. This implies that ingestion typically occurs 12 hours before voiding, which is not reasonable given a 6.a.m. voiding time.*

R41. While absorption within a single diary event is a linear function of time, the cumulative effect over many events is not linear. Suppose the daily absorption fraction is selected to be 48%. Then the hourly rate used in SHEDS-Wood is 4% (which is 48%/12). Suppose for simplicity that an activity diary consists entirely of events of 30 minutes duration each. In the first event, 2% of the ingested exposure is absorbed (4%/hr * 1/2 hour), and 98% remains in the GI tract. In the second diary event (assumed also to be 30 minutes), the rate of absorption is still 2% of the GI tract loading, but the amount available is only 98% of the original. Thus, the second event results in a further 1.96% of the original amount being absorbed, with 96.04% remaining in the GI tract. Each subsequent event results in a smaller amount being absorbed, as less remains available. It takes 33 such 30 minute events for the cumulative amount absorbed to reach 48% of the amount originally ingested. Thus, a child who ingested arsenic at 1:30 p.m. would absorb 48% of the ingested amount by 6 a.m., when the remainder is voided. This is a reasonable average for the time of ingestion.

C42. *The model uses different mechanisms for the ingestion and absorption of residues versus soil. This is not supported by physiological differences, but is a consequence of available input data.*

R42. The model uses the same mechanism for absorption of residues and soil, except for a difference in the rate constant. The soil ingestion does not use the hand-mouth transfer approach that is used for residues. As noted, this is primarily due to the availability of input data. A model run was conducted to compare the soil exposure using the hand-mouth transfer approach, assuming the same modeling parameters as for residues. The results were comparable to the direct soil ingestion results, with the new results slightly lower (roughly 30%). However, the comment C35 suggests that the direct ingestion is overestimated. Any change in this value would not affect the soil-hand-mouth transfer result, so lower soil ingestion rates would make the agreement even closer.

C43. *The fitting of beta distributions for GI absorption rates needs justification.*

R43. As pointed out by the reviewers, the means and medians for the beta distributions fall within the 90% confidence intervals for the values from the Casteel et al. (2003) study. The comparison of the widths in the confidence intervals on the mean in this study to the distribution width (difference between the mean and 95th percentile) is not appropriate.

C44. *The motivation for conducting a special analysis using a GI absorption rate of 100%/day is inappropriate.*

R44. The special analysis does not claim that a rate of 100% is realistic. It is simply a 'bounding scenario' or a 'sensitivity analysis'.

C45. *The values in Table 53 do not agree with those in Table 30.*

R45. New values for Table 53 are given in the Errata.

C46. *The comparisons of results between models in Table 53 are inappropriate and misleading.*

R46. As the reviewers point out, the models are very different and therefore direct comparisons are difficult. The goal of Table 53 was not a formal model comparison. Table 53 presents a range of values from the SHEDS-Wood results and various point estimates from other models. All of the models focus on the exposures of the upper tail of the population, but perhaps to differing degrees. Therefore, it is not obvious which statistics from the SHEDS-Wood runs should be compared to the other runs, especially when a qualitative reasonable maximum exposure (RME) estimate is generated by some of these models, by multiplication of various numbers corresponding to different exposure factors (each presumably selected from an empirical range of moderate to high values). The text in the report refers to the comparison of the means and medians of the SHEDS-Wood results to the other model results; the SHEDS-Wood values are usually within a factor of two of Gradient's results. The reviewers chose to compare the SHEDS-Wood 95th percentile values to the other models, which explains the apparent discrepancies to which the reviewers refer.

C47. *The size of the subset of the population to which the SHEDS-Wood assessment applies is not clear.*

R47. The Agency has defined the population for this particular assessment to be those children who come into frequent contact with a CCA-treated playset in a public (that is, non-residential) location. This includes playsets at schools and daycare centers, but excludes all playsets that do not contain CCA-treated wood. This immediately excludes 86% of all playsets and the children who use them, and in addition excludes children who do not frequently use a playset. The report does not attempt to estimate the number of children in the target population.

C48. *It would be helpful if the table of input distributions (Table 12) reported additional statistics such as p5, p95, and p99 percentiles.*

R48. The parameters of all input distributions are provided, so the interested reader can generate additional percentiles without difficulty.

C49. *The distribution for body weight is not included in Table 12.*

R49. Body weight is handled differently than other variables, and does not involve any user input. Each child is first assigned a height, depending on their age and gender. Height is normally distributed, based on data from the NHANES III study. Body weight is then determined, it is lognormally distributed as a function of height. The parameters for the body weight distributions also come from the NHANES III study. Once initial values are set for each child, they are adjusted monthly as the child ages. The height gain is normally distributed, but is truncated at zero, so it is never negative. A new value is drawn from the body weight distribution for the new height, and the new body weight is set to the average of this new value (with a statistical weight of 30%) and the body weight from the previous month (statistical weight of 70%). It is found that this method reproduces the correct distribution for body weight at each year of age, while allowing a child to move from one body weight percentile to another as the child ages, yet still maintaining correlation in weight over time.

C50. *The uncertainty analysis did not identify any of the factors relating to the frequency of exposure to CCA-treated wood as being important contributors to overall uncertainty.*

R50. The inputs for the frequency of contact days were not part of the uncertainty analysis. The main reason for this is that the modified bootstrap algorithm used to assess uncertainty in inputs is not applicable to inputs that are assigned point values. While these inputs undoubtedly have some uncertainty, it was not quantifiable with the existing approach. However, the sensitivity analysis performed included these and other factors (see Tables 28 and 29).

The sensitivity analysis illustrates the impact that would result from changes in these inputs. For example, in Table 28, if the average number of public playset contact days per year is reduced from 126 to 63, then the ADD for the Arsenic warm climate scenario is reduced by a factor of 1.45 (or 31%). If one then ascribes a particular range for the uncertainty in the original value, one can estimate the corresponding range of uncertainty in the results. While it is true that the overall uncertainty is a collective effect of all inputs together (and so is not simply the sum of the uncertainties due to each input considered separately), this still gives some appreciation for the magnitude of the result.

C51. *The uncertainty analysis should be expanded to provide a broader perspective on the sources of uncertainty, beyond that which is quantifiable in the input variables.*

R51. It is acknowledged that other sources of uncertainty are substantial (see response R32). However, these are often difficult to quantify, and any such assessment would be subject to interpretation. The uncertainty that arises just from the fitting of distributions to input parameters (excluding point inputs) amounts to a factor of three near the mean and a factor of four near the 95^{th} percentile (page 149). It is also acknowledged (see response R16) that in some cases when the true value of a parameter was unknown, a conservative assumption was made. Clearly, the total uncertainty (including sources other than just the input distributions) would be larger.

C52. *The aggregate ADD or LADD across pathways (residue ingestion, soil ingestion, dermal residues, dermal soil) does not equal the sum of the individual pathways in the tables.*

R52. For the means, the aggregate is always the sum of the four pathways, within the rounding error. For the percentiles (including the median), this is generally not the case. The reason is that the same percentile for different pathways corresponds to a different person. Thus, the person who is at the 95^{th} percentile in aggregate is not necessarily at the 95^{th} percentile in any of the individual pathways. Only for the same person does the sum of the individual pathways equal the aggregate.

C53. *Report confuses total chromium and hexavalent chromium.*

R53. There is no contradiction. Table 9 simply states that samples were analyzed for hexavalent chromium as well as for total chromium. They do not report finding hexavalent chromium, which is consistent with the statement on page 6 that it was not detectable.

C54. *LOD reference in Table 9, column 3 is unclear.*

R54. It applies to arsenic**.** Table 9 refers to comparison of arsenic studies.

C55. *The input distributions for pica / non-pica children appear to be the same, yet the percentiles are very different.*

R55. The pica children use the portion of the lognormal that exceeds 500 mg/day, whereas the typical children use the portion under 500 mg/day. See response R24 as to how this was implemented.

C56. *The data used for the cold climate scenario for Cr deck residues needs a reference.*

R56. The word 'their' in the sentence on cold climate refers to ACC (2003b), as for the warm climate.

C57. *The cold climate Cr results exceed the warm climate results for the intermediate term, but not for any other scenarios.*

R57. The data reported in Tables 24-26 come from the same model runs, so it is not surprising that the same case was anomalous in all three tables. The fact that the reported residue ingestion was slightly higher in the cold climates as compared to warm (for example, 3.1E-5 compared to 3.0E-5 in Table 26 for residue ingestion from playsets, for children with decks) is not significant, as in another model run the results could well be different. These numbers are within 3% of each other, and there is more stochastic variation than this from run to run. It would be better to say that the cold and warm climates had little or no significant difference in residue ingestion.

C58. *Desire to review underlying data used to fit the SHEDS-Wood input distributions. In particular, data from ACC(2003, 2003a, 2003b), O'Rourke(2003b), Kissel(2003), Wester et al.(2003).*

R58. The data from O'Rourke and Kissel were obtained through personal communication with these experts, and published data are not yet available. For the other data, the Agency is in the process of responding to this request.

Attachment 1

Errata

Errata

Page	Location	Comment
4	bullet 8	The first sentence should read '... the total mean and median LADD were both reduced by a factor of 1.3, assuming hand washing follows exposure.'
14	parag 2	Two of the clauses refer to 'CCA-containing soil'. This is more accurately described as 'soil containing As or Cr near CCA-treated structures'.
42	parag 4	The first sentence should read: 'Warm and cold climate scenario distributions for As and Cr residue concentrations used new data on wood and hand wipe residues collected by ACC from aged CCA-treated decks (ACC, 2003b).' The second sentence should be deleted.
56,57	Table 10,11	Units for wipe data and maximum hand loading are mg/cm^2. Transfer efficiency is a dimensionless ratio.
60	Table 12	The data sources are listed incorrectly for soil chromium concentrations. As mentioned in the text on page 42, the warm scenario used data from Solo-Gabriele et al.(2001) and the cold scenario used data from Doyle and Malaiyandi (1992, 1993) and Stilwell (1998).
67	next to last parag	The reference to Stilwell (1998) be changed to Stilwell and Gorny (1997).
68	last parag	Delete final sentence.
71	last parag	The sentence near the middle of the paragraph containing the number '41' should read as '...was 41 mg/day with a ...' .
126	first parag	The sentence ending '...were reduced by a factor of 1.4 and 1.3, respectively.' should read 'were each reduced by a factor of 1.3'.
176	Reference	"Dang, W. (2003)" should be "Dang, W. and Chen, J. (2003)."
179	Add new reference	D. Stilwell & K. Gorny, (1997), "Contamination of Soil with Copper, Chromium, and Arsenic Under Decks Built from Pressure Treated Wood", Bulletin Environmental Contamination and Toxicology, 58:22-29.
169-172	Table 53	The SHEDS-Wood results should be revised as on the following page.

New EPA values for Table 53

Short-term ADD

	residue ingestion		soil ingestion		dermal residues		dermal soil		aggregate	
	warm	cold	warm	cold	warm	cold	warm	cold	warm	cold
mean	4.6E-05	3.5E-05	9.5E-06	4.6E-07	2.0E-05	4.6E-06	1.8E-06	2.7E-08	7.8E-05	4.0E-05
std	1.0E-04	9.3E-05	2.7E-05	2.5E-06	4.7E-05	1.1E-05	4.3E-06	1.2E-07	1.5E-04	1.0E-04
p25	4.2E-06	2.4E-06	4.6E-07	5.0E-09	1.9E-06	3.6E-07	2.0E-07	9.0E-10	1.0E-05	3.1E-06
p50	1.3E-05	1.0E-05	1.8E-06	3.2E-08	6.2E-06	1.3E-06	6.2E-07	4.2E-09	2.8E-05	1.3E-05
p75	4.3E-05	3.0E-05	6.6E-06	1.8E-07	1.8E-05	4.1E-06	1.7E-06	1.7E-08	7.8E-05	3.5E-05
p90	1.1E-04	7.8E-05	2.1E-05	8.0E-07	4.9E-05	1.0E-05	4.2E-06	5.6E-08	1.9E-04	8.8E-05
p95	1.9E-04	1.3E-04	4.3E-05	1.8E-06	8.4E-05	2.1E-05	6.6E-06	1.2E-07	3.1E-04	1.6E-04

LADD

	residue ingestion		soil ingestion		dermal residues		dermal soil		aggregate	
	warm	cold	warm	cold	warm	cold	warm	cold	warm	cold
mean	3.1E-06	2.3E-06	5.8E-07	3.8E-08	1.5E-06	3.5E-07	1.3E-07	2.0E-09	5.3E-06	2.6E-06
std	5.7E-06	3.9E-06	1.1E-06	1.7E-07	2.4E-06	5.6E-07	1.8E-07	4.4E-09	8.0E-06	4.4E-06
p25	5.1E-07	4.0E-07	6.5E-08	1.2E-09	3.0E-07	7.2E-08	3.2E-08	2.0E-10	1.4E-06	5.3E-07
p50	1.3E-06	9.7E-07	1.9E-07	4.9E-09	7.5E-07	1.7E-07	7.4E-08	6.5E-10	2.7E-06	1.2E-06
p75	3.3E-06	2.4E-06	6.0E-07	1.9E-08	1.7E-06	3.8E-07	1.6E-07	2.0E-09	6.1E-06	2.9E-06
p90	7.2E-06	5.5E-06	1.4E-06	6.6E-08	3.4E-06	7.9E-07	2.9E-07	4.7E-09	1.2E-05	6.4E-06
p95	1.1E-05	8.3E-06	2.3E-06	1.4E-07	5.5E-06	1.3E-06	4.3E-07	8.6E-09	1.8E-05	9.6E-06