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4 NON-DIETARY INGESTION FACTORS

4.1 INTRODUCTION

Young children have the potential for exposure to toxic substances through non-dietary ingestion pathways other than soil and dust ingestion (e.g., ingesting pesticide residues that have been transferred from treated surfaces to the hands or objects that are mouthed). Young children mouth objects or their fingers as they explore their environment. Mouthing behavior includes all activities in which objects, including fingers, are touched by the mouth or put into the mouth except for eating and drinking, and includes licking, sucking, chewing, and biting (Groot et al., 1998). Videotaped observations of children's mouthing behavior demonstrate the intermittent nature of hand to mouth and object to mouth behaviors in terms of the number of contacts recorded per unit of time (e.g., Ko et al., 2007).

In a large non-random sample of children born in Iowa, non-nutritive sucking behaviors were reported by parents to be very common in infancy, and to continue for a substantial proportion of children up to the third and fourth birthdays (Warren et al., 2000). Hand to mouth behavior has been observed in both pre-term and full term infants (Rochat et al., 1988, Blass et al., 1989, Takaya et al., 2003). Infants are born with a sucking reflex for breast feeding, and within a few months, they begin to use sucking or mouthing as a means to explore their surroundings. Sucking also becomes a means of comfort when a child is tired or upset. In addition, teething normally causes substantial mouthing behavior (i.e., sucking or chewing) to alleviate discomfort in the gums (Groot et al., 1998). Children's mouthing behavior can potentially result in ingestion of toxic substances (Lepow et al., 1975).

There are three general approaches to gather data on children's mouthing behavior: real-time hand recording, in which trained observers manually record information (e.g., Davis et al., 1995); video-transcription, in which trained videographers tape a child's activities and subsequently extract the pertinent data manually or with computer software (e.g., Black et al., 2005); and questionnaire, or survey response, techniques (e.g., Stanek et al., 1998). With real-time hand recording, observations made by trained professionals (rather than parents) may offer the advantage of consistency in interpreting visible behaviors and may be less subjective than observations made by someone who maintains a care giving relationship to the child. On the other hand, young children's behavior may be influenced by the presence of unfamiliar people (e.g., Davis et al., 1995). Groot et al. (1998) indicated that parent observers perceived that deviating from their usual care giving behavior by observing and recording mouthing behavior appeared to have influenced the children's behavior. With video-transcription methodology, an assumption is made that the presence of the videographer or camera does not influence the child's behavior. This assumption may result in minimal biases introduced when filming newborns, or when the camera and videographer are not visible to the child. However, if the children being studied are older than newborns and can see the camera or videographer, biases may be introduced. Ferguson et al. (2006) described apprehension caused by videotaping and described situations where a child's awareness of the videotaping crew caused "play-acting" to occur, or parents indicated that the child was behaving differently during the taping session. Another possible source of measurement error may be introduced when children's movements or positions cause their mouthing not to be captured by the camera. Data transcription errors can bias results in either the negative or positive direction. Finally, measurement error can occur if situations arise in which care givers are absent during videotaping and researchers must stop videotaping and intervene to prevent risky behaviors (Zartarian et al., 1995). Survey response studies rely on responses to questions about a child's mouthing behavior posed to parents or care givers. Measurement errors from these studies could occur for a number of different reasons, including language/dialect differences between interviewers and respondents, question wording problems and lack of definitions for terms used in questions, differences in respondents' interpretation of questions, and recall/memory effects.

Some researchers express mouthing behavior as the frequency of occurrence (e.g., contacts per hour or contacts per minute). Others describe the duration of specific mouthing events, expressed in units of seconds or minutes. This handbook does not address issues related to contaminant transfer from thumbs, fingers, or objects or surfaces, into the mouth, and subsequent ingestion. The recommendations for mouthing

frequency and duration are provided in Section 4.2, along with a summary of the confidence ratings for these recommendations. The recommended values are based on key studies identified by U.S. EPA for this factor. Although some studies in sections 4.3.1 and 4.4.1 are classified as key, they were not directly used to provide the recommendations. They are included as key because they were used by Xue et al., 2007 in a meta analysis, which is the primary source of the recommendations provided in this chapter for hand-to-mouth frequency. Following the recommendations, key and relevant studies on mouthing frequency (section 4.3) and duration (section 4.4) are summarized and the methodologies used in the key and relevant studies are described. Information on the prevalence of mouthing behavior is presented in Section 4.5.

4.2 RECOMMENDATIONS

The key studies described in Section 4.3 and Section 4.4 were used to develop recommended values for mouthing frequency and duration, respectively, among children. In several cases, key studies pre-dated the recommendations on age groups in U.S. EPA's *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA, 2005), and were performed on groups of children of varying ages. For cases in which age groups of children in the key studies did not correspond exactly to U.S. EPA's recommended age groups, the closest age group was used.

Table 4-1 shows recommended mouthing frequencies, expressed in units of contacts per hour, between either any part of the hand (including fingers and thumbs) and the mouth, or between an object or surface and the mouth. The recommended hand-to-mouth frequencies are based on data from Xue et al. (2007). Xue et al. (2007) conducted a secondary analysis of data from several of the studies summarized in this chapter, as well as data from unpublished studies. Xue et al. 2007, provided data for the age groups of interest to U.S. EPA and categorized the data according to indoor and outdoor contacts. The recommendations for frequency of object-to-mouth contact are based on data from Reed et al., (1999), Freeman et al., (2001), Tulve et al., (2002), AuYeung et al., (2004), and Black et al., 2005. Recommendations for duration of object-to-mouth are based on data from Juberg et al., (2001) and Greene, (2002). Recommendations for hand-to-mouth duration are not provided since those estimates may not be relevant to environmental exposures. Table 4-2 presents the confidence ratings for the recommended values. The overall confidence rating is low for both frequency and duration of hand-to-mouth and object-to-mouth.

Table 4-1. Summary of Recommended Values for Mouthing Frequency and Duration

Age Group	Hand-to-Mouth				Source
	Indoor Frequency (contacts/hour)		Outdoor Frequency (contacts/hour)		
	Mean	95th Percentiile	Mean	95th Percentile	
Birth to <1 month	-	-	-	-	Xue et al., 2007
1 to <3 months	-	-	-	-	
3 to <6 months	28	65	-	-	
6 to <12 months	19	52	15	47	
1 to <2 years	20	63	14	42	
2 to <3 years	13	37	5	20	
3 to <6 years	15	54	9	36	
6 to <11 years	7	21	3	12	
11 to <16 years	-	-	-	-	
16 to <21 years	-	-	-	-	
Object-to-mouth					
	Mean Frequency (contacts/hour)		95th Percentile Frequency (contacts/hour)		
Birth to <1 month	-		-		Reed et al., 1999; Freeman et al., 2001; Tulve et al., 2002; AuYeung et al., 2004; and Black et al., 2005.
1 to <3 months	-		-		
3 to <6 months	-		-		
6 to <12 months	24[a]		-		
1 to <2 years	20[b]		-		
2 to <3 years	10[c]		-		
3 to <6 years	10[c]		-		
6 to <11 years	1[d]		-		
11 to <16 years	-		-		
16 to <21 years	-		-		
	Mean Duration (minutes/hour)		95th Percentile Duration (minutes/hour)		
Birth to <1 month	-		-		Juberg et al., 2001 and Greene, 2002.
1 to <3 months	-		-		
3 to <6 months	11[e]		26[f]		
6 to <12 months	11[e]		26[f]		
1 to <2 years	8		22		
2 to <3 years	13[g]		16[h]		
3 to <6 years	-		-		
6 to <11 years	-		-		
11 to <16 years	-		-		
16 to <21 years	-		-		

[a] Mean calculated from Black et al., 2005 (7 to 12 months).

[b] Mean calculated from Tulve et al., 2002 (≤24 months), AuYeung et al., 2004 (≤24 months), and Black et al., 2005 (1 and 2 years).

[c] Mean calculated from Reed et al., 1999 (2 to 6 years), Freeman et al., 2001 (3 to 4 years and 5 to 6 years), Tulve et al., 2002 (>24 months), AuYeung et al., 2004 (2 to 6 years), and Black et al., 2005 (37 to 53 months).

[d] Mean calculated from Freeman et al., 2001 (7 to 8 years and 10 to 12 years).

[e] Mean calculated from Juberg et al., 2001 (0 to 18 months) and Greene, 2002 (3 to 12 months).

[f] Calculated 95th percentile from Greene, 2002 (3 to 12 months).

[g] Mean calculated from Juberg, et al., 2001 (19 to 36 months) and Greene, 2002 (24 to 36 months).

[h] Calculated 95th percentile from Greene, 2002 (24 to 36 months).

– = No data.

Table 4-2. Confidence in Recommendations for Mouthing Frequency and Duration

General Assessment Factors	Rationale	Rating
Soundness		Low
Adequacy of Approach	The approaches for data collection and analysis used were adequate to provide estimates of children's mouthing frequencies and durations. Sample sizes were very small relative to the population of interest. Almost all key studies published primary data; in cases where secondary data were used, U.S. EPA judged the secondary data to be of suitable utility for the purposes for developing recommendations.	
Minimal (or defined) Bias	Bias in either direction likely exists in both frequency and duration estimates; the magnitude of bias is unknown.	
Applicability and Utility		Low
Exposure Factor of Interest	Key studies for older children focused on mouthing behavior while the infant studies were designed to research developmental issues.	
Representativeness	Most key studies were of samples of U.S. children, but due to the small sample sizes and small number of locations under study, the study subjects may not be representative of the overall U.S. child population.	
Currency	The studies were conducted over a wide range of dates. However, the currency of the data are not expected to affect mouthing behavior recommendations.	
Data Collection Period	Extremely short data collection periods may not represent behaviors over longer time periods.	
Clarity and Completeness		Low
Accessibility	The journal articles are in the public domain, but in many cases, primary data were unavailable.	
Reproducibility	Data collection methodologies were capable of providing results that were reproducible within a certain range, when compared with results obtained using alternate data collection techniques (e.g., Smith and Norris, 2003).	
Quality Assurance	Several of the key studies applied and documented quality assurance/quality control measures.	
Variability and Uncertinty		Low
Variability in Population	The key studies characterized inter-individual variability to a limited extent, and did not characterize intra-individual variability over diurnal or longer term time frames.	
Description of Uncertainty	The study authors typically did not attempt to quantify uncertainties inherent in data collection methodology (such as the influence of observers on behavior), although some described these uncertainties qualitatively. The study authors typically did attempt to quantify uncertainties in data analysis methodoloogies (if video-transcription methods were used). Uncertainties arising from short data collection periods typically were unaddressed either qualitatively or quantitatively.	
Evaluation and Review		Medium
Peer Review	All key studies appear in peer review journals.	
Number and Agreement of Studies	Several key studies were available for both frequency and duration, but data were not available for all age groups. The results of studies from different researchers are generally in agreement.	
Overall rating		**Low**

4.3 NON-DIETARY INGESTION - MOUTHING FREQUENCY STUDIES

4.3.1 Key Studies of Mouthing Frequency

4.3.1.1 *Zartarian et al.,1997a - Quantifying Videotaped Activity Patterns: Video Translation Software and Training Technologies/Zartarian et al., 1997b - Quantified Dermal Activity Data From a Four-Child Pilot Field Study/Zartarian et al., 1998 - Quantified Mouthing Activity Data From a Four-Child Pilot Field Study*

Zartarian et al. (1997a, 1997b, 1998) conducted a pilot study of the video-transcription methodology to investigate the applicability of using videotaping for gathering information related to children's activities, dermal exposures and mouthing behaviors. The researchers had conducted studies using the real-time hand recording methodology, resulting in poor inter-observer reliability and observer fatigue when attempted for long periods of time, prompting the investigation into using videotaping with transcription of the children's activities at a point in time after the observations (videotaping) occurred.

Four Mexican-American farm worker children in the Salinas Valley of California each were videotaped with a hand-held videocamera during their waking hours, excluding time spent in the bathroom, over one day in September 1993. The boys were 2 years 10 months old and 3 years, 9 months old; the girls were 2 years 5 months old and 4 years 2 months old. Time of videotaping was 6.0 hours for the younger girl, 6.6 hours for the older girl, 8.4 hours for the younger boy and 10.1 hours for the older boy. The videotaping gathered information on detailed micro-activity patterns of children to be used to evaluate software for videotaped activities and translation training methods. The researchers reported measures taken to assess inter-observer reliability and several problems with the video-transcription process.

The hourly data showed that non-dietary object mouthing occurred in 30 of the 31 hours of tape time, with one child eating during the hour in which no non-dietary object mouthing occurred. Average object to mouth contacts for the four children were reported to be 9 contacts per hour, with the average per child ranging from 1 to 19 contacts per hour (Zartarian et al., 1997a). Objects mouthed included bedding/towels, clothes, dirt, grass/vegetation, hard surfaces, hard toys, paper/card, plush toy, and skin (Zartarian et al., 1997a). Average hand to mouth contacts for the four children were reported to be 13 contacts per hour (averaging the sum of left hand and right hand to mouth contacts and averaging across children, from Zartarian et al., 1997b), with the average per child ranging from 9 to 19 contacts per hour.

This study's primary purpose was to develop and evaluate the video-transcription methodology; a secondary purpose was collection of mouthing behavior data. The sample of children studied was very small and not likely to be representative of the national population. As with other video-transcription studies, the presence of non-family-member videographers and a video camera may have influenced the children's behavior.

4.3.1.2 *Reed et al., 1999 - Quantification of Children's Hand and Mouthing Activities Through a Videotaping Methodology*

In this study, Reed et al. (1999) used a video-transcription methodology to quantify the frequency and type of children's hand and mouth contacts, as well as a survey response methodology, and compared the videotaped behaviors with parents' perceptions of those behaviors. Twenty children ages 3 to 6 years old selected randomly at a day care center in New Brunswick, New Jersey, and ten children ages 2 to 5 years old at residences in Newark and Jersey City, New Jersey who were not selected randomly, were studied (gender not specified). For the video-transcription methodology, inter-observer reliability tests were performed during observer training and at four points during the two years of the study. The researchers compared the results of videotaping the ten children in the residences with their parents' reports of the children's daily activities. Mouthing behaviors studied included hand to mouth and hand bringing object to mouth.

The video-transcription mouthing contact frequency results are presented in Table 4-3. The authors analyzed parents' responses on frequencies of their children's mouthing behaviors and compared those responses with the children's videotaped behaviors, which revealed certain discrepancies. Parents' reported hand to mouth contact of "almost never"

corresponded to overall somewhat lower videotaped hand to mouth frequencies than those of children whose parents reported "sometimes," but there was little correspondence between parents' reports of object to mouth frequency and videotaped behavior.

The advantages of this study were that it compared the results of video-transcription with the survey response methodology results, and described quality assurance steps taken to assure reliability of transcribed videotape data. However, only a small number of children were studied, some were not selected for observation randomly, and the sample of children studied may not be representative of either the locations studied or the national population. Due to the children's ages, the presence of unfamiliar persons following the children with a video camera may influence the video-transcription results. The parents' survey responses may also be influenced by recall/memory effects and other limitations of survey methodologies.

4.3.1.3 *Freeman et al., 2001 - Quantitative Analysis of Children's Microactivity Patterns: The Minnesota Children's Pesticide Exposure Study*

Freeman et al. (2001) conducted a survey response and video-transcription study of some of the respondents in a phased study of children's pesticide exposures in the summer and early fall of 1997. A probability-based sample of 168 families with children ages 3 to <14 years old in urban (Minneapolis/St. Paul) and non-urban (Rice and Goodhue Counties) areas of Minnesota answered questions about children's mouthing of paint chips, food-eating without utensils, eating of food dropped on the floor, mouthing of non-food items, and mouthing of thumbs/fingers. For the survey response portion of the study, parents provided the responses for children ages 3 and 4 years, and collaborated with or assisted older children with their responses. Of the 168 families responding to the survey, 102 were available, selected, and agreed to measurements of pesticide exposure. Of these 102 families, 19 agreed to videotaping of the study children's activities for a period of four consecutive hours.

Based on the survey responses for 168 children, the 3 year olds had significantly more positive responses for all reported behavior compared to the other age groups. The authors stated that they did not know whether parent reporting of 3 year olds' behavior influenced the responses given. Table 4-4 shows the percent of children, grouped by age, who were reported to exhibit non-food related mouthing behaviors. Table 4-5 presents the mean and median number of mouthing contacts by age for the 19 videotaped children. Among the four age categories of these children, object to mouth activities were significantly greater for the 3 and 4 year olds than any other age group, with a median of 3 and a mean of 6 contacts per hour ($P = 0.002$, Kruskal Wallis test comparison across four age groups). Hand to mouth contacts had a median of 3.5 and mean of 4 contacts per hour for the three 3 and 4 year olds observed, median of 2.5 and mean of 8 contacts per hour for the seven 5 and 6 year olds observed, median of 3 and mean of 5 contacts per hour for the four 7 and 8 year olds observed, and median of 2 and mean of 4 for the five 10, 11 and 12 year olds observed. Gender differences were observed for some of the activities, with boys spending significantly more time outdoors than girls. Hand to mouth and object to mouth activities were less frequent outdoors than indoors for both boys and girls.

For the 19 children in the video-transcription portion of the study, inter-observer reliability checks and quality control checks were performed on randomly sampled tapes. For four children's tapes, comparison of the manual video-transcription with a computerized transcription method (Zartarian et al., 1995) was also performed; no significant differences were found in the frequency of events recorded using the two techniques. The frequency of six behaviors (hand to mouth, hand to object, object to mouth, hand to smooth surface, hand to textured surface, and hand to clothing) was recorded. The amount of time each child spent indoors, outdoors, in contact with soil or grass, and whether the child was barefoot was also recorded. For the four children whose tapes were analyzed with the computerized transcription method, which calculates event durations, the authors stated that most hand to mouth and object to mouth activities were observed during periods of lower physical activity, such as television viewing.

An advantage to this study is that it included results from two separate methodologies, and included quality assurance steps taken to assure reliability of

transcribed videotape data. However, the children in this study may not be representative of all children in the U.S. Variation in who provided the survey responses (sometimes parents only, sometimes children with parents) may have influenced the responses given. Children studied using the video-transcription methodology were not chosen randomly from the survey response group. The presence of unfamiliar persons following the children with a video camera may have influenced the video-transcription methodology results.

4.3.1.4 *Tulve et al., 2002 - Frequency of Mouthing Behavior in Young Children*

Tulve et al. (2002) coded the unpublished Davis et al. (1995) data for location (indoor and outdoor) and activity type (quiet or active) and analyzed the subset of the data that consisted of indoor mouthing behavior during quiet activity (72 children, ranging in age from 11 to 60 months). A total of 186 15-minute observation periods were included in the study, with the number of observation periods per child ranging from 1 to 6.

Results of the data analyses indicated that there was no association between mouthing frequency and gender, but a clear association between mouthing frequency and age was observed. The analysis indicated that children ≤24 months had the highest frequency of mouthing behavior (81 events/hour) and children >24 months had the lowest (42 events/hour) (Table 4-6). Both groups of children were observed to mouth toys and hands more frequently than household surfaces or body parts other than hands.

An advantage of this study is that the randomized design may mean that the children studied were relatively representative of young children living in the study area, although they may not be representative of the U.S. population. Due to the ages of the children studied, the observers' use of headphones and manual recording of mouthing behavior on observation sheets may have influenced the children's behavior.

4.3.1.5 *AuYeung et al., 2004 - Young Children's Mouthing Behavior: An Observational Study via Videotaping in a Primarily Outdoor Residential Setting*

AuYeung et al. (2004) used a video-transcription methodology to study a group of 38 children (20 females and 18 males; ages 1 to 6 years), 37 of whom were selected randomly via a telephone screening survey of a 300 to 400 square mile portion of the San Francisco, California peninsula, along with one child selected by convenience due to time constraints. Families who lived in a residence with a lawn and whose annual income was >$35,000 were asked to participate. Videotaping took place between August 1998 and May 1999 for approximately two hours per child. Videotaping by one researcher was supplemented with field notes taken by a second researcher who was also present during taping. Most of the videotaping took place during outdoor play, however, data were included for several children (one child <2 years old and 8 children >2 years old) who had more than 15 minutes of indoor play during their videotaping sessions.

The videotapes were translated into ASCII computer files using VirtualTimingDevice™ software described in Zartarian et al. (1997a). Both frequency and duration (see Section 4.4.2.5 of this Chapter) were analyzed. Between 5 and 10 percent of the data files translated were randomly chosen for quality control checks for inter-observer agreement. Ferguson et al. (2006) described quality control aspects of the study in detail.

For analysis, the mouthing contacts were divided into indoor and outdoor locations, and 16 object/surface categories. Mouthing frequency was analyzed by age and gender separately, and in combination. Mouthing contacts were defined as contact with the lips, inside of the mouth, and/or the tongue; dietary contacts were ignored. Mouthing frequencies for indoor locations are shown in Table 4-7. For the one child observed that was ≤24 months of age, the total mouthing frequency was 84.8 contacts/hour; for children >24 months, the median indoor mouthing frequency was 19.5 contacts/hour. Outdoor median mouthing frequencies (Table 4-8) were very similar for children ≤24 months of age (13.9 contacts/hour) and >24 months (14.6 contacts/hour).

Nonparametric tests, such as the Wilcoxon rank sum test were used for the data analyses. Both age and gender were found to be associated with differences in mouthing behavior. Girls had significantly higher frequencies of mouthing contacts with the hands and non-dietary objects than boys (p = 0.01 and p = 0.008, respectively).

This study provides distributions of outdoor mouthing frequencies with a variety of objects and surfaces. Although indoor mouthing data were also included in this study, the results were based on a small number of children (N=9) and a limited amount of indoor play. The sample of children may be representative of certain socioeconomic strata in the study area, but is not likely to be representative of the national population. Due to the children's ages, the presence of unfamiliar persons following the children with a video camera may have influenced the video-transcription methodology results.

4.3.1.6 *Black et al., 2005 - Children's Mouthing and Food-Handling Behavior in an Agricultural Community on the U.S./Mexico Border*

Black et al. (2005) studied mouthing behavior of children in a Mexican-American community along the Rio Grande River in Texas, in the spring and summer of 2000, using a survey response and a video-transcription methodology. A companion study of this community (Shalat et al., 2003) identified 870 occupied households during the April 2000 U.S. census and contacted 643 of these via in-person interview to determine presence of children under the age of 3 years. Of the 643 contacted, 91 had at least one child under the age of 3 years (Shalat et al., 2003). Of these 91 households, the mouthing and food-handling behavior of 52 children (26 boys and 26 girls) from 29 homes was videotaped, and the children's parents answered questions about children's hygiene, mouthing and food-handling activities (Black et al., 2005). The study was of children ages 7 to 53 months, grouped into four age categories: infants (7 to 12 months), 1 year olds (13 to 24 months), 2 year olds (25 to 36 months), and preschoolers (37 to 53 months).

The survey asked questions about children's ages, genders, reported hand-washing, mouthing and food-handling behavior (N=52), and activities (N=49). Parental reports of thumb/finger placement in the mouth showed decreases with age. The researchers attempted to videotape each child for four hours. The children were followed by the videographers through the house and yard, except for times when they were napping or using the bathroom. Virtual Timing Device™ software was used to analyze the videotapes.

Based on the results of videotaping, most of the children (49 of 52) spent the majority of their time indoors. Of the 39 children who spent time both indoors and outdoors, all three behaviors (hand to mouth, object to mouth and food handling) were more frequent and longer while the child was indoors. Hand to mouth activity was recorded during videotaping for all but one child, a 30 month old girl.

For the four age groups, the mean hourly hand to mouth frequency ranged from 11.9 (2 year olds) to 22.1 (preschoolers), and the mean hourly object to mouth frequency ranged from 7.8 (2 year olds) to 24.4 (infants). No significant linear trends were seen with age or gender for hand to mouth hourly frequency. A significant linear trend was observed for hourly object to mouth frequency, which decreased as age increased (adjusted R^2 = 0.179; P = 0.003). Results of this study are shown in Table 4-9.

One advantage of this study is that it compared survey responses with videotaped information on mouthing behavior. A limitation is that the sample was fairly small and was from a limited area (mid-Rio Grande Valley) and is not likely to be representative of the national population. Due to the children's ages, the presence of unfamiliar persons following the children with a video camera may have influenced the video-transcription methodology results.

4.3.1.7 *Xue et al., 2007 - A Meta-analysis of Children's Hand-to-Mouth Frequency Data for Estimating Nondietary Ingestion Exposure*

Xue et al. (2007) gathered hand-to-mouth frequency data from 9 available studies representing 429 subjects and more than 2,000 hours of behavior observation. The studies used in this analysis included several of the studies summarized in this chapter (Zartarian et al. ,1998; Reed et al., 1999; Freeman et al., 2001; Greene, 2002; Tulve et al., 2002; and Black et al., 2005), as well as several other sets of unpublished data. These data were used to conduct a meta-analysis

to study differences in hand-to-mouth behavior. The purpose of the analysis was to:

1) examine differences across studies by age (using the new U.S. EPA recommended age groupings (U.S. EPA, 2005)), gender, and indoor/outdoor location;
2) fit variability distributions to the available hand-to-mouth frequency data for use in one dimensional Monte Carlo exposure assessments;
3) fit uncertainty distributions to the available hand-to-mouth frequency data for use in two dimensional Monte Carlo exposure assessments; and
4) assess hand-to-mouth frequency data needs using the new U.S. EPA recommended age groupings (U.S. EPA, 2005).

The data were sorted into age groupings. Visual inspection of the data and statistical methods (method of moments and maximum likelihood estimation) were used, and goodness-of-fit tests were applied to verify the selection among lognormal, Weibull, and normal distributions (Xue et al., 2007). Analyses to study inter- and intra- individual variability of indoor and outdoor hand to mouth frequency were conducted. There were 894 hours of behavior observation data for the 429 children, ages 0.3 to 12 years, across all available studies. It was found that age and location (indoor vs. outdoor) were important factors contributing to hand to mouth frequency, but study and gender were not (Xue et al., 2007). Distributions of hand to mouth frequencies were developed for both indoor and outdoor activities. Distributions are presented in Table 4-10 for indoor settings and Table 4-11 for outdoor settings. Hand to mouth frequencies decreased for both indoor and outdoor activity as age increased, and were higher indoors than outdoors for all age groups (Xue et al., 2007).

A strength of this study is that it is the first effort to fit hand to mouth distributions using U.S. EPA's recommended age groups using available data on mouthing behavior from studies using different methodologies, of children in different locations. Limitations of the studies used in this meta-analysis apply to the results from the meta-analysis as well; the uncertainty analysis in this study does not account for uncertainties arising out of differences in approaches used in the various studies used in the meta-analysis.

4.3.2 Relevant Studies of Mouthing Frequency

4.3.2.1 *Davis et al., 1995 - Soil Ingestion in Children with Pica: Final Report*

In 1992, under a Cooperative Agreement with U.S. EPA, the Fred Hutchinson Cancer Research Center conducted a survey response and real-time hand recording study of mouthing behavior data. The study included 92 children (46 males, 46 females) ranging in age from <12 months to 60 months, from Richland, Kennewick, and Pasco, Washington. The children were selected randomly based on date of birth through a combination of birth certificate records and random digit dialing of residential telephone numbers. For each child, data were collected during a seven day period in January to April, 1992. Eligibility included residence within the city limits, residence duration >1 month, and at least one parent or guardian who spoke English. Most of the adults who responded to the survey reported their marital status as being married (90 percent), their race as Caucasian (89 percent), their household income in the >$30,000 range (56 percent) or their housing status as single-family home occupants (69 percent).

The survey asked questions about thumb-sucking and frequency questions about pacifier use, placing fingers, hands and feet in the mouth, and mouthing of furniture, railings, window sills, floor, dirt, sand, grass, rocks, mud, clothes, toys, crayons, pens, and other items. Table 4-12 shows the survey responses for the 92 study children. For most of the children in the study, the mouthing behavior real-time hand recording data were collected simultaneously by parents and by trained observers who described and quantified the mouthing behavior of the children in their home environment. The observers recorded mouth and tongue contacts with hands, other body parts, natural objects, surfaces, and toys every 15 seconds during 15-minute observation periods spread over 4 days. Parents and trained observers wore headphones that indicated elapsed time (Davis et al., 1995). If all attempted observation periods were successful, each child would have a total of 16 15-minute observation periods with 60 15-second intervals per 15-minute observation period, or 960 15-second intervals in all. The number

of successful intervals of observation ranged from 0 to 840 per child. Comparisons of the inter-observer reliability between the trained observers and parents showed "a high degree of correlation between the overall degree of both mouth and tongue activity recorded by parents and observers. For total mouth activity, there was a significant correlation between the rankings obtained according to parents and observers, and parents were able to identify the same individuals as observers as being most and least oral in 60 percent of the cases."

One advantage of this study is the simultaneous observations by both parents and trained observers that allows comparisons to be made regarding the consistency of the recorded observations. The random nature in which the population was selected may provide a representative population of the study area, within certain limitations, but not of the national population. Simultaneous collection of food, medication, fecal, and urine samples that occurred as part of the overall study (not described in this summary) may have contributed a degree of deviation from normal routines within the households during the 7 days of data collection and may have influenced children's usual behaviors. Wearing of headphones by parents and trained observers during mouthing observations, presence of non-family-member observers, and parents' roles as observers as well as care givers may also have influenced the results; the authors state "Having the child play naturally while being observed was challenging. Usually the first day of observation was the most difficult in this respect, and by the third or fourth day of observation the child generally paid little attention to the observers."

4.3.2.2 *Lew and Butterworth, 1997 - The Development of Hand-Mouth Coordination in 2- to 5-Month-Old Infants: Similarities With Reaching and Grasping*

Lew and Butterworth (1997) studied 14 mostly first-born infants (10 males, 4 females) in Stirling, United Kingdom, in 1990 using a video-transcription methodology. Attempts were made to study each infant within a week of the infant's 2-month, 3-month, 4-month and 5-month birthdays. After becoming accustomed to the testing laboratory, and with their mothers present, infants were placed in semi-reclining seats and filmed during an experimental protocol in which researchers placed various objects into the infants' hands. Infants were observed for two baseline periods of 2 minutes each. The researchers coded all contacts to the face and mouth that occurred during baseline periods (prior to and after the object handling period) as well as contacts occurring during the object handling period. Hand to mouth contacts included contacts that landed directly in or on the mouth as well as those in which the hand landed on the face first and then moved to the mouth. The researchers assessed inter-observer agreement using a rater not involved with the study, for a random proportion (approximately 10 percent) of the movements documented during the object handling period, and reported inter-observer agreement of 0.90 using Cohen's kappa (a measure of the agreement between two raters) for the location of contacts. The frequency of contacts ranged between 0 and 1 contacts per minute.

The advantages of this study were that use of video cameras could be expected to have minimal impact on infant behavior for infants of these ages, and the researchers performed tests of inter-observer reliability. A disadvantage is that the study included baseline observation periods of only 2 minutes' duration, during which spontaneous hand to mouth movements could be observed. The extent to which these infants' behavior is representative of other infants of these ages is unknown.

4.3.2.3 *Tudella et al., 2000 - The Effect of Oral-Gustatory, Tactile-Bucal, and Tactile-Manual Stimulation on the Behavior of the Hands in Newborns*

Tudella et al. (2000) studied the frequency of hand to mouth contact, as well as other behaviors, in 24 full-term Brazilian newborns (10 to 14 days old) using a video-transcription methodology. Infants were in an alert state, in their homes in silent and previously heated rooms in a supine position and had been fed between 1 and 1 1/2 hours before testing. Infants were studied for a four minute baseline period without stimuli before experimental stimuli were administered. Results from the four minute baseline period, without stimuli, indicated that the mean frequency of hand to mouth contact (defined as right hand or left hand touching the lips or entering the buccal cavity, either with or without

rhythmic jaw movements) was almost 3 right hand contacts and slightly more than 1.5 left hand contacts, for a total hand to mouth contact frequency of about 4 contacts in the four minute period. The researchers performed inter-observer reliability tests on the videotape data and reported an inter-coder Index of Concordance of 93 percent.

The advantages of this study were that use of video cameras could be expected to have virtually no impact on newborns' behavior, and inter-observer reliability tests were performed. However, the study data may not represent newborn hand to mouth contact during non-alert periods such as sleep. The extent to which these infants' behavior is representative of other full-term 10 to 14 day old infants' behavior is unknown.

4.3.2.4 *Ko et al., 2007 - Relationships of Video Assessments of Touching and Mouthing Behaviors During Outdoor Play in Urban Residential Yards to Parental Perceptions of Child Behaviors and Blood Lead Levels*

Ko et al. (2007) compared parent survey responses with results from a video-transcription study of children's mouthing behavior in outdoor settings, as part of a study of relationships between children's mouthing behavior and other variables with blood lead levels. A convenience sample of 37 children (51 percent males, 49 percent females) 14 to 69 months old was recruited via an urban health center and direct contacts in the surrounding area, apparently in Chicago, Illinois. Participating children were primarily Hispanic (89 percent). The mouth area was defined as within 1 inch of the mouth, including the lips. Items passing beyond the lips were defined as in the mouth. Placement of an object or food item in the mouth along with part of the hand was counted as both hand and food or object in mouth. Mouthing behaviors included hand-to-mouth area both with and not with food, hand-in-mouth with or without food, and object-in-mouth including food, drinks, toys or other objects.

Survey responses for the 37 children who were also videotaped included parents reporting children's inserting hand, toys or objects in mouth when playing outside, and inserting dirt, stones or sticks in mouth. Video-transcription results of outdoor play for these 37 children indicated 0 to 27 hand-in-mouth, and 3 to 69 object-in-mouth touches per hour for the 13 children reported to frequently insert hand, toys or objects in mouth when playing outside; 0 to 67 hand in mouth, and 7 to 40 object-in-mouth touches per hour for the 10 children reported to "sometimes" perform this behavior; 0 to 30 hand-in-mouth, and 0 to 125 object in mouth touches per hour for the 12 children reported to "hardly ever" perform this behavior, and 1 to 8 hand-in-mouth, and 3 to 6 object-in-mouth touches per hour for the 2 children reported to "never" perform this behavior.

Videotaping was attempted for two hours per child over two or more play sessions, with videographers trying to avoid interacting with the children. Children played with their usual toys and partners, and no instructions were given to parents regarding their supervision of the children's play. The authors stated that during some portion of the videotape time, children's hands and mouths were out of camera view. Videotape transcription was performed manually, according to a modified version of the protocol used in the Reed et al. (1999) study. Inter-observer reliability between three video-transcribers was checked with seven 30 minute video segments.

One strength of this study is its comparison of survey responses with results from the video-transcription methodology. A limitation is that the non-randomly selected sample of children studied is unlikely to be representative of the national population. Comparing results from this study with results from other video-transcription studies may be problematic due to inclusion of food handling with hand to mouth and object to mouth frequency counts. Due to the children's ages, their behavior may have differed from normal patterns due to the presence of strangers who videotaped them.

4.4 NON-DIETARY INGESTION - MOUTHING DURATION STUDIES

4.4.1 Key Mouthing Duration Studies

4.4.1.1 *Juberg et al., 2001 - An Observational Study of Object Mouthing Behavior by Young Children*

Juberg et al. (2001) studied 385 children ages 0 to 36 months in western New York state, with parents collecting real-time hand-recording mouthing behavior data, primarily in children's own home environments. The study consisted of an initial pilot study conducted in February 1998, a second phase conducted in April

1998, and a third phase conducted at an unspecified later time. The study's sample was drawn from families identified in a child play research center database or whose children attended a child care facility in the same general area; some geographic variation within the local area was obtained by selecting families with different zip codes in the different study phases. The pilot phase had 30 children who participated out of 150 surveys distributed; the second phase had 187 children out of approximately 300 surveys distributed, and the third phase had 168 participants out of 300 surveys distributed.

Parents were asked to observe their child's mouthing of objects only; hand to mouth behavior was not included. Data were collected on a single day (pilot and second phases) or five days (third phase); parents recorded the insertion of objects into the mouth by noting the "time in" and "time out" and the researchers summed the recorded data to tabulate total times spent mouthing the various objects during the day(s) of observation. Thus, the study data were presented as minutes per day of object mouthing time. Mouthed items were classified as pacifiers, teethers, plastic toys, or other objects.

The results of the combined pilot and second phase II data are shown in Table 4-13. For both age groups, mouthing time for pacifiers greatly exceeded mouthing time for non-pacifiers, with the difference more acute for the older age group than for the younger age group. Histograms of the observed data show a peak in the low end of the distribution (0 to 100 minutes per day) and a rapid decline at longer durations.

A third phase of the study focused on children between the ages of 3 and 18 months and included only non-pacifier objects. Subjects were observed for 5 non-consecutive days over a 2 month period. A total of 168 participants returned surveys for at least one day, providing a total of 793 person-days of data. The data yielded a mean non-pacifier object mouthing duration of 36 minutes per day; the mean was the same when calculated on the basis of 793 person-days of data as on the basis of 168 daily average mouthing times.

One advantage of this study is the large sample size (385 children); however, the children apparently were not selected randomly, although some effort was made to obtain local geographic variation among study participants. There is no description of the socioeconomic status or racial and ethnic identities of the study participants. The authors do not describe the methodology (such as stopwatches, analog or digital clocks, or guesses) parents used to record mouthing event durations. The authors stated that using mouthing event duration units of minutes, rather than seconds, may have yielded observations rounded to the nearest minute.

4.4.1.2 *Greene, 2002 - A Mouthing Observation Study of Children Under Six Years of Age*

The U.S. Consumer Product Safety Commission (CPSC) conducted a survey response and real-time hand recording study between December 1999 and February 2001 to quantify the cumulative time per day that young children spend awake, not eating, and mouthing objects. "Mouthing" was defined as sucking, chewing, or otherwise putting an object on his/her lips or into his/her mouth. Participants were recruited via a random digit dialing telephone survey in urban and nearby rural areas of Houston, Texas and Chicago, Illinois. Of the 115,289 households surveyed, 1,745 households had a child under the age of 6 years and were willing to participate. In the initial phase of the study, 491children ages 3 to 81 months participated. Parents were instructed to use watches with second hands, or count seconds to estimate mouthing event durations. Parents also were to record mouthing frequency and types of objects mouthed. Parents collected data in four separate, non-consecutive 15-minute observation periods. Initially, parents were called back by the researchers and asked to provide their data over the telephone. Of the 491 children, 43 children (8.8 percent) had at least one 15-minute observation period with mouthing event durations recorded as exceeding 15 minutes. Due to this data quality problem, the researchers excluded the parent observation data from further analysis.

In a second phase, trained observers used stopwatches to record the mouthing behaviors and mouthing event durations of the subset of 109 of these children ages 3 to 36 months, and an additional 60 children (total in second phase, 169), on two hours of each of two days. The observations were done at different times of the day at the child's home and/or child care facility. Table 4-14 shows the prevalence of observed mouthing among the 169 children in the

second phase. All children were observed to mouth during the four hours of observation time; 99 percent mouthed the category defined as "anatomy." Pacifiers were mouthed by 27 percent in an age-declining pattern ranging from 47 percent of children less than 12 months old to 10 percent of the 2 to <3 year olds.

Table 4-15 provides the average mouthing time by object category and age in minutes per hour. The average mouthing time for all objects ranged from 5.3 to 10.5 minutes per hour, with the highest mouthing time corresponding to children <1 year of age and the lowest to the 2 to <3 years of age category. Among the objects mouthed, pacifiers represented about one third of the total mouthing time, with 3.4 minutes per hour for the youngest children, 2.6 minutes per hour for the children between 1 and 2 years and 1.8 minutes per hour for children 2 to <3 years old. The next largest single item category was anatomy. In this category, children under 1 year of age spent 2.4 minutes per hour mouthing fingers and thumbs; this behavior declined with age to 1.2 minutes per hour for children 2 to <3 years old.

Of the 169 children in the second phase, there were usable data on the time awake and not eating (or "exposure time") for only 109; data for the remaining 60 children were missing. Thus, in order to develop extrapolated estimates of daily mouthing time, from the 2 hours of observation per day for two days, for the 109 children, the researchers developed a statistical model that accounted for the children's demographic characteristics, in order to estimate exposure times for the 60 children for whom exposure time data were missing, and then computed statistics for the extrapolated daily mouthing times for all 169 children, using a "bootstrap" procedure. Using this method, the estimated mean daily mouthing time of objects other than pacifiers ranged from 37 minutes/day to 70 minutes/day with the lowest number corresponding to the 2 to <3 year old children and the largest number corresponding to the 3 to <12 month old children.

The 551 child participants were 55 percent males, 45 percent females. The study's sample was drawn in an attempt to duplicate the overall U.S. demographic characteristics with respect to race, ethnicity, socioeconomic status and urban/suburban/rural settings. The sample families' reported annual incomes were generally higher than those of the overall U.S. population.

This study's strength was that it consisted of a randomly selected sample of children from both urban and non-urban areas in two different geographic areas within the U.S. However, the observers' presence and use of a stopwatch to time mouthing durations may have affected the children's behavior.

4.4.2 Relevant Mouthing Duration Studies

4.4.2.1 *Barr et al., 1994 - Effects of Intra-Oral Sucrose on Crying, Mouthing and Hand-Mouth Contact in Newborn and Six Week Old Infants*

Barr et al. (1994) studied hand to mouth contact, as well as other behaviors, in 15 newborn (8 males, 7 females) and 15 five to seven week old (8 males, 7 females) full-term Canadian infants using a video-transcription methodology. The newborns were 2 to 3 days old, in a quiet, temperature-controlled room at the hospital, in a supine position and had been fed between 2 1/2 and 3 1/2 hours before testing. Barr et al. (1994) analyzed a one minute baseline period, with no experimental stimuli, immediately before a sustained crying episode lasting 15 seconds. For the newborns, reported durations of hand to mouth contact during 10 second intervals of the one minute baseline period were in the range of 0 to 2 percent. The five to seven week old infants apparently were studied at primary care pediatric facilities when they were in bassinets inclined at an angle of 10 degrees. For these slightly older infants, the baseline periods analyzed were less than 20 seconds in length, but Barr et al. (1994) reported similarly low mean percentages of the 10 second intervals (approximately 1 percent of the time with hand to mouth contact). Hand to mouth contact was defined as "any part of the hand touching the lips and/or the inside of the mouth." The researchers performed inter-observer reliability tests on the videotape data and reported a mean inter-observer reliability of 0.78 by Cohen's kappa (a measure of the agreement between two raters).

The advantages of this study were that use of video cameras could be expected to have virtually no impact on newborns' or five to seven week old infants' behavior, and inter-observer reliability tests were performed. The study data did not represent newborn or five to seven week old infant hand to mouth contact

during periods in which infants of these ages were in a sleeping or other non-alert state, and may only represent behavior immediately prior to a state of distress (sustained crying episode). The extent to which these infants' behavior is representative of other full-term infants of these ages is unknown.

4.4.2.2 *Zartarian et al., 1997a - Quantifying Videotaped Activity Patterns: Video Translation Software and Training Technologies/Zartarian et al., 1997b - Quantified Dermal Activity Data From a Four-Child Pilot Field Study/Zartarian et al., 1998 - Quantified Mouthing Activity Data From a Four-Child Pilot Field Study*

As described in Section 4.3.1.1, Zartarian et al. (1997a, 1997b, 1998) conducted a pilot study of the video-transcription methodology to investigate the applicability of using videotaping for gathering information related to children's activities, dermal exposures and mouthing behaviors. The researchers had conducted studies using the real-time hand recording methodology, resulting in poor inter-observer reliability and observer fatigue when attempted for long periods of time, prompting the investigation into using videotaping with transcription of the children's activities at a point in time after the observations (videotaping) occurred.

Four Mexican-American farm worker children in the Salinas Valley of California each were videotaped with a hand-held videocamera during their waking hours, excluding time spent in the bathroom, over one day in September 1993. The boys were 2 years 10 months old and 3 years, 9 months old; the girls were 2 years 5 months old and 4 years 2 months old. Time of videotaping was 6.0 hours for the younger girl, 6.6 hours for the older girl, 8.4 hours for the younger boy and 10.1 hours for the older boy. The videotaping gathered information on detailed micro-activity patterns of children to be used to evaluate software for videotaped activities and translation training methods.

The four children mouthed non-dietary objects an average of 4.35 percent (range 1.41 to 7.67 percent) of the total observation time, excluding the time during which the children were out of the camera's view (Zartarian et al., 1997a). Objects mouthed included bedding/towels, clothes, dirt, grass/vegetation, hard surfaces, hard toys, paper/card, plush toy, and skin (Zartarian et al., 1997a). Frequency distributions for the four children's non-dietary object contact durations were reported to be similar in shape. Reported hand to mouth contact presumably is a subset of the object to mouth contacts described in Zartarian et al., 1997a, and is described in Zartarian et al., 1997b. The four children mouthed their hands an average of 2.35 percent (range 1.0 to 4.4 percent) of observation time. The researchers reported measures taken to assess inter-observer reliability and several problems with the video-transcription process.

This study's primary purpose was to develop and evaluate the video-transcription methodology; a secondary purpose was collection of mouthing behavior data. The sample of children studied was very small and not likely to be representative of the national population. Thus, U.S. EPA did not judge it to be suitable for consideration as a key study of children's mouthing behavior. As with other video-transcription studies, the presence of non-family-member videographers and a video camera may have influenced the children's behavior.

4.4.2.3 *Groot et al., 1998 - Mouthing Behavior of Young Children: An Observational Study*

In this study, Groot et al. (1998) examined the mouthing behavior of 42 Dutch children (21 boys and 21 girls) between the ages of 3 and 36 months in late July and August 1998. Parent observations were made of children in 36 families. Parents were asked to observe their children ten times per day for 15 minute intervals (i.e., 150 minutes total per day) for two days and measure mouthing times with a stopwatch. In this study, mouthing was defined as "all activities in which objects are touched by mouth or put into the mouth except for eating and drinking. This term includes licking as well as sucking, chewing and biting."

For the study, a distinction was made between toys meant for mouthing (e.g., pacifiers, teething rings) and those not meant for mouthing. Inter-observer and intra-observer reliability was measured by trained observers who co-observed a portion of observation periods in three families, and who co-observed and repeatedly observed some video-transcriptions made of one child. Another quality assurance procedure performed for the extrapolated total mouthing time data

was to select 12 times per hour randomly during the entire waking period of four children during one day, in which the researchers recorded activities and total mouthing times.

Although the sample size was relatively small, the results provided estimates of mouthing times, other than pacifier use, during a day. The results were extrapolated to the entire day based on the 150 minutes of observation per day, and the mean value for each child for the two days of observations was interpreted as the estimate for that child. Summary statistics are shown in Table 4-16. The standard deviation in all four age categories except the 3 to 6 month old children exceeded the estimated mean. The 3 to 6 month children (N=5) were estimated to have mean non-pacifier mouthing durations of 36.9 minutes per day, with toys as the most frequently mouthed product category, and the 6 to 12 month children (N=14) 44 minutes per day (fingers most frequently mouthed). The 12 to 18 month olds' (N=12) estimated mean non-pacifier mouthing time was 16.4 minutes per day, with fingers most frequently mouthed, and 18 to 36 month olds' (N=11) estimated mean non-pacifier mouthing time was 9.3 minutes per day (fingers most frequently mouthed).

One strength of this study is that the researchers recognized that observing children's behavior might affect the behavior, and emphasized to the parents the importance of making observations under conditions that were as normal as possible. In spite of these efforts, many parents perceived that their children's behavior was affected by being observed, and observation interfered with care giving responsibilities such as comforting children when they were upset. Other limitations included a small sample size that was not representative of the Dutch population and that also may not be representative of U.S. children. Technical problems with the stopwatches affected at least 14 of 36 parents' data.

4.4.2.4 *Smith and Norris, 2003 - Reducing the Risk of Choking Hazards: Mouthing Behavior of Children Aged 1 Month to 5 Years/Norris and Smith, 2002 - Research Into the Mouthing Behaviour of Children up to 5 Years Old*

Smith and Norris (2003) conducted a real-time hand recording study of mouthing behavior among 236 children (111 males, 125 females) in the United Kingdom (exact locations not specified) who were from 1 month to 5 years old. Children were observed at home by parents, who used stopwatches to record the time that mouthing began, the type of mouthing, the type of object being mouthed, and the time that mouthing ceased. Children were observed for a total of 5 hours over a two week period; the observation time consisted of twenty 15 minute periods spread over different times and days during the child's waking hours. Parents also recorded the times each child was awake and not eating meals so that the researchers could extrapolate estimates of total daily mouthing time from the shorter observation periods. Mouthing was defined as licking/lip touching, sucking/trying to bite, biting or chewing, with a description of each category, together with pictures, given to parents as guidance for what to record.

The results of the study are shown in Table 4-17. While no overall pattern could be found in the different age groups tested, a Kruskal-Wallis test on the data for all items mouthed indicated that there was a significant difference between the age groups. Across all age groups and types of items, licking and sucking accounted for 64 percent of all mouthing behavior. Pacifiers and fingers exhibited less variety on mouthing behavior (principally sucking), while other items had a higher frequency of licking, biting, or other mouthing.

The researchers selected 25of the 236 children randomly for a single 15 minute observation of each child (total observation time across all children: 375 minutes), in order to compare the mouthing frequency and duration data obtained according to the real-time hand recording and the video-transcription methodologies, as well as the reliability of parent observations versus those made by trained professionals. For this group of 25 children, the total number of mouthing behavior events recorded by video (160) exceeded those recorded by parents (114) and

trained observers (110). Similarly, the total duration recorded by video (24 minutes and 15 seconds) exceeded that recorded by observers (parents and trained observers both recorded identical totals of 19 minutes and 44 seconds). The mean and standard deviation of observed mouthing time were both lower when recorded by video versus real-time hand recording. The maximum observed mouthing time was also lower (6 minutes and 7 seconds by video versus 9 minutes and 43 seconds for both parents and trained observers).

The strengths of this study were its comparison of three types of observation (parents, trained professional observers, and videotaping), and its detailed reporting of mouthing behaviors by type, object/item mouthed, and age group. However, the children studied may not be representative of the study population, and may not be representative of U.S. children.

4.4.2.5 *Au Yeung et al, 2004 - Young Children's Mouthing Behavior: An Observational Study via Videotaping in a Primarily Outdoor Residential Setting*

As described in Section 4.3.1.5, AuYeung et al. (2004) used a video-transcription methodology to study a group of 38 children (20 females and 18 males; ages 1 to 6 years), 37 of whom were selected randomly via a telephone screening survey of a 300 to 400 square mile portion of the San Francisco, California peninsula, along with one child selected by convenience due to time constraints. Families who lived in a residence with a lawn and whose annual income was >$35,000 were asked to participate. Videotaping took place between August 1998 and May 1999 for approximately two hours per child. Videotaping by one researcher was supplemented with field notes taken by a second researcher who was also present during taping. Most of the videotaping took place during outdoor play, however, data were included for several children (one child <2 years old and 8 children >2 years old) who had more than 15 minutes of indoor play during their videotaping sessions.

The videotapes were translated into ASCII computer files using VirtualTimingDevice™ software described in Zartarian et al. (1997a). Both frequency (see Section 4.3.1.5 of this Chapter) and duration were analyzed. Between 5 and 10 percent of the data files translated were randomly chosen for quality control checks for inter-observer agreement. Ferguson et al. (2006) described quality control aspects of the study in detail.

For analysis, the mouthing contacts were divided into indoor and outdoor locations, and 16 object/surface categories. Mouthing durations were analyzed by age and gender separately, and in combination. Mouthing contacts were defined as contact with the lips, inside of the mouth, and/or the tongue; dietary contacts were ignored. Mouthing durations are shown in Table 4-18 (outdoor locations). For the children in all age groups, the median duration of each mouthing contact was 1 to 2 seconds, confirming the observations of other researchers that children's mouthing contacts are of very short duration. For the one child observed that was ≤24 months, the total indoor mouthing duration was 11.1 minutes/hour; for children >24 months, the median indoor mouthing duration was 0.9 minutes/hour (Table 4-19). For outdoor environments, median contact durations for these age groups decreased to 0.8 and 0.6 minutes/hour, respectively (Table 4-20).

Nonparametric tests, such as the Wilcoxon rank sum test were used for the data analyses. Both age and gender were found to be associated with differences in mouthing behavior. Girls' hand to mouth contact durations were significantly shorter than for boys (p = 0.04).

This study provides distributions of outdoor mouthing durations with a variety of objects and surfaces. Although indoor mouthing data were also included in this study, the results were based on a small number of children (N=9) and a limited amount of indoor play. The sample of children may be representative of certain socioeconomic strata in the study area, but is not likely to be representative of the national population. Due to the children's ages, the presence of unfamiliar persons following the children with a video camera may have influenced the video-transcription methodology results.

4.5 MOUTHING PREVALENCE

4.5.1 Stanek et al., 1998 - Prevalence of Soil Mouthing/Ingestion Among Healthy Children Aged 1 to 6

Stanek et al. (1998) characterized the prevalence of mouthing behavior among healthy children based on a survey response study of parents or guardians of 533 children (289 females, 244 males) ages 1 to 6 years old. Study participants were attendees at scheduled well-child visits at three clinics in Western Massachusetts in August through October, 1992. Participants were questioned about the frequency of 28 mouthing behaviors of the children over the preceding month in addition to exposure time (e.g., time outdoors, play in sand or dirt) and children's characteristics (e.g., teething).

Table 4-21 presents the prevalence of reported non-food ingestion/mouthing behaviors by child's age as the percent of children whose parents reported the behavior in the preceding month. The table includes a column of data for the 3 to <6 year age category; this column was calculated by U.S. EPA as a weighted mean value of the individual data for 3, 4, and 5 year olds in order to conform to the standardized age categories used in this handbook. Among all the age groups, 1 year olds had the highest reported daily sucking of fingers/thumb; the proportion dropped for two year olds, but rose slightly for three and four year olds and declined again after age 4. A similar pattern was reported for more than weekly finger/thumb sucking, while more than monthly finger/thumb sucking showed a very slight increase for 6 year olds. Reported pacifier use was highest for one year olds and declined with age for daily and more than weekly use; for more than monthly use of a pacifier several six year olds were reported to use pacifiers, which altered the age-declining pattern for the daily and more than weekly reported pacifier use. A pattern similar to pacifier use existed with reported mouthing of teething toys, with highest reported use for one year olds, a decline with age until age 6 when reported use for daily, more than weekly, and more than monthly use of teething toys increased.

The authors developed an outdoor mouthing rate for each child as the sum of rates for responses to four questions on mouthing specific outdoor objects. Survey responses were converted to mouthing rates per week, using values of 0, 0.25, 1, and 7 for responses of never, monthly, weekly, and daily ingestion. Reported outdoor soil mouthing behavior prevalence was found to be higher than reported indoor dust mouthing prevalence, but both behaviors had the highest reported prevalence among 1 year old children and decreased for children 2 years and older. The investigators conducted principal component analyses on responses to four questions relating to ingestion/mouthing of outdoor objects in an attempt to characterize variability. Outdoor ingestion/mouthing rates constructed from the survey responses were that children 1 year of age were reported to mouth or ingest outdoor objects 4.73 times per week while 2 to 6 year olds were reported to mouth or ingest outdoor objects 0.44 times per week. The authors developed regression models to identify factors related to high outdoor mouthing rates. The authors found that children who were reported to play in sand or dirt had higher outdoor object ingestion/mouthing rates.

A strength of this study is that it was a large sample obtained in an area with urban and semi-urban residents within various socioeconomic categories and with varying racial/ethnic identities. However, difficulties with parents' recall of past events may have caused either over-estimates or under-estimates of the behaviors studied.

4.5.2 Warren et al., 2000 - Non-nutritive Sucking Behaviors in Preschool Children: A Longitudinal Study

Warren et al. (2000) conducted a survey response study of a non-random cohort of children born in certain Iowa hospitals from early 1992 to early 1995, as part of a study of children's fluoride exposure. For this longitudinal study of children's non-nutritive sucking behaviors, 1,374 mothers were recruited at the time of their newborns' birth, and over 600 were active in the study until the children were at least 3 years old. Survey questions on non-nutritive sucking behaviors were administered to the mothers when the children were 6 weeks, 3, 6, 9, 12, 16 and 24 months old, and yearly after age 24 months. Questions were posed regarding the child's sucking behavior over the previous 3 to 12 months.

The authors reported that nearly all children sucked non-nutritive items, including pacifiers, thumbs

or other fingers, and/or other objects, at some point in their early years. The parent-reported sucking behavior prevalence peaked at 91 percent for 3 month old children. At 2 years of age, a majority (53 percent) retained a sucking habit, while 29 percent retained the habit at age 3 years and 21 percent at age 4 years. Parent-reported pacifier use was 28% for 1 year olds, 25% for 2 year olds, and 10% for 3 year olds. The authors cautioned against generalizing the results to other children due to study design limitations.

Strengths of this study were its longitudinal design and the large sample size. A limitation is that the non-random selection of original study participants and the self-selected nature of the cohort of survey respondents who participated over time means that the results may not be representative of other U.S. children of these ages.

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Table 4-3. New Jersey Children's Mouthing Frequency (contacts/hour) from Video-transcription

Category	Minimum	Mean	Median	90th Percentile	Maximum
Hand to mouth	0.4	9.5	8.5	20.1	25.7
Object to mouth	0	16.3	3.6	77.1	86.2

Source: Reed et al., 1999.

Table 4-4. Survey-Reported Percent of 168 Minnesota Children Exhibiting Behavior, by Age

Age Group	Thumbs/fingers in Mouth	Toes in Mouth	Non-food Items in Mouth
3 years	71	29	71
4 years	63	0	31
5 years	33	-	20
6 years	30	-	29
7 years	28	-	28
8 years	33	-	40
9 years	43	-	38
10 years	38	-	38
11 years	33	-	48
12 years	33	-	17

\- = No data.

Source: Freeman et al., 2001.

Table 4-5. Video-transcription Median (Mean) Observed Mouthing in 19 Minnesota Children (contacts/hour)

Age Group	N	Object-to-mouth[a]	Hand-to-mouth
3 to 4 years	3	3 (6)	3.5 (4)
5 to 6 years	7	0 (1)	2.5 (8)
7 to 8 years	4	0 (1)	3 (5)
10 to 12 years	5	0 (1)	2 (4)

[a] Kruskal Wallis test comparison across four age groups, P=0.002.
N = Number of observations.

Source: Freeman et al., 2001.

Table 4-6. Variability in Objects Mouthed by Washington State Children (contacts/hour)

Variable	All Subjects				≤24 Months				>24 Months			
	N[a]	Mean[b]	Median	95% CI[c]	N[a]	Mean[b]	Median	95% CI[c]	N[a]	Mean[b]	Median	95% CI[c]
Mouth-body	186	8	2	2-3	69	10	4	3-6	117	7	1	0.8-1.3
Mouth-hand	186	16	11	9-14	69	18	12	9-16	117	16	9	7-12
Mouth-surface	186	4	1	0.8-1.2	69	7	5	3-8	117	2	1	0.9-1.1
Mouth-toy	186	27	18	14-23	69	45	39	31-48	117	17	9	7-12
Total events	186	56	44	36-52	69	81	73	60-88	117	42	31	25-39

[a] Number of observations.
[b] Arithmetic mean.
[c] The 95% confidence intervals (CI) apply to median. Values were calculated in logs and converted to original units.

Source: Tulve et al., 2002.

Table 4-7. Indoor Mouthing Frequency (Contacts per hour), Video-transcription of 9 Children with >15 minutes in View Indoors

Age Group	N	Statistic	Hands	Total non-dietary[a]
13 to 84 months	9	Mean	20.5	29.6
		Median	14.8	22.1
		Range	2.5 - 70.4	3.2 - 82.2
≤24 months	1	-	73.5	84.8
>24 months	8	Mean	13.9	22.7
		Median	13.3	19.5
		Range	2.2 - 34.1	2.8 - 51.3

[a] Object/surface categories mouthed indoors included: Clothes/towels, hands, metal, paper/wrapper, plastic, skin, toys, and wood.
N = Number of subjects.

Source: AuYeung et al., 2004.

Table 4-8. Outdoor Mouthing Frequency (Contacts per hour), Video-transcription of 38 Children

Age Group	N	Statistic	Hands	Total non-dietary[a]
13 to 84 months	38	Mean	11.7	18.3
		5th percentile	0.4	0.8
		25th percentile	4.4	9.2
		50th percentile	8.4	14.5
		75th percentile	14.8	22.4
		95th percentile	31.5	51.7
		99th percentile	47.6	56.6
≤24 months	8	Mean	13.0	20.4
		Median	7.0	13.9
		Range	1.3 - 47.7	6.2 - 56.4
>24 months	30	Mean	11.3	17.7
		5th percentile	0.2	0.6
		25th percentile	4.7	7.6
		50th percentile	8.6	14.6
		75th percentile	14.8	22.4
		95th percentile	27.7	43.8
		99th percentile	39.5	53.0

[a] Object/surface categories mouthed outdoors included: animal, clothes/towels, fabric, hands, metal, non-dietary water, paper/wrapper, plastic, skin, toys, vegetation/grass, and wood.
N = Number of subjects.

Source: AuYeung et al., 2004.

Table 4-9. Videotaped Mouthing Activity of Texas Children, Median Frequency (Mean ± SD)

Age	N	Hand to mouth	Object to Mouth
		Frequency (contacts/hour)	Frequency (contacts/hour)
Infant	13	14 (19.8 ± 14.5)	18.1 (24.4 ± 11.6)
1 year	12	13.3 (15.8 ± 8.7)	8.4 (9.8 ± 6.3)
2 years	18	9.9 (11.9 ± 9.3)	5.5 (7.8 ± 5.8)
Preschool	9	19.4 (22.1 ± 22.1)	8.4 (10.1 ± 12.4)

N = Number of subjects.
SD = Standard deviation.

Source: Black et al., 2005.

Table 4-10. Indoor Hand-to-Mouth Frequency (contacts/hour) Distributions from Various Studies

Age Group	N	Mean	SD	Percentiles				
				5	25	50	75	95
3 to <6 months	23	28.0	21.7	3.0	8.0	23.0	48.0	65.0
6 to <12 months	119	18.9	17.4	1.0	6.6	14.0	26.4	52.0
1 to <2 years	245	19.6	19.6	0.1	6.0	14.0	27.0	63.0
2 to <3 years	161	12.7	14.2	0.1	2.9	9.0	17.0	37.0
3 to <6 years	169	14.7	18.4	0.1	3.7	9.0	20.0	54.0
6 to <11 years	14	6.7	5.5	1.7	2.4	5.7	10.2	20.6

N = Number of subjects.
SD = Standard deviation.

Source: Xue et al., 2007.

Table 4-11. Outdoor Hand-to-Mouth Frequency (contacts/hour) Distributions from Various Studies

Age Group	N	Mean	SD	Percentiles				
				5	25	50	75	95
6 to <12 months	10	14.5	12.3	2.4	7.6	11.6	16.0	46.7
1 to <2 years	32	13.9	13.6	1.1	4.2	8.0	19.2	42.2
2 to <3 years	46	5.3	8.1	0.1	0.1	2.6	7.0	20.0
3 to <6 years	55	8.5	10.7	0.1	0.1	5.6	11.0	36.0
6 to <11 years	15	2.9	4.3	0.1	0.1	0.5	4.7	11.9

N = Number of subjects.
SD = Standard deviation.

Source: Xue et al., 2007.

Table 4-12. Survey Reported Mouthing Behaviors for 92 Washington State Children

Behavior	Never		Seldom		Occasionally		Frequently		Always		Unknown	
	N	%	N	%	N	%	N	%	N	%	N	%
Hand/Foot in Mouth	4	4	27	30	23	25	31	34	4	4	3	3
Pacifier	74	81	6	7	2	2	9	10	1	1	0	0
Mouth on Object	14	15	30	33	25	27	19	21	1	1	3	3
Non-Food in Mouth	5	5	25	27	33	36	24	26	5	5	0	0
Eat Dirt/Sand	37	40	39	43	11	12	4	4	1	1	0	0

N = Number of subjects.

Source: Davis et al. 1995.

Table 4-13. Estimated Daily Mean Mouthing Times of New York State Children, for Pacifiers and Other Objects

Object Type	Age 0 to 18 months		Age 19 to 36 months	
	All Children	Only Children Who Mouthed Object [a]	All Children	Only Children Who Mouthed Object [a]
	Minutes	Minutes	Minutes	Minutes
Pacifier	108 (N = 107)	221 (N=52)	126 (N=110)	462 (N=52)
Teether	6 (N=107)	20 (N=34)	0 (N=110)	30 (N=1)
Plastic Toy	17 (N=107)	28 (N=66)	2 (N=110)	11 (N=21)
Other Objects	9 (N=107)	22 (N=46)	2 (N=110)	15 (N=18)

[a] Refers to means calculated for the subset of the sample children who mouthed the object stated (zeroes are eliminated from the calculation of the mean).

N = Number of children.

Source: Juberg et al., 2001.

Table 4-14. Percent of Houston-area and Chicago-area Children Observed Mouthing, by Category and Child's Age

Object Category	All ages	<1 year	1 to 2 years	2 to 3 years
All Objects	100	100	100	100
Pacifiers	27	43	27	10
Non-pacifiers	100	100	100	100
Soft Plastic Food Content Items	28	13	30	41
Anatomy	99	100	97	100
Non-soft Plastic Toys, Teethers, and Rattles	91	94	91	86
Other Items	98	98	97	98

Source: Greene, 2002.

Table 4-15. Estimates of Mouthing Time for Various Objects (minutes/hour)

Age Group	Mean (SD)	Median	95th Percentile	99th Percentile
All Items[a]				
3 to <12 months	10.5 (7.3)	9.6	26.2	39.8
12 to <24 months	7.3 (6.8)	5.5	22.0	28.8
24 to <36 months	5.3 (8.2)	2.4	15.6	47.8
Non Pacifiers[b]				
3 to <12 months	7.1 (3.6)	6.9	13.1	14.4
12 to <24 months	4.7 (3.7)	3.6	12.8	18.9
24 to <36 months	3.5 (3.6)	2.3	12.8	15.6
All Soft Plastic Items				
3 to <12 months	0.5 (0.6)	0.1	1.8	2.5
12 to <24 months	0.4 (0.4)	0.2	1.3	1.9
24 to <36 months	0.4 (0.6)	0.1	1.6	2.9
Soft Plastic Items Not Food Contact				
3 to <12 months	0.4 (0.6)	0.1	1.8	2.0
12 to <24 months	0.3 (0.4)	0.1	1.1	1.5
24 to <36 months	0.2 (0.4)	0.0	1.3	1.8
Soft Plastic Toys, Teethers, and Rattles				
3 to <12 months	0.3 (0.5)	0.1	1.8	2.0
12 to <24 months	0.2 (0.3)	0.0	0.9	1.3
24 to <36 months	0.1 (0.2)	0.0	0.2	1.6
Soft Plastic Toys				
3 to <12 months	0.1 (0.3)	0.0	0.7	1.1
12 to <24 months	0.2 (0.3)	0.0	0.9	1.3
24 to <36 months	0.1 (0.2)	0.0	0.2	1.6
Soft Plastic Teethers and Rattles				
3 to <12 months	0.2 (0.4)	0.0	1.0	2.0
12 to <24 months	0.0 (0.1)	0.0	0.1	0.6
24 to <36 months	0.0 (0.1)	0.0	0.0	1.0
Other Soft Plastic Items				
3 to <12 months	0.1 (0.2)	0.0	0.8	1.0
12 to <24 months	0.1 (0.1)	0.0	0.4	0.6
24 to <36 months	0.1 (0.3)	0.0	0.5	1.4

Table 4-15. Estimates of Mouthing Time for Various Objects (minutes/hour) (continued)

Age Group	Mean (SD)	Median	95th Percentile	99th Percentile
Soft Plastic Food Contact Items				
3 to <12 months	0.0 (0.2)	0.0	0.3	0.9
12 to <24 months	0.1 (0.2)	0.0	0.7	1.2
24 to <36 months	0.2 (0.4)	0.0	1.2	1.9
Anatomy				
3 to <12 months	2.4 (2.8)	1.5	10.1	12.2
12 to <24 months	1.7 (2.7)	0.8	8.3	14.8
24 to <36 months	1.2 (2.3)	0.4	5.1	13.6
Non Soft Plastic Toys, Teethers, and Rattles				
3 to <12 months	1.8 (1.8)	1.3	6.5	7.7
12 to <24 months	0.6 (0.8)	0.3	1.8	4.6
24 to <36 months	0.2 (0.4)	0.1	0.9	2.3
Other Items				
3 to <12 months	2.5 (2.1)	2.1	7.8	8.1
12 to <24 months	2.1 (2.0)	1.4	6.6	9.0
24 to <36 months	1.7 (2.6)	0.7	7.1	14.3
Pacifiers				
3 to <12 months	3.4 (6.9)	0.0	19.5	37.3
12 to <24 months	2.6 (6.5)	0.0	19.9	28.6
24 to <36 months	1.8 (7.9)	0.0	4.8	46.3

[a] Object category "all items" is subdivided into pacifiers and non-pacifiers.

[b] Object category "non-pacifiers" is subdivided into all soft plastic items, anatomy (which includes hair, skin, fingers and hands), non-soft plastic toys/teethers/rattles, and other items.

[c] Object category "all soft plastic items" is subdivided into food contact items, nonfood contact items (toys, teethers and rattles) and other soft plastic.

SD = Standard deviation.

Source: Greeene, 2002.

Table 4-16. Mouthing Times of Dutch Children Extrapolated to Total Time While Awake, Without Pacifier, in Minutes per Day

Age Group	N	Mean	SD	Minimum	Maximum
3 to 6 months	5	36.9	19.1	14.5	67
6 to 12 months	14	44	44.7	2.4	171.5
12 to 18 months	12	16.4	18.2	0	53.2
18 to 36 months	11	9.3	9.8	0	30.9

Note: The object most mouthed in all age groups was the fingers, except for the 6 to 12 month group which mostly mouthed toys.
N = Number of children.
SD = Standard deviation.

Source: Groot et al., 1998.

Table 4-17. Estimated Mean Daily Mouthing Duration by Age Group for Pacifiers, Fingers, Toys, and Other Objects (hours:minutes:seconds)

Item Mouthed	Age Group											
	1 to 3 months	3 to 6 months	6 to 9 months	9 to 12 months	12 to 15 months	15 to 18 months	18 to 21 months	21 to 24 months	2 years	3 years	4 years	5 years
N =	9	14	15	17	16	14	16	12	39	31	29	24
Dummy (Pacifier)	0:47:13	0:27:45	0:14:36	0:41:39	1:00:15	0:25:22	1:09:02	0:25:12	0:32:55	0:48:42	0:16:40	0:00:20
Fingers	0:18:22	0:49:03	0:16:54	0:14:07	0:08:24	0:10:07	0:18:40	0:35:34	0:29:43	0:34:42	0:19:26	0:44:06
Toys	0:00:14	0:28:20	0:39:10	0:23:04	0:15:18	0:16:34	0:11:07	0:15:46	0:12:23	0:11:37	0:03:11	0:01:53
Other Objects	0:05:14	0:12:29	0:24:30	0:16:25	0:12:02	0:23:01	0:19:49	0:12:53	0:21:46	0:15:16	0:10:44	0:10:00
Not Recorded	0:00:45	0:00:24	0:00:00	0:00:01	0:00:02	0:00:08	0:00:11	0:14:13	0:02:40	0:00:01	0:00:05	0:02:58
Total (all objects)	1:11:48	1:57:41	1:35:11	1:35:16	1:36:01	0:15:13	1:58:49	1:43:39	1:39:27	1:50:19	0:50:05	0:59:17

N = Number of children in sample.

Source: Smith and Norris, 2003.

Table 4-18. Outdoor Median Mouthing Duration (seconds per contact), Video-transcription of 38 Children

Age Group	N	Statistic	Hands	Total non-dietary[a]
13 to 84 months	38	Mean	3.5	3.4
		5th percentile	0	0
		25th percentile	1	1
		50th percentile	1	1
		75th percentile	2	3
		95th percentile	12	11
		99th percentile	41.6	40
≤24 months	8	Mean	9	2
		Median	3	1
		Range	0 to 136	0 to 40
>24 months	30	Mean	3.5	3.4
		5th percentile	0	0
		25th percentile	1	1
		50th percentile	1	1
		75th percentile	2	3
		95th percentile	12	11
		99th percentile	41.6	40

[a] Object/surface categories mouthed outdoors included: animal, clothes/towels, fabric, hands, metal, non-dietary water, paper/wrapper, plastic, skin, toys, vegetation/grass, and wood.
N = Number of subjects.

Source: AuYeung et al., 2004.

Table 4-19. Indoor Mouthing Duration (minutes per hour), Video-transcription of 9 Children with >15 minutes in View Indoors

Age Group	N	Statistic	Hands	Total non-dietary[a]
13 to 84 months	9	Mean	1.8	2.3
		Median	0.7	0.9
		Range	0-10.7	0-11.1
≤24 months	1	Observation	10.7	11.1
>24 months	8	Mean	0.7	1.2
		Median	0.7	0.9
		Range	0-1.9	0-3.7

[a] Object/surface categories mouthed indoors included: Clothes/towels, hands, metal, paper/wrapper, plastic, skin, toys, and wood.
N = Number of subjects.

Source: AuYeung et al., 2004.

Table 4-20. Outdoor Mouthing Duration (minutes per hour), Video-transcription of 38 Children

Age Group	N	Statistic	Hands	Total non-dietary[a]
13 to 84 months	38	Mean	0.9	1.2
		5th percentile	0	0
		25th percentile	0.1	0.2
		50th percentile	0.2	0.6
		75th percentile	0.6	1.2
		95th percentile	2.6	2.9
		99th percentile	11.2	11.5
		Range	0-15.5	0-15.8
≤24 months	8	Mean	2.7	3.1
		5th percentile	0	0.2
		25th percentile	0.2	0.2
		50th percentile	0.4	0.8
		75th percentile	1.5	3.1
		95th percentile	11.5	11.7
		99th percentile	14.7	15
		Range	0-15.5	0.2-15.8
>24 months	30	Mean	0.4	0.7
		5th percentile	0	0
		25th percentile	0.1	0.2
		Median	0.2	0.6
		75th percentile	0.4	1
		95th percentile	1.2	2.1
		99th percentile	2.2	2.5
		Range	0-2.4	0-2.6

[a] Object/surface categories mouthed outdoors included: animal, clothes/towels, fabric, hands, metal, non-dietary water, paper/wrapper, plastic, skin, toys, vegetation/grass, and wood.

N = Number of subjects.

Source: AuYeung et al., 2004.

Table 4-21. Reported Daily Prevalence of Massachusetts Children's Non-Food Mouthing/Ingestion Behaviors

Object or substance mouthed or ingested	Percent of children reported to mouth/ingest daily				
	1 year	2 years	3 to <6 years[a]	6 years	All years
	N=171	N=70	N=265	N=22	N=528
Grass, leaves, flowers	16	0	1	0	6
Twigs, sticks, woodchips	12	0	0	0	4
Teething toys	44	6	2	9	17
Other toys	63	27	12	5	30
Blankets, cloth	29	11	10	5	16
Shoes, Footwear	20	1	0	0	7
Clothing	25	7	9	14	14
Crib, chairs, furniture	13	3	1	0	5
Paper, cardboard, tissues	28	9	5	5	13
Crayons, pencils, erasers	19	17	5	18	12
Toothpaste	52	87	89	82	77
Soap, detergent, shampoo	15	14	2	0	8
Plastic, plastic wrap	7	4	1	0	3
Cigarette butts, tobacco	4	0	1	0	2
Suck fingers/thumb	44	21	24	14	30
Suck feet or toes	8	1	0	0	3
Bite nails	2	7	10	14	7
Use pacifier	20	6	2	0	9

[a] Weighted mean of 3, 4, and 5 year-olds' data calculated by U.S. EPA to conform to standardized age categories used in this Handbook.

Source: Stanek et al. (1998).