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6. OTHER NON-DIETARY INGESTION FACTORS

6.1 INTRODUCTION

Young children (i.e., ages 6 months through approximately 4 years) have the potential for exposure to toxic substances through non-dietary ingestion pathways other than soil ingestion (e.g., ingesting pesticide residues that have been transferred from treated surfaces to the hands or objects that are mouthed). These children have an urge to mouth objects or their fingers in exploring their environment, as a sucking reflex and as a habit (Groot et al., 1998). Exposure via this route may exceed other routes of ingestion (i.e., food, pica, drinking water, breast milk) and dermal exposure, because non-dietary ingestion may result in higher ingestion rates of contaminated material (Weaver et al., 1998). This exposure route is also difficult to assess because there is little literature or research on mouthing behavior (Reed et al., 1999) and little information on the susceptibility of children to toxic substances (Weaver et al., 1998).

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). Children's contact with surfaces is intermittent and nonuniform over different parts of the body and the nature of the mouthing itself is intermittent and nonuniform, making this pathway difficult to model (Zartarian et al., 1997).

Children exhibit large differences in mouthing behavior (Groot et al., 1998). 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. Children will use both sucking and licking to explore their environment. Sucking also becomes a means of comfort when a child is tired or upset. In addition, teething normally causes substantial mouthing behavior—sucking or chewing—to alleviate discomfort in the gums. Each child is different, and large differences occur between children, even within the same family.

Mouthing becomes critical in exposure to potentially toxic substances when it involves the behavior of a small child around potentially contaminated sources. Children play close to the ground and are frequently licking their fingers or mouthing toys or objects. As a result, mouthing becomes a potentially significant exposure route. Children may ingest more toxic constituents through this behavior than from dietary ingestion or inhalation because they may

1 place wet, sticky fingers on potentially-contaminated surfaces, and more toxic substances may
2 adhere to the fingers than if the fingers were dry (Gurunathan et al., 1998).

3 Gurunathan et al. (1998) estimated that young children spend as much as 90 percent of
4 their days inside, so exposure to contaminants that may infiltrate the home through the vapor
5 phase (e.g., volatile organic compounds (VOCs) and semi-VOCs (SVOCs)) may be of concern.
6 This may be a significant pathway of exposure to SVOCs because these compounds can be
7 deposited on surfaces in the home or become absorbed onto plastic toys or in stuffed animals
8 where they can serve as reservoirs for toxic constituents (Gurunathan et al., 1998).

9 Few studies have investigated this potential exposure route. The shortage of research and
10 data may be due to the difficulty in observing very young children and the labor-intensive effort
11 in gathering the data (Hubal et al., 2000). The applicable research efforts use two general
12 approaches to gather data: real-time hand recording, in which trained persons observe a child and
13 manually record information on a survey sheet or score sheet; and videotaping, in which trained
14 videographers tape a child's activities and subsequently extract the pertinent data manually or
15 with computer software (Hubal et al., 2000).

16 Some researchers express mouthing behavior in terms of frequency of occurrence (e.g.,
17 contacts per hour or contacts per minute). Others express mouthing behavior as a rate in units of
18 minutes per hour of mouthing time. Both approaches have their use in exposure assessments.
19 The former approach is more appropriate when studying children's behavior during various
20 microactivities. The latter, however, is more useful when studying children's behavior during
21 macroactivities. Macroactivities can be described by a child's general activities such as
22 sleeping, watching television, playing, and eating. Microactivities refer to the specific behavior
23 a child is engaged in such as hand-to-surface contacts and hand-to-mouth behavior (Hubal et al.,
24 2000). Time spent in various macroactivities in several microenvironments (e.g., indoors at
25 home) are presented in Chapter 9.

26 27 **6.2 STUDIES RELATED TO NON-DIETARY INGESTION**

28 **6.2.1 Davis, 1995**

29 In 1992, the Fred Hutchinson Cancer Research Center under Cooperative Agreement
30 with EPA, conducted a study to estimate children's soil intake rates and collect mouthing
31 behavior data. Originally, the study was designed with two primary purposes: (1) to describe

1 and quantify the distribution of soil ingestion values in a group of children under the age of five
2 who exhibit behaviors that would be likely to result in the ingestion of larger than normal
3 amounts of soil; and (2) to assess and quantify the degree to which soil ingestion varies among
4 children according to season of the year (summer vs. winter). The study was conducted during
5 the first four months of 1992 and included 92 children from the Tri-Cities area in Washington
6 State. The children were volunteers among a group selected through random digit dialing and
7 their ages ranged between 0 and 48 months. The study was conducted during a 7-day period.

8 Because there was no standard methodology to study mouthing behavior, a pretest and a
9 series of pilot studies were conducted to examine various aspects of the methodology. As a
10 result of the pilot studies, it was determined that although parents could be taught to conduct
11 observations using the instrument, the resulting ranking of children according to degree of
12 mouthing behavior did not correspond very well to the rankings based on observations of the
13 same children by trained staff observers. Therefore, using parents' observations to select a group
14 with high mouthing activity was not deemed appropriate. Funding constraints made it
15 impractical to continue with the original design of screening a large number of children and
16 conducting field work during two different times of the year.

17 The Davis (1995) research recognizes that mouthing behavior is intermittent. Therefore,
18 a practice called the "interval method" of observation was used. This method measures both
19 frequency and duration of the behavior. Under this method, children were observed during 15
20 second intervals, during which the mouthing behavior was recorded. Based on the types of
21 behaviors observed in the testing of the instrument, two mouthing behaviors were selected for
22 the full study. These included: 1) tongue contacts object; and 2) object in mouth. In addition
23 four other behaviors were included in an attempt to better describe the types of behaviors that
24 would likely result in soil ingestion: 1) hand touches ground; 2) child is repulsed by object in
25 mouth and tries to get it out; 3) other person stops child's contact with object; and 4) child is out
26 of sight or view. To further characterize potential exposures to soil associated with the three
27 types of mouthing behaviors, six object categories were included along with the behaviors: 1)
28 hand, finger, or thumb; 2) other body parts, including toes, feet, arms; 3) natural materials,
29 including dirt, sand, rocks, leaves; 4) toys and other objects, including books, utensils, keys; 5)
30 surfaces, including window sills, floors, furniture, carpet; and 6) food or drink. An additional
31 code was added to indicate whether an object was swallowed by the child. The type of activity

1 the child was engaged in during the observation period was also recorded. In addition to
2 mouthing behavior data, information about how long the child spent indoors and outdoors each
3 day, and the general types of outdoor settings in which the child played was collected.

4 Mouthing behavior data were collected during a 4-day period. Both trained observers
5 and one parent observed the children to record mouthing behavior data. Trained observers
6 recorded mouthing behavior data for 1 hour during active play time, and the parent recorded
7 mouthing behavior data for the first 15 minutes of that hour.

8 The basic measure of each type of mouthing activity derived from the observation form
9 was the percent of time spent in that activity. This measure was defined as the percentage of the
10 total number of intervals observed that indicate such an activity took place. If there was no
11 activity in an interval, that interval was excluded. For tabulating the object categories, multiple
12 instances of the same object in a single interval were counted only once in that interval.
13 Multiple instances of different objects in a single interval were counted separately under each
14 object category.

15 Based on the mouthing behavior data collected in this study, EPA calculated that during
16 the period of observation (assumed to be 1 hour) the average mouthing activity was 6.2 minutes
17 and the average tongue activity was 0.70 minutes. It is important to note that this is based on
18 one hour of observation. In order to estimate the overall mouthing activity in a day, one would
19 have to make some assumptions about the amount of time a child is involved in active play time
20 in a day. These values may also be underestimates because they assume that all the children in
21 the study were observed for one hour on each of the four days. If this were true, each child
22 would have a total of 960 intervals of observations (i.e., 3,600 seconds x intervals/15 seconds x 4
23 days). The data show that the number of intervals of observation ranged from 80 to 840. It can
24 be concluded that some children were either observed for less than one hour or less than 4 days.

25 In order to compare the values estimated by Groot et al. (1998) whose work also used
26 time as a basis for measuring mouthing activity, it is necessary to multiply the Davis (1995)
27 hourly estimate by an estimate of how long the children are awake during the day. According to
28 Davis (1995), small children aged 0 to 48 months are awake approximately 8.9 hours per day.
29 Based upon this estimate, the Davis (1995) findings translate into about 55 minutes per day of
30 mouthing activity and 6 minutes per day of tongue activity. The 55 minutes compares favorably
31 to the 37 minutes and 44 minutes estimated by Groot et al. (1998) for 3- to 6-month and 6- to 12-

1 month old children, respectively, but is significantly above the 16.4 minutes and 9.3 minutes
2 estimated for the 12- to 18-month and 18- to 36-month old children, respectively. The difference
3 may be attributable to differences in sleep time between children at either end of the continuum
4 of ages included in the study (0 to 48 months).

5 Although the research included the largest sample population of the reviewed literature,
6 92 sample points is still a small number considering the wide variability associated with
7 mouthing in children. The random nature in which the population was selected probably
8 provides a representative population of the northwest U.S., but not the national population in
9 general. The interval time of 15 seconds would also appear to be small and potentially easily
10 skewed for those children observed less than an hour. In addition, most other studies used
11 observation times of 15 minutes to continuous observation throughout waking hours.

12 13 **6.2.2 Groot et al., 1998**

14 In this study, Groot et al. (1998) examined the mouthing behavior of infants and young
15 children between the ages of 3 and 36 months in the Netherlands. The study was part of a larger
16 effort to determine if PVC toys softened with phthalates could pose health risks to children from
17 mouthing. As part of the effort, the investigators asked parents to observe their children and
18 gather information that could be used to estimate how often children engage in mouthing and the
19 duration spent mouthing during a day. Parents were asked to observe their children ten times per
20 day for 15-minute intervals (i.e., 150 minutes total per day) for two days and measure mouthing
21 with a stopwatch. In total, 36 parents participated in the study and 42 children were observed by
22 their parents. For the study, a distinction was made between toys meant for mouthing (e.g.,
23 pacifiers, teething rings) and those not meant for mouthing. The time a child spent mouthing a
24 dummy (e.g., pacifier) was not included in the time recorded.

25 Although the sample size was relatively small, the results provide a first-order estimate
26 on mouthing times during a day. The results (Table 6-1) show wide variation. The standard
27 deviation in all four age categories except the 3- to 6-month old children exceeds the mean time
28 estimated mouthing during a day. The large standard deviations is not unexpected given the vast
29 behavioral differences from child to child and the small sample size of the study. The overall
30 trend of the data, however, may be accurate in that it shows that as the children age, the time
31 spent mouthing decreases. The 3- to 6-month children were estimated to mouth 37 minutes per

1 day and the 6- to 12-month children 44 minutes per day. After 12 months, the estimated
2 mouthing time drops quickly to 16 minutes per day for 12- to 18-month children and 9 minutes
3 per day for 18- to 36-month children.

4 The study has several limitations that have an impact on the usability of the data. The
5 initial drawback concerns the small size of the study. The authors of the study acknowledge this
6 shortcoming and recommend further study using a larger sample population. In addition, the
7 study also incorporated mostly higher-educated persons. The area where the study was
8 performed consisted primarily of parents with higher education. The study had recruited persons
9 of lower education and socioeconomic levels, but these persons chose not to participate in the
10 study after recruitment. Therefore, the results do not reflect data from the full spectrum of the
11 population. The study also recorded only the time spent mouthing and not the number of times
12 that mouthing occurred and did not differentiate the types of objects mouthed. In addition,
13 children were observed for a period of two consecutive days and may not reflect long-term
14 behavior. Because this study was conducted in the Netherlands, it may not be representative of
15 the U.S. population.

16 17 **6.2.3 Reed et al., 1999**

18 In this study, Reed et al. (1999) used videotaping to quantify the frequency and type of
19 contacts children have during the course of an hour. The contacts included numerous categories:
20 hand to clothing, hand to dirt, hand to hand, hand to mouth, hand to object, object to mouth, hand
21 to smooth surface (e.g., counter tops, table tops), hand to textured surface (e.g., stuffed animal).
22 A total of 30 children were observed in this study. Children were observed in both day care (20
23 children 3-6 years old) and residential (10 children 2-5 years old) settings. Parents and daycare
24 providers were also asked to complete questionnaires describing the behavior of the children. In
25 addition, the study also differentiated between the use of right and left hands.

26 Over the course of the research, the investigators found that the behavior of children in
27 daycare and residential settings was similar except for the contact rate of hand to smooth
28 surfaces. Children in residential settings had higher contact rates with smooth surfaces than
29 children in day care centers. The results of the study are compiled in Table 6-2. The highest
30 contacts were with object (123 contacts/hr), smooth surfaces (84 contacts/hr), and other (83
31 contacts/hr). The two lowest contact rates were the hand-to-mouth (9.5 contacts/hr) and object-

1 to-mouth (16.3 contacts/hr). Because the contact rates of hand-to-objects and smooth surfaces
2 are high, these results indicate that the fingers would appear to provide a continual dose per
3 hand-to-mouth contact because of constant touching of potentially contaminated surfaces.
4 Pesticides and other SVOCs are partitioned between the vapor and deposited phases (e.g., on
5 dust or absorbed on a plastic toy or stuffed animal) such that a child's fingers, especially if wet
6 from mouthing, will continually be acquiring doses of these types of constituents (Gurunathan et
7 al., 1998).

8 The investigators also noted that children acted equally on their environment with both
9 hands with the exception of object-to-mouth behavior. Therefore, the compiled data are reported
10 as combined right and left hand data. The object-to-mouth behavior showed a strong preference
11 for the right hand over the left hand for nearly all children (Reed et al., 1999). The preference
12 ratio for the right hand over the left hand for this category was 6.8 to 1.

13 The advantages of this study is that it incorporates a wide variety of contacts that small
14 children have, not just the hand-to-mouth or object-to-mouth. This information allows assessors
15 to identify areas or surfaces that may serve as sources for toxic constituent transfer. This is
16 especially important for exposure to SVOCs such as pesticides (e.g., chlorpyrifos) that have an
17 affinity for absorption onto dust particles, plastic toys, and into the polyurethane foam (PUF) that
18 is used in many stuffed animals (Gurunathan et al., 1998). Another strength of this study is the
19 agreement it shows with earlier work by Zartarian et al. (1998) for the hand to mouth contacts.
20 Some of the shortcomings are the small sample size of the study and the lack of comment as to
21 the representativeness of the sample population to the U.S. population. The authors
22 acknowledged the weakness in regard to the sample size and recommended further work with a
23 larger population. The study makes no mention of the representativeness of the sample
24 population or addresses the need for a representative population for any additional study.
25

26 **6.2.4 Zartarian et al., 1997 and 1998**

27 Zartarian et al. (1997, 1998) conducted a pilot study of four children of farm workers to
28 investigate the applicability of using videotaping for gathering information related to children's
29 interaction with their environment. The evaluation of the videotaping included observation of
30 the children's contact frequency and duration with objects in their environment, duration spent in
31 different locations, activity levels, and frequency distributions.

1 Four Mexican-American farm worker children— two girls and two boys between the
2 ages of 2.5 and 4.2 years— were videotaped for 33 hours using hand-held cameras over the
3 course of a single day in 1993. The videotaping gathered information on detailed micro-activity
4 patterns of children to be used to evaluate software for videotaped activities and translation
5 training methods The data were also reported by type of object/surface and by left or right hand.

6 The investigators presented the data for their observations on a per child and per hand
7 basis. None of the children had average contact frequencies for either hand, individually, lower
8 than 3 contacts/hr for hand to mouth contact, and the investigators estimated the average as 9
9 contacts/hr with an average range of 1 to 29 contacts/hr. As also reported by Reed et al. (1999),
10 the most frequently contacted objects were toys and hard (i.e., smooth) surfaces. The average
11 contact time with objects is only 2 to 3 seconds; therefore, according to the authors,
12 questionnaires and diaries would be insufficient in gathering that level of activity.

13 This study has several weaknesses. The sample population is very small, only four
14 children; however, the work was reported as a pilot study completely acknowledging that further
15 work was necessary. The effort was intended to evaluate the methodology of collecting
16 observations, not the contact data itself. The data are not presented in a format that can be used
17 to support other research or supply recommended estimates for contact frequency. This study
18 may not reflect long-term behavior. In addition, the sample population is not representative of
19 the U.S. population in general.

21 **6.2.5 Stanek et al., 1998**

22 Stanek et al. (1998) presented a methodology that characterizes the prevalence of
23 mouthing behavior among healthy children . Data regarding the frequency of 28 mouthing
24 behaviors were collected via face-to-face interviews over a period of 3 months from parents or
25 guardians of 533 children ages 1 to 6 years old attending well-visits in Western Massachusetts.
26 Three clinics participated in this study during the months of August, September, and October,
27 1992: Kaiser Permanente’s clinic in Amherst, a private clinic associated with the Cooley
28 Dickinson Hospital in Northampton, and the Bay State Medical Center clinic in Springfield.
29 Participants were questioned about the frequency of 28 mouthing behaviors of the children over
30 the past month in addition to exposure time (e.g., time outdoors, play in sand or dirt) and

1 children's characteristics (e.g., teething). Response categories of the clinic questionnaire
2 corresponded to daily, at least weekly, at least monthly, and never.

3 The authors expressed the mouthing rate for each child as the sum of rates for responses
4 to four questions on mouthing specific outdoor objects. Regression models with variables in a
5 step-wise manner identified factors related to high outdoor mouthing rates. The authors first
6 considered variables that indicated opportunity for exposure, then subjects' characteristics (e.g.,
7 teething) and environmental factors, and finally, concurrent reported behaviors.

8 Table 6-3 presents the prevalence of non-food ingestion/mouthing behaviors by child's
9 age as the percent of children whose parents reported the behavior in the past month. The table
10 includes a column of data for the 3 to <6 year age category; this column was calculated by EPA
11 as a weighted mean value of the individual data for 3-, 4-, and 5-year-olds in order to conform to
12 the standardized age categories used in this Handbook. Outdoor soil mouthing behavior
13 prevalence was found to be higher than indoor dust mouthing prevalence, but both behaviors had
14 the highest prevalence among 1-year-old children and dropped quickly among children 2 years
15 old and older. The investigators conducted principal component analyses on responses to four
16 questions relating to ingestion/mouthing of outdoor objects (Table 6-3) in an attempt to
17 characterize variability. Responses were converted to mouthing rates per week, using values of
18 0, 0.25, 1, and 7 for responses of never, monthly, weekly, and daily ingestion. Outdoor
19 ingestion/mouthing rates for were 4.73 per week and 0.44 per week for children 1 year of age
20 and 2-6 years of age, respectively. The frequency with which children played in sand/dirt was
21 estimated as a measure of potential exposure; 71% of the children were reported to have played
22 in sand or dirt at least weekly, and 45% were reported to have played in the sand or dirt daily.
23 The authors found that children who played in the sand or dirt had higher outdoor object
24 ingestion/mouthing rates. Thus, children with higher direct exposure to sand or dirt were more
25 likely to ingest or mouth outdoor objects. The investigators found similar results when
26 comparing the time spent outdoors to reported outdoor ingestion and mouthing rates; the data
27 indicate that 65% of one-year old children and 42 percent of children 2-6 years old spend less
28 than 3 hours per day outdoors. A strength of this study is that it focuses on the prevalence
29 of specific behaviors to quantify soil mouthing or ingestion among healthy children. The results
30 of this study might have important health implications as it showed that 1-year-old children with
31 high general levels of mouthing behavior have the potential for high risk soil ingestion.

1 A limitation associated with this study is that the data are based on recall behavior from
2 the summer previous to the interview. Extrapolation to other seasons may be difficult. In
3 addition, data were collected for children in Western Massachusetts and data were only available
4 for the healthy children who were present for well-visits.

6 **6.2.6 Freeman et al., 2001**

7 As part of the Minnesota Children's Pesticide Exposure Study (MNCPEs), macroactivity
8 and microactivity data were collected via questionnaire from the families of a group of 168
9 children, and a subset of 19 of these children were videotaped for four consecutive hours during
10 the months of August and September 1997. The children were between the ages of 3 and 12
11 years old and were living in both urban and rural areas of Minnesota. For the time/activity
12 questionnaires, the parents provided the responses for children ages 3 and 4, and collaborated
13 with or assisted older children with their responses. The videotapes were analyzed using the
14 methods reported by Reed (1999), and for comparison, four children's videotapes were also
15 analyzed using the VideoTraQ transcription system described by Zartarian et al. (1995).
16 Videotapes were transcribed once for the left hand and once for the right hand, and the frequency
17 of six behaviors (hand-to-mouth, hand-to-object, object-to-mouth, hand-to-smooth surface, hand-
18 to-textured surface, and hand-to-clothing) was recorded. The amount of time each child spent
19 indoors, outdoors, in contact with soil or grass, and whether the child was barefoot was also
20 recorded. Statistical analyses were performed using SPSS and Systat.

21 For the survey responses, only eating food dropped on the floor was significantly greater
22 for one age group (3-4 year olds), when compared to two other age groups (Table 6-4). When
23 the survey responses were further broken down by age, the 3-year-olds had significantly more
24 positive responses for all reported behavior compared to the other age groups. High response
25 rates (>70%) to additional questions directed toward the 3- and 4-year-old children, regarding
26 the use of blankets and toys indicated that these questions should also have been asked of the
27 older children.

28 Among the four age categories studied for the 19 videotaped children, object-to-mouth
29 activities were significantly greater for the 3-year-olds than any other age group, with a mean of
30 6 contacts per hour ($P = 0.002$) (Table 6-5). Contact with clothing was slightly more frequent

1 and contact with smooth surfaces less frequent among the two oldest groups of children, but
2 neither of these differences was statistically significant.

3 Gender differences were observed for some of the activities, with boys spending
4 significantly more time outdoors than girls (Table 6-6). Hand-to-mouth and object-to-mouth
5 activities were less frequent outdoors than indoors for both boys and girls. No significant
6 differences were observed in the frequency of events recorded using the Reed manual counting
7 system and the VideoTraQ computer-based video transcription system.

8 The advantage of this study is that it contains both survey and videotaped information on
9 mouthing behavior, and that various ages were studied. The limitations of the study are that the
10 sample size is small and was from a limited area (urban area of St. Paul/Minneapolis) not
11 representative of the national population in general.

12 13 **6.2.7 Juberg et al., 2001**

14 Juberg et al. (2001) used a diary-based approach to record mouthing behavior in children
15 up to three years of age. An initial pilot study involved 30 children, including 15 between the
16 ages of 0 and 18 months and 15 between the ages of 19 and 36 months. A second phase of the
17 study added 92 children to the younger group and 95 to the older group, for a total pooled data
18 set of 107 and 110 persons, respectively. For the pilot and second study, diary forms were
19 distributed to approximately 450 families; the distribution was split equally between a
20 commercial child play research center and a nursery school/daycare center. Parents were asked
21 to observe their child's behavior on a single day of their choosing during a three-week period,
22 and record the insertion of objects into the mouth by noting the "time in" and "time out."
23 Mouthed items were classified as pacifiers, teethingers, plastic toys, or other objects. In the data
24 analysis, pacifiers were examined as a separate category and data for all other items were pooled
25 into a "non-pacifier" category.

26 The results of the combined pilot and Phase II data are shown in Table 6-7. For both age
27 groups, mouthing time for pacifiers greatly exceeded mouthing time for non-pacifiers, with the
28 difference more acute for the older age group than for the younger age group. Histograms of the
29 observed data show a peak in the low end of the distribution (0 to 100 minutes per day) and a
30 rapid decline at longer durations.

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

7 The advantages of this study are that it involved a large number of participants compared
8 to other studies of mouthing behavior. It also exhibited consistency of results from the pilot
9 study to the second and third phases. The potential sources of error include the limited
10 geographic range of the study (western New York state) and the subjective nature of the
11 observation and diary-based approach. Another limitation of this study is that it focused on
12 object mouthing behavior and did not include hand-to-mouth behavior.

13 14 **6.2.8 Greene, 2002**

15 The U.S. Consumer Product Safety Commission (CPSC) investigated the potential health
16 risks to children under three years of age from teething, rattles, and toys made from polyvinyl
17 chloride (PVC) containing various dialkyl phthalate (DAP) plasticizers. They conducted an
18 observational study to quantify the cumulative time per day that young children spend mouthing
19 objects, including toys and other children's products. The study was conducted from December
20 1999 through February 2001 in two geographical areas: Houston, TX and Chicago, IL. Subjects
21 were recruited using telephone random digit dialing techniques.

22 During the first phase of the study, the parent or legal guardian observed the child and
23 recorded all mouthing behaviors for four 15-minute segments over two days. If the child was
24 under 36 months of age, they were recruited to participate in phase II. During phase II, a trained
25 observer recorded the child's behavior for a total of four hours on at least two different days.
26 The observations were done at different times of the day at home or at the child care facility
27 attended by the child. A total of 491 children participated in phase I. The total number of
28 participants in phase II was 169. The age of the children were between 3 months and 3 years of
29 age. Of the 169 children in phase II, 109 participated in phase I. Data from phase I were
30 analyzed and reported independently from phase II and were not provided by Greene (2002).

1 Table 6-8 provides the average mouthing time by object category and age in minutes per
2 hour. Mouthing time statistics by object categories and age are presented in Table 6-9. The
3 average mouthing time for all objects ranged from 5.3 to 10.5 minutes per hour, with the highest
4 mouthing time corresponding to children <1 year of age and the lowest to the 2-3 years of age.
5 Among the objects mouthed, pacifiers represent about one third of the total mouthing time, with
6 3.4 minutes per hour for the youngest children, 2.6 minutes per hour for the children between 1
7 and 2 years and 1.8 minutes per hour for children over 2 years old. The next largest single item
8 category was anatomy, representing children sucking fingers and thumbs. In this category,
9 children under 1 year of age spent 2.4 minutes per hour and it declined with age, with the 1.2
10 minutes per hours for the 2-3 years old.

11 Daily mouthing times were estimated using a bootstrap procedure using a normally
12 distributed random variable for the exposure time based on the child's age. The bootstrap
13 procedure is a statistical technique in which a set of collected data is randomly sub-sampled
14 hundreds or thousands of times in order to empirically derive confidence limits on the mean of
15 the main sample set. The empirical distribution of mouthing time was used to calculate statistics
16 and confidence intervals and was selected independently of exposure time. The bootstrap
17 sampling was done 5000 times to generate mean, median, and 95th percentile daily mouthing
18 time for each age group and object category. The results of the bootstrap procedure are
19 presented in Table 6-10. The estimated mean daily mouthing time for non-pacifiers ranged from
20 37 min/day to 70 min/day with the lowest number corresponding to the 2-3 years old and the
21 largest number corresponding to the 3 months -12 months old.

22 23 **6.2.9 Tulve et al., 2002**

24 In this study, previously unpublished data from the Fred Hutchinson Cancer Research
25 Center, Seattle, Washington were analyzed. Data were collected by trained observers who
26 described and quantified the mouthing behavior of 90 children in their home environment. The
27 children ranged in age from 10-60 months. The observers recorded mouth and tongue contacts
28 with hands, other body parts, natural objects, surfaces, and toys every 15 seconds for a minimum
29 of 15 minutes. Children's activities were coded as quiet or active play, and locations were coded
30 as indoor or outdoor environments. The final data set that was analyzed for this study included
31 only those children who were coded as engaging in quiet play in an indoor environment (72

1 children, ranging in age from 11-60 months). A total of 186 observations were included in the
2 study, with the number of observations per child ranging from 1-6. Data analyses to evaluate the
3 influence of age and gender were conducted using a linear SAS model (Version 8.02; SAS
4 Institute, Cary, NC).

5 Results of the data analyses indicated that there was no association between mouthing
6 frequency and gender, but a clear association between mouthing frequency and age was
7 observed. Using a tree analysis, children ≤ 24 months had the highest frequency of mouthing
8 behavior (81 events/hour) and children >24 months had the lowest (42 events/hour) (Table 6-11).
9 Both groups of children were observed to mouth toys and hands more frequently than body parts
10 other than hands and surfaces.

11 The advantage of this study is that mouthing data is provided for different age groups and
12 for a variety of objects (mouth-body, -hand, -surface, and -toy). This study is limited in that it
13 focuses on children involved in quiet play in an indoor environment.

14 15 **6.2.10 Smith and Norris, 2003**

16 Smith and Norris (2003) conducted a diary-based observational study of mouthing
17 behavior among 236 children between the ages of 1 month and 5 years. Children were observed
18 at home by parents, who recorded the time that mouthing began, the type of mouthing (licking,
19 sucking, chewing, etc.), the type of object being mouthed, and the time that mouthing ceased.
20 Children were observed for a total of 5 hours over a two-week period; the observation time
21 consisted of twenty 15-minute periods evenly distributed through the week and throughout the
22 child's waking hours. Results of the study are shown in Table 6-12. While no overall pattern
23 could be found in the different age groups tested, a Kruskal-Wallis test on the data for all items
24 mouthed indicated that there was a significant difference between the age groups. Across all age
25 groups and types of items, licking and sucking accounted for 64% of all mouthing behavior.
26 Pacifiers and fingers exhibited less variety on mouthing behavior (principally sucking), while
27 other items had a higher frequency of licking, biting, or other mouthing.

28 The principal advantage of this study is its inclusion of the type of mouthing behavior in
29 the survey. However, it suffers from the same limitations as many other survey-based studies,
30 including observer bias, a relatively low sample size (especially when broken down by age), and
31 a limited geographic scope. The study was conducted in the United Kingdom.

6.2.11 AuYeung *et al.*, 2004

AuYeung *et al.* videotaped 38 children (20 female and 18 male; ages 1-6 years) for two hours during indoor and outdoor play. Children were recruited for the study by calling telephone numbers randomly extracted from the telephone directory for an approximately 400 square mile portion of the San Francisco peninsula. 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. 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, which allowed the duration of very short mouthing events to be captured.

For analysis, the mouthing contacts were divided into indoor and outdoor locations, and 16 object/surface categories. Mouthing frequency, contact duration, and hourly duration were all 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. Nonparametric tests, such as the Wilcoxon rank sum test were used for the data analyses.

Mouthing frequencies for indoor locations are shown in Table 6-13. For the one child observed that was ≤24 months, 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 6-14) were very similar for children ≤24 months (13.9 contacts/hour) and >24 months (14.6 contacts/hour).

For the children in all age groups, the median duration of each mouthing contact was 1-2 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 6-15). For outdoor environments, median contact durations for these age groups decreased to 0.8 and 0.6 minutes/hour, respectively (Table 6-16).

Both age and gender were found to be associated with differences in mouthing behavior. Children ≤24 months had significantly longer hand-to-mouth contact durations than older children ($p = 0.04$), but no significant age-related differences were found in mouthing frequencies or hourly mouthing durations. Girls had significantly higher frequencies of

1 mouthing contacts with the hands and non-dietary objects than boys ($p = 0.01$ and $p = 0.008$,
2 respectively). Girls' hand-to-mouth contact durations were also significantly shorter than for
3 boys ($p = 0.04$).

4 This study is useful in that it provides distributions of outdoor mouthing frequencies and
5 durations with a variety of objects and surfaces. Although indoor mouthing data are also
6 included in this study, the results are based on a small number of children ($n=9$) and a limited
7 amount of indoor play.

8 9 **6.2.12 Black et al., 2005**

10 In a recent study, the mouthing and food-handling behavior of 52 children (26 boys and
11 26 girls) from 29 homes in the mid-Rio Grande Valley was videotaped as part of a year-long
12 pesticide exposure study (Black et al., 2005). The children were grouped into four age
13 categories: infants (7-12 months), 1-year-olds (13-24 months), 2-year-olds (25-36 months), and
14 preschoolers (37-53 months). Detailed baseline and activity questionnaires were administered,
15 and each child was videotaped for four hours. The children were followed by the videographers
16 through the house and yard, except for times when they were napping or using the bathroom.
17 Records were kept of any significant interruptions during videotaping. Virtual Timing Device
18 software, a refinement of the videotape software described by Zartarian et al. (1997) was used to
19 analyze the videotapes. Statistical Package for the Social Sciences software was used to analyze
20 microactivity data and questionnaire results.

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

25 For the four age groups, the mean hourly hand-to-mouth frequency ranged from 11.9 (2-
26 year-olds) to 22.1 (preschoolers), the mean hourly object-to-mouth frequency ranged from 7.8
27 (2-year-olds) to 24.4 (infants), and the mean hourly hand-to-food frequency ranged from 10.8
28 (infants) to 17.2 (1-year-olds). Significant linear trends were observed for hourly object-to-
29 mouth frequency, which decreased as age increased (adjusted $R^2 = 0.179$; $P = 0.003$), and hand-
30 to-mouth frequency, which increased with increasing food contact frequency for children over 12
31 months (adjusted $R^2 = 0.291$; $P = 0.002$). Results of this study are shown in Table 6-17.

1 The advantage of this study is that it includes both survey and videotaped information on
2 mouthing behavior. The limitations of this study are that the sample population was fairly small
3 and was from a limited area (mid-Rio Grande Valley) not representative of the national
4 population in general. In addition, the duration data in this study is presented as “% of tape
5 time” and cannot be converted to a “minutes/day” format for comparison with other studies.
6

7 **6.3 RECOMMENDATIONS**

8 Due to the paucity of the available research data, mouthing frequency data should be
9 used with caution. Table 6-18 summarizes the studies on mouthing behavior that were described
10 in this chapter. Table 6-19 summarizes the mean mouthing time and frequencies for hand-to-
11 mouth, object-to-mouth, and totals from these studies. Table 6-20 and 6-21 summarize the
12 recommended mean values for mouthing time and frequency, respectively, for the recommended
13 age categories. The data for each of the standardized age categories in Table 6-20 and 6-21 are
14 calculated as a weighted mean of values from studies in this chapter that are relevant to each age
15 category. In some cases the age categories used in the studies did not correspond exactly to
16 EPA’s recommended age groups. In those cases, the closest age group was used as indicated in
17 the Tables 6-20 and 6-21. As mentioned earlier, the studies in this chapter use different units of
18 reporting mouthing behavior. If the assessor is interested in estimating exposures during
19 macroactivities, then the total amount of time engaged in mouthing behavior (Table 6-20) may
20 be the unit of interest. If the assessor is interested in estimating exposures to various
21 microactivities, then the number of contacts with hands or objects per unit of time (Table 6-21)
22 may be the unit of interest. No data were available for infants from birth to <1 month old. There
23 were also no recommendations presented for 1 to <3 months in Table 6-21 and 6-22 or for 3 to
24 <6 years in Table 6-20. Smith and Norris (2003) included children from 1 - 5 years of age.
25 However, the study is biased high because it included children who were sucking their thumb or
26 finger. According to Smith and Norris (2003), this effect is more significant in the older children
27 in the study.

28 Total mean mouthing time ranged from 7 min/day to 65 min/day, with the lowest value
29 corresponding to 2 to 6 years old and the highest value corresponding to 6 to <12 months old.
30 Total mean mouthing frequency ranged from 5 contacts/hr to 54 contacts/hr, with the lowest
31 value corresponding to the 6 to <11 years old and the highest value corresponding to the 1 to <2

1 years old. Mean hand-to-mouth contact ranged from 4 contacts/hr to 20 contacts/hr, with the
2 lowest value corresponding to the 6 to <11 years old and the highest value corresponding to the 6
3 to <12 months old.

4 Table 6-22 presents the confidence ratings for the recommended values. The overall
5 confidence rating was low because sample sizes were small for some of the age groups.
6 Children's behavior is difficult to measure and somewhat subjective because it depends on the
7 experience of the observer.

8

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6

Table 6-1. Extrapolated Total Mouthing Times Minutes per Day (time awake)

Age (months)	No. Children	Mean	Standard Dev.	Minimum	Maximum
3 - 6	5	36.9	19.1	14.5	67
6 - 12	14	44	44.7	2.4	171.5
12 - 18	12	16.4	18.2	0	53.2
18 - 36	11	9.3	9.8	0	30.9

Note: The object most mouthed in all age groups in the fingers except for the 6 - 12 month group which mostly mouthed on toys.

Source: Groot et al. (1998)

Table 6-2. Frequency of Contact (Contacts per Hour)

Variable	Mean	Median	Minimum	Maximum	90 th Percentile
Clothing	66.6	65	22.8	129.2	103.3
Dirt	11.4	0.3	0	146.3	56.4
Hand	21.1	14.2	6.3	116.4	43.5
Hand to mouth	9.5	8.5	0.4	25.7	20.1
Object	122.9	118.7	56.2	312	175.8
Object to mouth	16.3	3.6	0	86.2	77.1
Other	82.9	64.3	8.3	243.6	199.6
Smooth surface	83.7	80.2	13.6	190.4	136.9
Textured surface	22.1	16.3	0.2	68.7	52.2

Source: Reed et al. (1999)

Table 6-3. Prevalence of Non-Food Ingestion/Mouthing Behaviors by Child's Age: Percent of Children Whose Parents Reports the Behavior in the Past Month

Non-Food Ingestion/mouthing	Prevalence of Behavior	Child's Age (years)							
		1	2	3	4	5	6	3 to <6 ^a	All
		N=171	N=70	N=93	N=82	N=90	N=22	N= 265	N=528
Outdoor "soil" mouthing/Ingestion									
Sand, stones	% > Monthly	54	26	19	9	7	9	12	27
	% > Weekly	36	10	6	2	4	5	4	16
	% Daily	17	0	2	1	1	5	1	6
Grass, leaves, flowers	% > Monthly	48	16	24	13	9	5	16	26
	% > Weekly	34	7	14	4	6	0	8	16
	% Daily	16	0	2	1	1	0	1	6
Twigs, sticks, woodchips	% > Monthly	42	23	13	13	11	5	12	23
	% > Weekly	29	7	9	5	7	0	7	14
	% Daily	12	0	0	1	0	0	0	4
Soil, dirt	% > Monthly	38	21	5	7	3	9	5	18
	% > Weekly	24	7	3	2	1	9	2	10
	% Daily	11	0	1	0	1	0	1	4
Dust, lint, dustballs	% > Monthly	14	4	2	0	0	5	1	6
	% > Weekly	7	1	1	0	0	0	0	3
	% Daily	2	0	0	0	0	0	0	1
Plaster, chalk	% > Monthly	8	10	3	2	3	5	3	5
	% > Weekly	5	3	0	1	0	0	0	2
	% Daily	2	0	0	1	0	0	0	1
Paintchips, splinters	% > Monthly	6	0	0	4	1	0	2	3
	% > Weekly	2	0	0	1	0	0	0	1
	% Daily	0	0	0	0	0	0	0	0
General mouthing of objects									
Other toys	% > Monthly	88	53	64	44	42	23	50	62
	% > Weekly	82	44	42	26	28	9	32	49
	% Daily	63	27	20	9	7	5	12	30
Paper, cardboard, tissues	% > Monthly	71	37	32	23	18	14	24	41
	% > Weekly	54	23	20	12	7	9	13	28
	% Daily	28	9	8	5	2	5	5	13
Teething toys	% > Monthly	65	29	15	4	3	9	8	29
	% > Weekly	55	16	9	1	1	9	4	22
	% Daily	44	6	6	0	0	9	2	17

Non-Food Ingestion/mouthing	Prevalence of Behavior	Child's Age (years)							
		1	2	3	4	5	6	3 to <6 ^a	All
		N=171	N=70	N=93	N=82	N=90	N=22	N= 265	N=528
Crayons, pencils, erasers	% > Monthly	56	54	46	50	41	36	46	50
	% > Weekly	41	37	25	27	26	27	26	32
	% Daily	19	17	4	6	4	18	5	12
Blankets, cloth	% > Monthly	51	21	26	22	22	14	23	32
	% > Weekly	42	17	17	18	14	14	16	25
	% Daily	29	11	9	13	7	5	10	16
Shoes, Footware	% > Monthly	50	23	8	7	2	5	6	22
	% > Weekly	42	10	3	2	1	5	2	16
	% Daily	20	1	0	0	0	0	0	7
Clothing	% > Monthly	49	34	37	43	26	27	35	39
	% > Weekly	39	24	23	28	16	14	22	27
	% Daily	25	7	11	9	6	14	9	14
Other items	% > Monthly	41	30	30	23	21	27	25	31
	% > Weekly	35	26	24	15	10	14	16	23
	% Daily	22	11	15	7	6	5	9	14
Crib, chairs, furniture	% > Monthly	37	11	8	10	4	5	7	17
	% > Weekly	26	9	3	5	2	0	3	11
	% Daily	13	3	1	1	0	0	1	5
Sucking of fingers, etc									
Suck fingers/thumb	% > Monthly	67	41	43	57	39	41	46	52
	% > Weekly	60	27	31	43	31	18	35	41
	% Daily	44	21	22	26	24	14	24	30
Suck feet or toes	% > Monthly	37	14	12	11	3	0	9	18
	% > Weekly	23	4	3	2	1	0	2	9
	% Daily	8	1	0	1	0	0	0	3
Use pacifier	% > Monthly	24	9	6	2	2	5	3	11
	% > Weekly	22	9	5	2	2	0	3	10
	% Daily	20	6	5	1	1	0	2	9
Suck hair	% > Monthly	1	3	8	9	10	5	9	5
	% > Weekly	1	3	2	2	4	5	3	2
	% Daily	1	1	1	0	2	0	1	1

Non-Food Ingestion/mouthing	Prevalence of Behavior	Child's Age (years)							
		1	2	3	4	5	6	3 to <6 ^a	All
		N=171	N=70	N=93	N=82	N=90	N=22	N= 265	N=528
“Disgusting” object mouthing/ingestion									
Soap, detergent, shampoo	% > Monthly	48	34	24	17	9	9	17	29
	% > Weekly	37	27	14	11	6	9	10	21
	% Daily	15	14	3	2	0	0	2	8
Plastic, plastic wrap	% > Monthly	32	19	8	7	9	0	8	17
	% > Weekly	22	11	3	4	4	0	4	10
	% Daily	7	4	1	0	1	0	1	3
Cigarette butts, tobacco	% > Monthly	16	6	5	4	3	5	4	8
	% > Weekly	10	4	4	1	2	5	2	5
	% Daily	4	0	1	1	1	0	1	2
Matches	% > Monthly	6	4	1	4	1	0	2	4
	% > Weekly	2	3	1	1	1	0	1	2
	% Daily	1	0	0	0	0	0	0	0
Insect	% > Monthly	5	1	2	4	2	0	3	3
	% > Weekly	2	0	1	4	2	0	2	2
	% Daily	0	0	1	2	2	0	2	1
Other ingestion and behaviors									
Toothpaste	% > Monthly	63	97	92	94	93	86	93	84
	% > Weekly	60	94	91	93	92	86	92	82
	% Daily	52	87	86	93	89	82	89	77
Chew gum	% > Monthly	18	56	76	76	91	100	81	58
	% > Weekly	10	40	60	60	69	68	63	43
	% Daily	3	17	18	13	21	36	17	14
Bite nails	% > Monthly	8	26	31	29	33	59	31	24
	% > Weekly	5	23	24	20	26	45	23	18
	% Daily	2	7	12	9	10	14	10	7
Suck hair	% > Monthly	62	76	85	96	88	73	89	78
	% > Weekly	57	64	77	88	81	68	82	71
	% Daily	42	39	43	55	52	45	50	45

^aWeighted mean of 3-, 4-, and 5-year-olds' data calculated by EPA to conform to standardized age categories used in this Handbook.

Source: Stanek et al. (1998).

Table 6-4. Percent of Children with Reported Behaviors From the Telephone Survey Conducted in the MNCPEs (n = 168).

Reported Behavior	Percent Reported by Age Group		
	3-4 Years (n=27)	5-9 Years (n=93)	10-12 Years (n=48)
Hand-to-mouth	56	39	35*
Non-feed items in mouth	52	31	37
Eats food dropped on floor	48	10	4**
Eats most food without utensils	37	29	19*
Puts paint chips in mouth	0	0	0

x² test, *P<0.10 between youngest and oldest groups; **significant difference across three groups.
Source: Freeman et al., 2001

Table 6-5. Median (Mean) Observed Activity Rate (Hand Contacts Per Hour) Based on 4 Hours of Observation Per Person.

Observed Activity Age	Age Category (Years)			
	3-4 (n=3)	5-6 (n=7)	7-8 (n=4)	10-12 (n=5)
Object-to-mouth***	3 (6)	0 (1)	0 (1)	0 (1)
Hand-to-mouth	3.5 (4)	2.5 (8)	3 (5)	2 (4)
Touch clothing**	26 (34)	22 (26)	50 (54)	35 (53)
Touch textured surface*	40 (52)	20 (32)	22 (58)	16 (24)
Touch smooth surface	134 (151)	111 (120)	120 (155)	94 (96)
Touch object	130 (153)	117 (132)	111 (164)	127 (179)

Kruskal Wallis test comparison across four age groups: *P=0.1108; **P=0.0796; ***P=0.002.
Source: Freeman et al., 2001

Table 6-6. Comparison of Observed Activities for Boys and Girls (Mean).

Observed Activity	Boys (n=8)	Girls (n=11)
Hours since last hand wash	5.9	3.5
Time spent outdoors (minutes)*	104.4	54.0
Time spent indoors (minutes)*	134.3	186.0
Hand-to-mouth indoors/hour*	4.7	8.1
Hand-to-mouth outdoors/hour	1.7	2.3
Object-to-mouth indoors/hour	1.0	2.6
Object-to-mouth outdoors/hour	0.1	1.0

*P<0.05 by Mann-Whitney test.

Source: Freeman et al., 2001

Table 6-7. Mouthing times for Pacifiers and Other Objects, by Age Category

Object Type	Age 0 to 18 months		Age 19 to 36 months	
	All Respondents (minutes/day)	Doers Only ^a (minutes/day)	All Respondents (minutes/day)	Doers Only ^a (minutes/day)
Pacifier	108 (n = 107)	221 (n=52)	126 (n=110)	462 (n=52)
Non-Pacifier	33 ^b (n=107)	not calculated	5 ^b (n=110)	not calculated
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)

^aDoers only analysis refers to means calculated for the subset of the sample population that participated in the activity; zeroes are eliminated from the calculation of the mean.

^bTotal for non-pacifiers may not equal sum of individual items due to rounding.

Source: Juberg et al., 2001

Table 6-8 Average Mouthing Time by Object Category and Age (min/hr)

Object Category	All Ages	3-12 months	12-24 months	24-36 months
All Objects	7.7	10.5	7.3	5.3
Pacifiers	2.6	3.4	2.6	1.8
Non Pacifiers	5.1	7.1	4.7	3.5
All Soft Plastic Items	0.4	0.5	0.4	0.4
Soft Plastic Items Not Food Contact	0.3	0.4	0.3	0.2
Soft Plastic Toys, Teethers and Rattles	0.2	0.3	0.2	0.1
Soft Plastic Toys	0.1	0.1	0.2	0.1
Soft Plastic Teethers and Rattles	0.1	0.2	0.0	0.0
Other Soft Plastic Items	0.1	0.1	0.1	0.1
Soft Plastic Food Contact Items	0.1	0.0	0.1	0.2
Anatomy	1.8	2.4	1.7	1.2
Non Soft Plastic Toys, Teethers and Rattles	0.9	1.8	0.6	0.2
Other Items	2.1	2.5	2.1	1.7

Source : Greene, 2002

Table 6-9. Mouthing Time Statistics for Various Objects (min/hr)

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

Table 6-9. Mouthing Time Statistics for Various Objects (min/hr)

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

Source: Greene, 2002

Table 6-10. Estimated Daily Mouthing Times for Various Objects (min/day)

Age Group	Mean (confidence intervals)	Median (confidence intervals)	95 th Percentile (confidence intervals)	99 th Percentile (confidence intervals)
Non Pacifiers				
3-12 months	70.1 (60.6 - 79.8)	65.6 (52.3 - 78.2)	134.4 (117.1 - 153.2)	153.1 (129.6 - 180.6)
12-24 months	47.4 (38.9 - 57.1)	37.0 (28.7 - 49.9)	121.5 (85.2 - 166.0)	180.3 (123.6 - 235.5)
24-36 months	37.0 (27.0 - 48.5)	23.8 (18.4 - 29.3)	124.3 (70.9 - 173.3)	167.9 (104.0 - 208.0)
Soft Plastic Items				
3-12 months	4.4 (3.0 - 6.1)	1.5 (0.3 - 3.7)	17.5 (12.2 - 23.3)	23.0 (16.2 - 30.1)
12-24 months	3.8 (2.8 - 4.9)	2.2 (1.0 - 3.8)	13.0 (9.6 - 17.8)	18.9 (12.8 - 23.8)
24-36 months	4.2 (2.5 - 6.1)	1.5 (0.2 - 3.0)	18.5 (9.6 - 29.4)	28.0 (15.9 - 37.6)
Soft Plastic Toys				
3-12 months	1.3 (0.7 - 2.0)	0.0 (0.0 - 0.3)	7.1 (3.9 - 11.0)	10.5 (5.8 - 13.7)
12-24 months	1.9 (1.2 - 2.6)	0.1 (0.0 - 0.6)	8.8 (5.6 - 11.7)	12.6 (9.0 - 16.0)
24-36 months	0.8 (0.3 - 1.6)	0.0 (0.0 - 0.2)	3.3 (1.4 - 16.3)	12.1 (2.0 - 21.0)

Note: Based on 5000 bootstrap samples.
Source: Greene, 2002

Table 6-11. Variability in Objects Mouthed for Different Age Groups.

Variable	All Subjects			≤24 Months			>24 Months					
	n ^a	Mean ^b (events/h)	Median (events/h)	95% CI ^c (events/h)	n ^a	Mean ^b (events/h)	Median (events/h)	95% CI ^c (events/h)	n ^a	Mean ^b (events/h)	Median (events/h)	95% CI ^c (events/h)
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 limits apply to median. Values were calculated in logs and converted to original units.

Source: Tulve et al., 2002

Table 6-12. Mouthing Duration by Age Group for Pacifiers, Fingers, Toys, and Other Objects

Item Mouthed	Age Group, sample size (<i>n</i>), and Mouthing Duration (hours:minutes:seconds)											
	1-3 months	3-6 months	6-9 months	9-12 months	12-15 months	15-18 months	18-21 months	21-24 months	2 years	3 years	4 years	5 years
	<i>n</i> = 9	<i>n</i> = 14	<i>n</i> = 15	<i>n</i> = 17	<i>n</i> = 16	<i>n</i> = 14	<i>n</i> = 16	<i>n</i> = 12	<i>n</i> = 39	<i>n</i> = 31	<i>n</i> = 29	<i>n</i> = 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

Source: Smith and Norris, 2003

Table 6-13. Indoor Mouthing Frequency (Contacts/Hour).^a

Age (months)	<i>n</i>	Statistic	Hands	Total non-dietary^b
≤24	1		73.5	84.8
>24	8	Mean	13.9	22.7
		Median	13.3	19.5
		Range	2.2 - 34.1	2.8 - 51.3
All ages ^c	9	Mean	20.5	29.6
		Median	14.8	22.1
		Range	2.5 - 70.4	3.2 - 82.2

^a Shows data from children who had more than 15 minutes in view indoors.

^b All object/surface categories included: animal, clothes/towels, fabric, hands, metal, non-dietary water, paper/wrapper, plastic, skin, toys, vegetation/grass, and wood.

^c Ages 1-6 years.

Source: AuYeung et al., 2004

Table 6-14. Outdoor Mouthing Frequency (Contacts/Hour).

Age (months)	<i>n</i>	Statistic	Hands	Total non-dietary ^a
≤24	8	Mean	13.0	20.4
		Median	7.0	13.9
		Range	1.3 - 47.7	6.2 - 56.4
>24	30	Mean	11.3	17.7
		5 th percentile	0.2	0.6
		25 th percentile	4.7	7.6
		Median	8.6	14.6
		75 th percentile	14.8	22.4
		95 th percentile	27.7	43.8
		99 th percentile	39.5	53.0
All ages ^c	38	Mean	11.7	18.3
		5 th percentile	0.4	0.8
		25 th percentile	4.4	9.2
		Median	8.4	14.5
		75 th percentile	14.8	22.4
		95 th percentile	31.5	51.7
		99 th percentile	47.6	56.6

^a All object/surface categories included: animal, clothes/towels, fabric, hands, metal, non-dietary water, paper/wrapper, plastic, skin, toys, vegetation/grass, and wood.

^c Ages 1-6 years.

Source: AuYeung et al., 2004

Table 6-15. Indoor Mouthing Contact Duration (Minutes/Hour).^a

Age (months)	<i>n</i>	Statistic	Hands	Total non-dietary ^b
≤24	1		10.7	11.1
>24	8	Mean	0.7	1.2
		Median	0.7	0.9
		Range	0 - 1.8	0.1 - 3.6
All ages ^c	9	Mean	1.8	2.3
		Median	0.7	0.9
		Range	0 - 10.0	0.1 - 10.5

^a Shows data from children who had more than 15 minutes in view indoors.

^b All object/surface categories included: animal, clothes/towels, fabric, hands, metal, non-dietary water, paper/wrapper, plastic, skin, toys, vegetation/grass, and wood.

^c Ages 1-6 years.

Source: AuYeung et al., 2004

Table 6-16. Outdoor Mouthing Contact Duration (Minutes/Hour).

Age (months)	<i>n</i>	Statistic	Hands	Total non-dietary ^a
≤24	8	Mean	2.7	3.1
		Median	0.4	0.8
		Range	0 - 14.7	0.2 - 15.0
>24	30	Mean	0.4	0.7
		5 th percentile	0	0
		25 th percentile	0.1	0.2
		Median	0.2	0.6
		75 th percentile	0.4	1.0
		95 th percentile	1.2	2.1
		99 th percentile	2.2	2.5
All ages ^c	38	Mean	0.9	1.2
		5 th percentile	0	0
		25 th percentile	0.1	0.2
		Median	0.2	0.6
		75 th percentile	0.6	1.2
		95 th percentile	2.6	2.9
		99 th percentile	11.2	11.5

^a All object/surface categories included: animal, clothes/towels, fabric, hands, metal, non-dietary water, paper/wrapper, plastic, skin, toys, vegetation/grass, and wood.

^c Ages 1-6 years.

Source: AuYeung et al., 2004

Table 6-17. Videotaped Mouthing and Food-handling Activity as Median Hourly Frequency (Contacts/Hour) and Median Duration (% of Tape Time) (Mean \pm SD)

Age	N	<u>Hand to mouth</u>		<u>Object to Mouth</u>		<u>Food</u>	
		Frequency	Duration	Frequency	Duration	Frequency	Duration
Infant	1 3	14 (19.8 \pm 14.5)	3.0 (4.6 \pm 6.0)	18.1 (24.4 \pm 11.6)	3.1 (4.0 \pm 2.4)	10.0 (10.8 \pm 9.0)	3.9 (7.0 \pm 7.4)
1 year old	1 2	13.3 (15.8 \pm 8.7)	2.2 (3.8 \pm 7.0)	8.4 (9.8 \pm 6.3)	1.3 (1.6 \pm 1.2)	16.1 (17.2 \pm 14.0)	5.2 (6.8 \pm 5.8)
2 year old	1 8	9.9 (11.9 \pm 9.3)	1.3 (1.5 \pm 1.3)	5.5 (7.8 \pm 5.8)	0.9 (1.3 \pm 1.1)	13.9 (14.7 \pm 10.9)	5.6 (5.0 \pm 3.8)
Preschool	9	19.4 (22.1 \pm 22.1)	1.5 (3.1 \pm 3.4)	8.4 (10.1 \pm 12.4)	1.9 (3.0 \pm 3.9)	10.2 (15.7 \pm 11.8)	5.6 (4.7 \pm 2.6)

Source: Black et al. (2005)

Table 6-18. Summary of Studies on Mouthing Behavior

Study	Population Size	Population Studied
Groot et al. 1998	42	3-36 months in Netherlands children from well educated parents
Reed et al. 1999	30	20 children 3-6 years 10 children 2-5 years Day care and residential settings
Zartarian 1997 and 1998	4	2.5-4.2 years children of farm workers
Davis 1995	92	10-60 months Washington State
Stanek et al. 1998	355	1-6 years private medical clinic Springfield, Massachusetts
Juberg et al., 2001	Phase 1 & 2: 217 Phase 3: 168	Phase 1 & 2: less than 3 yrs old Phase 3: 3 to 18 months Western New York - research center and day care
Freeman et al., 2001	168	3-12 years Urban and rural areas of Minnesota
Greene, 2002	169	3 - 36 months Chicago and Houston metropolitan area
Tulve et al., 2002	72	10-60 months Indoor home environment
Smith and Norris, 2003	236	Ages 1 month to 5 years in-home Netherlands
AuYeung et al., 2004	38	Ages 1-6 years Indoor and outdoor home environment San Francisco peninsula
Black et al., 2005	52	7-53 months Mid-Rio Grande Valley Agricultural community

Table 6-19. Summary of Mouthing Frequency Data

Age (months)	Mean Mouthing Frequency/Time			Population Size	Reference
	Hand-to-mouth	Object-to-Mouth	Total		
10-60			55 min/day		EPA analysis based on Davis 1995
2.5-4.2 years	9 contacts/hr			4	Zartarian 1997
3-6			37 min/day	5	Groot et al. 1998
6-12			44 min/day	14	
12-18			16 min/day	12	
18-36			9 min/day	11	
2-6 years	9.5 contacts/hr	16.3 contacts/hr	25.8 contacts/hr	30	Reed et al. 1999
3-4 years	4 contacts/hr	6 contacts/hr	10 contacts/hr	3	Freeman et al. 2001
5-6 years	8 contacts/hr	1 contacts/hr	9 contacts/hr	7	
7-8 years	5 contacts/hr	1 contacts/hr	6 contacts/hr	4	
10-12 years	4 contacts/hr	1 contacts/hr	5 contacts/hr	5	
0-18		70 min/day ^a		146	Juberg et al, 2001
18-36		56 min/day ^a		40	
3-12	2.4 min/hr; 26 min/day ^b		70 min/day	64	Greene, 2002
12-24	1.7 min/hr; 18 min/day ^b		48 min/day	60	
24-36	1.2 min/hr; 12 min/day ^b		37 min/day	45	
<24	18 contacts/hr	62 contacts/hr	81 ± 7 contacts/hr	28	Tulve et al. 2002
>24	16 contacts/hr	26 contacts/hr	42 ± 4 contacts/hr	44	

Table 6-19. Summary of Mouthing Frequency Data

Age (months)	Mean Mouthing Frequency/Time			Population Size	Reference
	Hand-to-mouth	Object-to-Mouth	Total		
1-3	50 min/day ^c	29 min/day	79 min/day ^c	9	Smith and Norris 2003
3-6	96 min/day ^c	132 min/day	228 min/day ^c	14	
6-9	77 min/day ^c	251 min/day	328 min/day ^c	15	
9-12	98 min/day ^c	156 min/day	254 min/day ^c	17	
12-15	36 min/day ^c	157 min/day	193 min/day ^c	16	
15-18	39 min/day ^c	136 min/day	175 min/day ^c	14	
18-21	80 min/day ^c	99 min/day	179 min/day ^c	16	
21-24	113 min/day ^c	142 min/day	255 min/day ^c	12	
2 years	148 min/day ^c	304 min/day	452 min/day ^c	39	
3 years	199 min/day ^c	179 min/day	378 min/day ^c	31	
4 years	171 min/day ^c	96 min/day	267 min/day ^c	29	
5 years	543 min/day ^c	64 min/day	607 min/day ^c	24	
≤24	7 contacts/hr 12 min/day ^b	1 contact/hr 1 min/day ^b	9 contacts/hr 12 min/day ^b	9	AuYeung et al., 2004 ^d
2-6	12 contacts/hr 2 min/day ^b	8 contacts/hr 1 min/day ^b	20 contacts/hr 3 min/day ^b	38	
7-12	20 contacts/hr	24 contacts/hr	44 contacts/hr	13	Black et al. 2005
13-24	16 contacts/hr	10 contacts/hr	26 contacts/hr	12	
25-36	12 contacts/hr	8 contacts/hr	20 contacts/hr	18	
37-53	22 contacts/hr	10 contacts/hr	32 contacts/hr	9	

^a Doers only from Table 6-8; totals calculated by adding all non pacifier objects

^b Daily mouthing estimated using 10 hours awake for children under 2 years old and 10.7 hours awake for children 2-3 years old from Greene (2002).

^c Includes finger/thumb sucking

^d Includes indoor and outdoor data.

Table 6-20. Summary of Recommended Values for Total Mouthing Time (minutes per day) ^a

Age	Mean Mouthing Time (min/day)	Source
birth to <1 month	no data	no data available
1 to <3 months	no data	no data available (Smith and Norris, 2003 were not used because thumb/finger sucking had a significant effect on results)
3 to <6 months	27	<i>Weighted mean of:</i> Groot et al., 1998 and Reed et al. 1999
6 to <12 months	65	<i>Weighted mean of:</i> Groot et al., 1998 and Greene, 2002 (used 3-12 months)
1 to <2 years	39	<i>Weighted mean of:</i> Groot et al., 1998 (used 12-18 months) Greene, 2002 AuYeung et al., 2004 (used ≤24 months)
2 to <3 years	32	<i>Weighted mean of:</i> Groot et al., 1998 (used 18-36 month group) Greene, 2002
3 to <6 years	no data	no data available (Smith and Norris (2003) data were not used because thumb/finger sucking had a significant effect on results)
2 to 6 years	7	AuYeung et al., 2004

^a Excludes mouthing pacifiers

Table 6-21. Summary of Recommended Values for Mouthing Frequency (contacts per hour)

Age	Mean Mouthing Frequency			Reference
	Hand-to-Mouth	Object-to-Mouth	Total	
birth to < 1 mo	no data	no data	no data	
1 to <3 mo	no data	no data	no data	
6 to <12 mo	20 contacts/hr	24 contacts/hr	44 contacts/hr	Black et al. 2005
1 to <2 years	16 contacts/hr	38 contacts/hr	54 contacts/hr	<i>Weighted mean of:</i> Tulve et al., 2002, AuYeung et al, 2004, and Black et al., 2005
2 to <3 years	12 contacts/hr	8 contacts/hr	20 contacts/hr	Hand-to-mouth is weighted mean of Zartarian 1997 and Black et al. 2005 Object-to-mouth is based on Black et al. 2005 Total is based on Black et al. 2005
2 to 6 years	12 contacts/hr	8 contacts/hr	20 contacts/hr	AuYeung et al, 2004
3 to <6 years	14 contacts/hr	19 contacts/hr	32 contacts/hr	<i>Weighted mean of:</i> Reed et al. 1999, Freeman et al. 2001, Tulve et al. 2002, and Black et al. 2005
6 to < 11 years	4 contacts/hr	1 contacts/hr	5 contacts/hr	Based on weighted mean of 7-8 and 10-12 years old from Freeman et al. 2001
1 year 2 years 3 years 4 years 5 years 6 years 3 to <6 years	Contact frequency with specific objects and surfaces (percent doing daily, weekly, and monthly)			Stanek et al., 1998 (Table 6-3)

Table 6-22. Confidence in Mouthing Behavior Recommendations

Considerations	Rationale	Rating
Study Elements		
Peer Review	There are eleven studies; nine of the studies are from peer-reviewed journals; one is an EPA analysis of raw data from a contractor's report to EPA and one is a government report	High
Accessibility	Studies in journals have wide circulation. Contractor's report only available through EPA	Medium
Reproducibility	Can follow analysis, but cannot reproduce the data unless raw data are provided.	Medium
Focus on factor of Interest	Studies focused on mouthing behavior as well as other hand contacts.	High
Data pertinent to U.S.	All but one of the studies were conducted in the U.S.	High
Primary data	Analyses were done on primary data. EPA did the analysis of the raw data from Davis et al. (1995) and composited data from the Stanek et al. (1998) study to conform to standardized age groupings.	High
Currency	Recent studies were evaluated.	High
Adequacy of data collection period	Data were collected for a period of several days, not enough to represent seasonal variations.	Medium
Validity of Approach	Measurements were made by observation methods. Both surveys and videotaping were used. Videotaping techniques may be more reliable, but resource intensive.	Medium
Representativeness of the population	Data for some age groups were not available. An effort was made to consider age and gender, but sample sizes were small; SES factors not evaluated	Low
Characterization of variability	An effort was made to consider age and gender, data for infants and older children are fairly limited.	Low
Lack of bias in study design	Subjects were selected from volunteers.	Medium
Measurement error	Measuring children's behavior is difficult and somewhat subjective and depends on the experience of the observer.	Medium
Other Elements		
Number of studies	Eleven studies were evaluated	Medium
Agreement between researchers	There is general agreement among the researchers.	High
Overall Rating	Although there are eleven studies, for some of the age groups sample size was small, variability in the population cannot be assessed. Variation in behavior due to seasons cannot be evaluated. Measuring children's behavior is difficult.	Low