Summary Report for the ATSDR Soil-Pica Workshop

June 2000 Atlanta, Georgia

March 20, 2001

The Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia

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for the
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Prepared for

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Division of Health Assessment and Consultation
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Note

This report was prepared by Eastern Research Group, Inc. (ERG), a contractor for the Agency for Toxic Substances and Disease Registry (ATSDR), as a general record of discussion for the "ATSDR Soil-pica Workshop," a workshop conducted by ATSDR. This report captures the main points of presentations and discussions among the expert panelists, but does not contain a verbatim transcript of all issues discussed during the meeting. Additionally, the report does not embellish, interpret, or enlarge upon matters that were incomplete or unclear. Except where noted, no statements in this report represent analyses or positions of ATSDR or ERG.

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Executive Summary

Ten expert panelists reviewed and discussed the state of the science on soil-pica behavior—an issue that is relevant to the Agency for Toxic Substances and Disease Registry's (ATSDR) ongoing work at sites with human exposures to contaminated soils. During a 2-day workshop in June 2000, in Atlanta, Georgia, the panelists thoroughly discussed and debated the prevalence of soil-pica behavior, ingestion rates for soil-pica, means for identifying people with soil-pica behavior, and additional topics. Common themes discussed throughout the workshop included the need for clear definitions of key terms, the lack of extensive research on the distribution of soil ingestion rates, and the need for additional research to fill data gaps.

After the workshop, the panelists drafted definitions of three key terms and prepared eight summary statements highlighting their most important findings, listed below. An overview of the panelists' discussion that led to these findings and recommendations for evaluating soil-pica behavior is documented throughout this report.

- The panelists used the following definitions to frame their discussions:
  - *soil ingestion* is the consumption of soil. This may result from various behaviors including, but not limited to, mouthing, contacting dirty hands, eating dropped food, or consuming soil directly.
  - *Soil-pica* is the recurrent ingestion of unusually high amounts of soil (i.e., on the order of 1,000–5,000 milligrams per day). Groups at risk of soil-pica behavior include children aged 6 years and younger and individuals who are developmentally delayed.
  - *Geophagy* is the intentional ingestion of earths and is usually associated with cultural practices.
- The panelists identified strengths and weaknesses associated with the different methods (e.g., observational, questionnaire, and analytical) that have been used to evaluate the prevalence of soil-pica. Given the limitations of individual methods, they agreed that a study that incorporates multiple methods would provide a means for validating the prevalence of soil-pica and the distribution of soil ingestion rates. Such validation is

needed to provide confidence in ATSDR's approach for conducting future public health assessments.

- Even with a definition of soil-pica, the panelists found it difficult to determine the prevalence of this behavior. The panelists agreed that soil-pica clearly exists, but the prevalence at a given soil ingestion rate has not been adequately characterized. Nonetheless, noting that soil ingestion is normal behavior among children, the panelists unanimously agreed that ATSDR should continue to evaluate the public health implications of all types of soil ingestion, including soil-pica.

- The panelists agreed that the existing soil ingestion studies—nearly all of which evaluated children's behavior for durations of 2 weeks or shorter—are inadequate for determining the frequency of, and seasonal variations in, soil-pica.

- The panelists noted that geophagy typically involves consumption of clay materials from known (and usually uncontaminated) sources at depth, rather than consumption of surface soils from residential properties. To address this type of ingestion, the panelists suggested that ATSDR survey communities of concern to determine if geophagy is practiced and where geophagical materials are obtained.

- The panelists thought that soil-pica among adults was probably rare. Given anecdotal accounts of soil-pica adults, the panelists suggested that ATSDR consider the possibility that this behavior occurs, perhaps by conducting surveys or availability sessions with communities. However, it is sometimes unclear from anecdotal accounts whether the behavior reported was soil-pica or geophagy.

- Because the literature on soil ingestion rates is extremely sparse, the panelists agreed that the distribution of age-specific soil ingestion rates had not been well characterized. Some panelists noted that ATSDR can estimate percentiles in this distribution by using a statistical analysis of existing soil ingestion data. However, the panelists stressed the need for field validation (including study of biomarkers and, where relevant, health effects) of any derived soil ingestion rate, as this ultimately would provide more confidence in ATSDR's public health evaluations of sites with contaminated soils.

- After lengthy discussions, the panelists noted that ATSDR's assumption that soil-pica children ingest 5,000 milligrams (mg) of soil per day appears to be supported by only a few subjects in soil ingestion studies (i.e., two children in Massachusetts and several children in Jamaica). Referring to the soil ingestion rates presented in the literature, as summarized in EPA's *Exposure Factors Handbook*, some panelists thought that ATSDR's assumed ingestion rate for soil-pica children was high. Other panelists agreed, however, that

ATSDR should err on the side of being protective and should use 5,000 mg until more data are collected. They also stressed the need for validating the 5,000 mg soil ingestion rate.

ATSDR views the contents of this report as advice for the agency to consider as it decides how to evaluate and address public health issues surrounding soil-pica. The contents of this report are NOT ATSDR policy.

1. INTRODUCTION

The Agency for Toxic Substances and Disease Registry (ATSDR) invited 10 expert panelists to a workshop, which focused on the current state of science on soil-pica behavior—an issue that is relevant to the agency's ongoing work at many sites where people may be exposed to contaminated soils. The 2-day workshop occurred in Atlanta, Georgia, on June 7–8, 2000, and focused on addressing three key issues: the prevalence of soil-pica behavior, soil ingestion rates for people who exhibit this behavior, and means for identifying people with this behavior.

This report summarizes the technical discussions among the expert panelists. The remainder of this introductory section describes the following topics in greater detail: ATSDR's concern about soil-pica behavior (Section 1.1), how the agency selected the expert panelists (Section 1.2) and briefed them (Section 1.3), the workshop charge and agenda (Section 1.4), and the organization of this report (Section 1.5).

1.1 Background

Under congressional mandate, ATSDR is required to conduct public health assessments for certain contaminated waste sites. At these sites, the agency may conduct a wide range of activities. One important activity is to evaluate the extent to which people may come into contact with hazardous substances in soil, groundwater, surface water, air, and food. To characterize potential exposures to soil contaminants, ATSDR considers several factors, such as the nature and extent of contamination, whether people have access to contaminated areas, and the amounts of soils they ingest.

With the growing number of sites where levels of soil contamination may be of public health concern, particularly among children who exhibit soil-pica behavior, ATSDR decided to convene a panel with expertise on the scientific, cultural, behavioral, and medical factors related to soil-

pica behavior. The panelists' findings will be used to focus on how ATSDR evaluates the public health implications of exposure to soil contaminants.

1.2 The Workshop Attendees

There were 10 panelists, including behavioral psychologists, scientists, pediatricians, and epidemiologists, who are experts in evaluating soil ingestion among children and adults. They included representatives from federal agencies, childrens' hospitals, and academia, and their collective expertise spans virtually every subject matter discussed at the workshop. Therefore, the expert panel offered a broad and balanced perspective on soil-pica behavior and its implications on the agency's health assessment process. Appendix A lists the names and affiliations of these panelists.

In addition to the panelists, about 20 observers attended one or both days of the 2-day workshop. The observers included community members, industry, consultants, ATSDR staff, and representatives from state and local health departments. Though the discussions at the workshop were primarily among the panelists, ATSDR gave observers the opportunity to comment on all key issues. Observers' comments are included in this report, usually at the end of the sections.

1.3 Briefing the Panelists

To focus the workshop discussions, ATSDR prepared a list of questions, commonly called a "charge," and asked the panelists to address charge questions (Appendix B has a list of the charge). The charge for this workshop addresses the three key topics identified earlier: the prevalence of soil-pica behavior, soil ingestion rates among people who exhibit this behavior, and methods for identifying people who have this behavior. Under each issue, the charge presents several questions that ATSDR asked the panelists to discuss. Additionally, the charge included an open-ended topic, under which the panelists were asked to discuss research needs,

bioavailability of metals in soils, and any other issue they thought the other charge questions did not address.

ATSDR also provided every panelist a packet of 12 publications on topics related to soil-pica behavior one month prior to the workshop (Section 7 lists these publications).

1.4 The Workshop and Overview Presentations

The 2-day workshop generally followed the agenda shown in Appendix C. Dr. Catherine McKinney (Centers for Disease Control and Prevention) facilitated the workshop, which opened with introductions, both by panelists and observers, and was followed by four overview presentations (summarized below). For the remainder of the workshop, some panelists gave presentations and all panelists provided recommendations, observations, and comments when answering the questions. The workshop was a free-flowing discussion among the panelists, and did not focus on trying to reach a consensus on any issue. A record of the panelists' discussions is presented in Sections 2 through 6, with key findings highlighted in the Executive Summary.

Following is a summary of the four overview presentations, which were delivered before the panelists addressed the charge questions:

- *Dr. Henry Falk, M.D., Assistant Administrator, ATSDR.* Dr. Falk gave an overview of ATSDR, explaining how the agency works with the Environmental Protection Agency (EPA), other federal agencies, state and local health departments, and communities to address public health issues related to environmental contamination. He also gave an overview of how soil-pica behavior factors into ATSDR's public health assessments and EPA's decision making process for Superfund.

  Noting that the complex issue of exposures to contaminated soil arises at many hazardous waste sites, Dr. Falk stressed that the panelists' inputs might weigh heavily in ATSDR's future evaluations of the public health implications of soil-pica behavior. Dr. Falk concluded his presentation by acknowledging that soil-pica is particularly important for

evaluating health risks to children—a topic that his colleague, Dr. Rob Amler, would discuss in greater detail, as described below.

- *Dr. Rob Amler, M.D., Chief Medical Officer, ATSDR.* Dr. Amler's presentation reviewed various ongoing activities that support ATSDR's Child Health Initiative, which addresses special vulnerabilities of children who live near hazardous waste sites. He first listed many reasons why children tend to have higher exposures to environmental contaminants: children often find openings in fences around restricted sites, they play vigorously in soil and water, and they breathe, drink, and eat more—on a body weight basis—than do adults.

  Dr. Amler noted that these reasons, coupled with the fact that children's exposures can occur during critical developmental stages and that persistent health effects might result from these exposures, have caused ATSDR and other agencies to focus research and outreach on children's health issues. Acknowledging that quantifying children's exposures can often be difficult, particularly for soil ingestion pathways, Dr. Amler stressed that the panelists' inputs on soil-pica behavior will be an important consideration for future site evaluations.

- *Dr. David Mellard, Ph.D., Toxicologist, ATSDR.* Dr. Mellard's presentation focused on the primary goal of the workshop—how ATSDR should evaluate exposures to children who exhibit soil-pica behavior. Dr. Mellard explained that ATSDR views "pica" as the intentional ingestion of large quantities of soil, which primarily occurs among preschool children. He then reviewed an approach typically used to evaluate residential exposure pathways for pica children, with key factors being the assumed soil ingestion rate and the duration over which this ingestion occurs.

  Dr. Mellard noted that soil ingestion rates of 5,000 mg/day have been documented in a few studies in the scientific literature, but the duration over which ingestion at this level occurs has not been studied. Dr. Mellard found it reasonable to assume that some children might have these very high daily ingestion rates at least once in their preschool lives, and he thought it was possible that soil-pica children might exhibit these very high daily ingestion rates several times a week, for several weeks in a row. However, given that such assumptions can lead to important remediation decisions, Dr. Mellard said that ATSDR seeks expert input on both the prevalence of soil-pica behavior and the ingestion rates among those who exhibit pica behavior. To highlight the importance of these issues, Dr. Mellard concluded his presentation by describing a site with extensive arsenic contamination in residential soils, where exposures among soil-pica children could be at levels known to be associated with adverse health effects.

- *Mr. Michael Maes and Mr. Anthony Thomas, Community Members.* Mr. Maes is a resident in a neighborhood that was recently designated a Superfund site because of extensive

arsenic contamination in soils—a designation that has caused heightened awareness in his community about soil ingestion and pica behavior. Mr. Maes listed several examples of behaviors among his community members that might be of concern, such as children ingesting soils and sediments while playing near large puddles, a teenager who said that she craves to eat dirt several times a year, and women of Mexican descent who consume dirt when they become pregnant.

Given these anecdotal accounts of soil ingestion, Mr. Maes believed that soil-pica behavior was an important issue for his community, and he looked forward to the panelists' insights on the prevalence and significance of this behavior. Mr. Anthony Thomas echoed many of these concerns, and wondered about the adverse health effects in individuals who exhibit soil-pica behavior.

1.5 Report Organization

During the meeting, the panelists commented on a wide range of issues pertaining to soil-pica behavior. A common theme was the need to communicate, using consistent terminology. Section 2 of this report presents the panelists' definitions of key terms used throughout the workshop. Sections 3 through 6 summarizes the panelists' comments on the four key topics outlined in the charge (e.g., Section 3 documents the discussion on topic #1, Section 4 documents the discussion on topic #2, and so on). Section 7 lists all references cited in the text.

In addition, Appendix A lists the expert panelists, Appendix B lists the charge, and Appendix C describes the meeting agenda.

2. DEFINITIONS

Central to every charge question was the need to define key terms, such as soil ingestion, soil-pica, and geophagy, and to avoid any ambiguities in the discussions. The panelists noted that their definitions might differ from ATSDR's definitions and from definitions published elsewhere. The panelists cautioned, therefore, that observers and readers should be aware of the definitions for soil-pica and geophagy used in this report and that other individuals or agencies might have different definitions. The panelists considered several factors for their definitions, as described below, but they eventually agreed on the following definitions:

- *Soil ingestion* is the consumption of soil. This may result from various behaviors including, but not limited to, mouthing, contacting dirty hands, eating dropped food, and consuming soil directly.
- *Soil-pica* is the recurrent ingestion of unusually high amounts of soil (i.e., on the order of 1,000–5,000 mg per day). Groups at risk of soil-pica include children aged 6 years and younger and developmentally delayed individuals.
- *Geophagy* is the intentional ingestion of earths and is usually associated with cultural practices.

When defining these terms, the panelists listed numerous factors related to the above terms. Several panelists decided, however, that the aspects of soil ingestion that seem to be most important to ATSDR are (1) the amount of soil ingested, (2) the frequency of ingestion, and (3) the type of material ingested. The panelists' inputs on these and other factors are:

- *Is soil-pica an intentional behavior?* One panelist noted that "pica" is often defined as being intentional ingestion of non-food items. Though not disagreeing, other panelists pointed out that the definition of soil-pica should not be limited to intentional soil ingestion, primarily because children can consume large amounts of soil from their typical behaviors and because differentiating intentional and unintentional behavior in young children is difficult. The panelists eventually agreed, and omitted the "intentional" aspect of soil-pica from their definition, suspecting that ATSDR ultimately is most interested in the quantities of soil that children ingest, regardless of whether the behavior is intentional or not.

- *Is soil-pica or geophagy an abnormal behavior?* Some panelists thought that soil-pica is often considered abnormal behavior, but the panelists eventually unanimously agreed to omit the word "abnormal" from their definitions because of the word's negative connotations. One panelist was concerned that too many people already believe geophagy to be abnormal, even though the practice occurs world-wide among millions of individuals who are rational and have different education backgrounds. The panelists pointed out that the normal exploratory behavior by a 1- or 2-year-old could involve eating soil while the same behavior in a 4- or 5-year-old might be considered abnormal. Therefore, the panelists chose not to categorize soil-pica as abnormal behavior.

- *Is soil-pica necessarily a recurrent behavior?* Some panelists indicated that definitions of soil-pica often imply that the behavior is recurrent, and possibly habitual.[1] After discussing this issue at length, the panelists agreed that the recurrent ingestion of unusually high amounts of soil is an important aspect of soil-pica. They also agreed that children who ingest large quantities of soils only once should not be considered soil-pica children, though they recommended that ATSDR continue to evaluate the health implications of 1-day exposures.

  Some observers questioned the panelists' inclusion of "recurrent" in the definition of soil-pica. One observer, for instance, thought the definition should not exclude children who might ingest large quantities of soils on just one occasion. Other observers thought the "recurrent" aspect of soil-pica actually reflected habitual behavior or a "behavioral inclination" to consume soils. The panelists considered these comments, but decided that children who consume large amounts of soil just one time should not be considered soil-pica children. Further, they thought the quantity of soil ingested is the factor that most distinguishes soil-pica behavior, regardless of whether the behavior is habitual, intentional, or inadvertent. Therefore, the panelists did not incorporate the observers' comments into their definition. When asked for a more specific definition of "recurrent," two panelists thought ATSDR should examine the results of soil ingestion surveys in the literature to develop more precise wording for the temporal component of the soil-pica definition.

- *What is the significance of the materials that people consume?* When defining geophagy, two panelists stressed that it typically involves consumption of clays from known, and usually uncontaminated sources. The fact that surface soils generally are not the main source of geophagical materials was often highlighted during the workshop. Soil-pica, however, is strictly consumption of surface soils (i.e., usually the top 2–3 inches).

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[1] The panelists briefly debated whether the definition should have the term "repeated ingestion" or "recurrent ingestion." Noting that "repeated ingestion" might imply a pattern of soil-pica events, rather than these events occurring randomly, the panelists agreed that "recurrent ingestion" is the most appropriate wording for this definition.

- *Is age a risk factor for soil-pica?* When defining soil-pica, the panelists suggested different age ranges for being at greatest risk of exhibiting this behavior. Two panelists noted survey data which indicate that soil ingestion is generally not of concern for infants (aged 0–12 months). Other panelists recommended saying that children 4 years old and under are at risk for soil-pica. Another panelist noted that EPA's children's health initiatives focus on children aged 6 years and younger as being at risk for elevated soil ingestion levels. Another panelist cited analytical studies reporting elevated soil ingestion rates among children up to 7 years old. The panelists decided that "children aged 6 years and younger" should be included in the definition as being at high risk for soil-pica.

  After the panelists defined soil-pica, an observer asked if the age group listed in the definition (6 years and younger) was simply chosen to be consistent with EPA's efforts. Suspecting that older children (i.e., 5- and 6-year-olds) have lower soil ingestion rates than younger ones (i.e., aged 4 and younger), this observer wondered if the age range specified in the definition was too broad. Two panelists justified their decision to include 5- and 6-year-olds in this definition. One panelist stressed that children's behaviors that contribute to soil ingestion differ considerably between 1-year-olds and 6-year-olds. However, she noted, behaviors associated with soil ingestion, particularly thumb sucking, tend to decrease markedly after age 6, due to pressures from peers and teachers. Thus, she thought that including children aged 6 years and younger in the definition of soil-pica was appropriate, recognizing that soil ingestion behaviors of children within this age range can vary widely. Another panelist noted that 5- and 6-year-olds may be less likely to engage in mouthing behavior than younger children, but that they are more likely to play outdoors frequently, which might increase their risk for ingesting soils. Therefore, he found it appropriate to indicate that children aged 6 years and younger are at risk for soil-pica.

  Eventually, two panelists noted that specifying an exact age range for children at risk for exhibiting pica behavior is somewhat arbitrary and no data adequately support the use of one age range as a cutoff over another. The reviewers summarized the main point of the discussion as follows: the risk of engaging in soil-pica behavior is clearly greatest in young children, as opposed to in infants, older children, adolescents, or adults.

3. TOPIC #1: PREVALENCE OF SOIL-PICA BEHAVIOR

When addressing the topic of prevalence of soil-pica behavior, two panelists briefly presented their research and all of the panelists answered the five charge questions pertaining to this topic. This section reviews both the presentations and the panelists' responses; key findings from this discussion are found in the Executive Summary.

Note: In this and other sections, the panelists' initials used to attribute comments are as follows: DC (Dr. Dave Campagna), SD (Dr. Scott Davis), NF (Dr. Natalie Freeman), BL (Dr. Bruce Lanphear), DM (Dr. David Mellard), JM (Dr. Jacqueline Moya), RO (Dr. Ralph O'Connor), PS (Dr. Peter Schantz), DV (Dr. Don Vermeer), and RW (Dr. Robert Wright).

3.1 Incidental Influences on Total Soil/Dust Ingestion: Dr. Natalie Freeman

Dr. Freeman's presentation focused on incidental ingestion of soil and dust that results from children's typical eating and mouthing behaviors. Though her most recent studies have primarily examined exposures to household dust, Dr. Freeman noted that 50–70% of household dust is believed to come from outdoor soils. Thus, she reports her results as ingestion of "soil/dust," rather than ingestion of strictly household dust.

Dr. Freeman explained that examining incidental soil ingestion among children is important, because national studies have suggested that 87% of children (aged 1–4 years) lie or play on the floor and nearly 50% play on grass or dirt. (Dr. Freeman acknowledged that these summary statistics reflect national trends and may not be representative of regional or local trends.) She added that her own research of children in Newark, New Jersey, has shown that a large proportion of children (aged 1–3 years) regularly engage in activities that can lead to soil ingestion, such as eating most of their food with their hands, eating food dropped on the floor, and putting their fingers in their mouths.

Dr. Freeman then outlined preliminary data she has collected in support of an ongoing "Children's Dietary Lead Study." She specifically addressed the extent to which children's food can be contaminated by their behavior patterns. This study characterized children's exposures to soil and dust in New Jersey urban centers by sampling levels of metals contamination on kitchen floors, children's hands, food that fell on the floor, and food that children handled. Dr. Freeman explained the approach used to attribute measured levels of metals in food to contributions from metals contamination in soils and household dust, and then presented preliminary results from her study. One preliminary result is that, on average (median), 2 mg of dust adheres to a slice of apple dropped on the floor, the maximum being 16 mg. Similarly, 8 mg of dust, on average (median), adheres to a slice of cheese dropped on the floor, the maximum amount being 59 mg. Based on her results for apples, cheese, bananas, and hot dogs, Dr. Freeman estimated that children, on average, may ingest 22 mg of household dust daily just from eating foods from the floor, with a 90^{th} percentile ingestion rate from this activity of 93 mg.

Dr. Freeman also presented preliminary estimates of soil ingestion rates resulting from children's typical mouthing behavior. These estimates were calculated from measurements of the amounts of dusts typically found on children's hands and the assumptions on hand-to-mouth rates, the percentage of the hand that enters a child's mouth, the extent to which the amount of dust on the hand might be replenished between mouthing events, and the number of hours a day in which children engage in mouthing behavior. Not surprisingly, the results varied with the assumptions made in the calculations. For instance, children with a median dust loading on their hands (i.e., 1.5 mg dust per hand) who have a hand-to-mouth rate of 8.5 events per hour were estimated to have an incidental dust ingestion rate—from mouthing behavior alone—of 14 mg per day. At the upper end of the soil ingestion range, children with the maximum dust loading on their hands (i.e., 58.2 mg dust per hand) who have a hand-to-mouth rate of 27.0 events per hour are estimated to have an ingestion rate of 1,800 mg per day. Dr. Freeman noted that this elevated ingestion rate was not actually observed, but was estimated using a statistical analysis of her data.

Dr. Freeman emphasized two assumptions that introduce uncertainty into these calculations. First, the dust loading on hands was assumed to fully replenish between mouthing events—an assumption that an observer suggested was conservative for the upper-end exposure scenario—and mouthing activity was assumed to be limited to 8 hours per day. Dr. Freeman explained that little data are available for soil/dust replenishment on hands, for mouthing activities during 24-hour time periods, and for the consistency of these behaviors across days or weeks. She noted that most observational studies are limited to 8 hours or less per child.

In conclusion, Dr. Freeman stressed that considerable amounts of soil and dust ingestion can occur on a daily basis as a result of children's typical behavior patterns, and not necessarily from what have traditionally been considered intentional soil-pica events.

3.2 Geophagical Clays—Extraction, Preparation, and Distribution: Dr. Don Vermeer

Dr. Vermeer addressed deliberate consumption of clays or earths, called geophagy (as defined in Section 2.0). He explained that geophagy has been observed on all continents, but that it is particularly prevalent among certain cultural groups. He noted that geophagy involves much higher ingestion rates than the incidental ingestion data presented by Dr. Freeman, but he stressed that the clays consumed are typically from known, and usually uncontaminated sources, as described below.

Noting that the geophagical practices in Africa are an antecedent to those practices in African-Americans, Dr. Vermeer first described the African tradition of consuming processed clays. He showed photographs of a typical source of geophagical clays, which were located about 2–3 feet below the surface. Dr. Vermeer stressed that surface soils are rarely consumed, and thus contamination confined to surface soils is likely not an issue for culturally-associated geophagical consumption of clays. He then explained how the extracted clays are stored and

processed into their final shapes, and he noted how the processing practices can vary from village to village. Dr. Vermeer said that some clays were prepared with various herbs and leaves for medical purposes.

Production of the geophagical clays, according to Dr. Vermeer, is estimated to be as high as 500 tons per year in African villages he visited. Consumption of these clays appears to be greatest among women, particularly pregnant ones, but was also prevalent among children. Dr. Vermeer noted that typical consumption of these clays among women ranges from 30 to 50 grams per day, but much higher levels of consumption have been observed.

Dr. Vermeer then characterized geophagical practices in the United States, which he said were transferred to the New World largely via the slave trade, though he acknowledged that indigenous Indian groups throughout the New World and European immigrants in the southern Appalachian region consumed geophagical clays. To illustrate the current practice of geophagy in the United States, Dr. Vermeer presented research he conducted on this activity in Holmes County, Mississippi, where clays are primarily extracted from the B horizon, 18 to more than 36 inches below the surface, and rarely from surface deposits. An extraction site typically is associated with one extended family. He added that geophagy has been documented to occur in recent years in various southern communities, including Atlanta, as well as in Hispanic cultures. In conclusion, Dr. Vermeer stressed that the geophagical clays consumed in the United States are primarily from known, and usually uncontaminated sources.

3.3 Approaches for Characterizing the Prevalence of Soil-Pica

In response to the first charge question—"What observational, questionnaire, and analytical studies are most valid for characterizing the extent of soil-pica behavior?"—the panelists discussed the different methods that have been used to evaluate the prevalence of soil-pica behavior, and identified strengths and weaknesses associated with each method. Given the

limitations of individual methods, the panelists eventually agreed that a study that incorporates multiple methods would provide the best means for validating the prevalence of soil-pica behavior and the distribution of soil ingestion rates. The panelists thought that such validation was needed to develop a robust characterization of the prevalence of soil-pica behavior. Following is a summary of the panelists' discussion that led to this conclusion.

- *The utility of questionnaires.* Two panelists noted that surveys on soil ingestion, which researchers typically administer to caretakers, are useful for getting meaningful insights on general issues (e.g., "does your child ever eat dirt?") but are not particularly useful for getting robust answers on specific issues (e.g., "how often does your child eat dirt?" or "how much dirt does your child consume?") (SD, NF). Expanding on this comment, one panelist indicated that parents typically do not observe their children constantly and therefore are not able to comment reliably on specific details of their soil ingestion behaviors (NF).

  Other panelists listed reasons why administering surveys to parents about their children's behavior might lead to spurious results. First, parents might provide responses they think surveyors want to hear, rather than responses that accurately reflect their children's behavior (NF). Second, parents might provide inaccurate responses in efforts to conceal information that might reflect badly on them as parents (e.g., their children eating large amounts of dirt) (JM, DV). Third, because "unusual" behavior is more easily recognized in families with multiple children, parents' perceptions of "unusual" behavior might vary from one family to the next, thus complicating efforts to characterize the prevalence of soil-pica behavior with surveys (PS).

- *The utility of analytical studies.* When discussing the different methods available to characterize the prevalence of soil-pica, several panelists noted that soil ingestion rates predicted by analytical methods (i.e., mass balance tracer research) have varied considerably from one study to the next (SD, BL, DM). One panelist suspected that these inconsistent findings might result from the difficulty short-term analytical studies have identifying rare events (DM). Another panelist agreed, explaining that the analytical studies he has conducted and reviewed characterize soil ingestion behavior for a small number of people over a very short time frame, typically 2 weeks or less (SD). With this study approach, he thought the analytical studies have a very small chance of identifying soil-pica events.

  The panelists raised several other concerns about analytical studies. For instance, one panelist was not convinced that analytical studies can provide the most reliable account of

soil ingestion, given his experience conducting two studies, both of which found that soil ingestion rates calculated from analytical approaches correlate very poorly with observational accounts of mouthing behavior and soil ingestion (SD). Another panelist added that inconsistent results might stem from the fact that studies are conducted in different regions and among children of various socio-economic status (DM). He was not surprised, for example, that soil ingestion rates observed among children in suburban communities in Massachusetts were different from those conducted on institutionalized children in Jamaica. One panelist did not think the prevalence of soil-pica behavior among the Jamaican children should be viewed as representative of that among children in the United States, given the small size of the study and the living conditions of the children considered (BL). Another panelist noted that mass balance studies assume an understanding of the digestive processes and degree of uptake, transformation, and excretion of tracers in young children (NF). She added that most tracer studies have been conducted on children, who have different gut permeability, metabolism rates, and excretion rates than adults. This reviewer commented that true mass balance studies would collect both feces and urine over a long period of time, because the temporal pattern of excretion in the two media will be different. She indicated that the mass balance studies included in the review materials were based only on fecal sampling over a limited time frame.

- *The utility of combining several methods.* Given their concerns about the various individual methods for characterizing soil ingestion, most panelists advocated the use of multiple methods in one study to derive a robust, validated distribution of soil ingestion rates. Specifically, panelists highlighted the need for conducting an extensive study that integrates information on levels of soil contamination, biomarkers of exposure, and various metrics of soil ingestion (e.g., analytical, observational, and surveyed accounts) (BL, RW). Several panelists noted that such a study would be expensive, but thought the community at the Vasquez Boulevard/Interstate 70 Superfund site might be an excellent subject population for such research (NF, BL). Though not disagreeing with these suggestions, one panelist cautioned that using multiple methods to characterize soil ingestion has led to conflicting results in his previous research and that using multiple methods to derive a validated soil ingestion rate for pica children will be quite challenging, though worth pursuing (SD).

When commenting on the use of integrated approaches to characterize soil ingestion rates, two panelists identified existing data sets that ATSDR should review. One panelist indicated that one of his past studies on soil ingestion, which included observational and analytical components, also has biomarker data (i.e., blood lead levels) that have yet to be thoroughly examined (SD). Another panelist noted that biomarker data (i.e., levels of arsenic in urine) are available for a Superfund site in Washington state where ingestion of contaminated soils is of concern (JM).

3.4 Prevalence of Soil-Pica

The second was: "What is the prevalence rate of soil-pica behavior among children, especially preschool children? among adults? among pregnant women?" The panelists stressed that the prevalence of pica behavior is highly dependent upon how it is defined, and eventually defined the various terms (e.g., soil ingestion, soil-pica, geophagy) used throughout the workshop. Even with a clear definition of soil-pica, however, the panelists had difficulty quantifying the prevalence among subpopulations, given the lack of extensive soil ingestion studies. Nonetheless, the panelists agreed that soil-pica exists and that ATSDR should continue to evaluate the public health implications of all types of soil ingestion behavior, including soil-pica. Following is a summary of the discussion that led to this conclusion.

- *The importance of clearly defined terminology.* The panelists repeatedly stressed that the prevalence of soil-pica behavior depends on how one defines this behavior. As an example of their concern, panelists noted that they have seen "soil-pica" defined in terms of quantities of soil ingested and whether the ingestion behavior is abnormal, intentional, or repetitive (BL, JM, DV). One panelist cautioned against limiting pica behavior to abnormal soil ingestion levels, because such a restricted definition would overlook the fact that children's typical behaviors can lead to relatively high soil/dust ingestion rates (see Section 3.1) (NF). The other panelists stressed that a clear, unambiguous definition of soil-pica must be crafted so that ATSDR can quantify the prevalence using the various methods discussed in Section 3.3. Given the importance of communicating with consistent terminology, the panelists defined soil ingestion, soil-pica, and geophagy at the close of the meeting. Refer to Section 2.0 for these definitions.

- *Comments on the distribution of soil ingestion rates.* When discussing the prevalence of soil-pica, two panelists suggested that ATSDR view soil ingestion rates as a continuum, possibly by characterizing the distribution of these rates (SD, JM). Knowing the distribution of soil ingestion rates, according to one panelist, would allow researchers to quantify the distribution of exposures to soil contaminants at sites where the nature and extent of soil contamination has been determined, but this panelist was not convinced that the data currently available are sufficient for estimating this distribution (SD). Another panelist then asked whether a table from a publication (Calabrese and Stanek, 1998) provides a reasonable estimate of the distribution of soil intakes (DM). The panelist responded that he was not sure, because he did not know how the estimate was derived

(SD).[2] Given the importance of knowing the distribution of soil ingestion rates for various age groups, one panelist suggested that ATSDR try to estimate these distributions from the various soil ingestion studies that have been published.

- *Comments on data reported in the scientific literature.* Though not commenting specifically on the prevalence of soil-pica behavior, several panelists noted relevant data documented in the scientific literature. For instance, one panelist noted that a team of researchers has estimated that 33% of children ingest more than 10 grams of soil 1 or 2 days a year (Calabrese and Stanek, 1998) (DM). Another panelist cautioned, however, that this estimate is based on an extrapolation of a short-term study and not on a study of soil ingestion over an entire year (NF). Another panelist noted that his analytical studies as well as those published by Ed Calabrese and Ed Stanek, and by Michael Wong present estimates of soil ingestion rates, though they do not have consistent findings (SD). Another panelist indicated that his research has found that 30% of children (aged 1–3 years) in Rochester, New York, ingest soils, based on a survey of parents, and that this behavior is associated with a 14% increase in blood lead levels (BL). This panelist cautioned about assuming that these findings might apply to other sites and other contaminants. Overall, the panelists thought their comments confirm that soil-pica exists, but they refrained from providing quantitative estimates of the prevalence of soil-pica behavior, largely because the available studies are limited in duration and not based on a population that represents all groups of children.

- *Prevalence of soil-pica among pregnant women.* One panelist noted that women in urban areas would likely not dig and process their own geophagical clays, but would likely purchase them or obtain them from areas where they were reared when relatives came to visit (DV). Further, he doubted that pregnant women in urban areas would consume surface soils from their backyards. Consistent with these comments, another panelist provided an anecdotal account of stores in the Atlanta area that sell geophagical clays, which pregnant women might consume (JM). The panelists eventually agreed that studies have not been conducted to determine the extent to which pregnant women exhibit soil-pica behavior, though they suspected that consumption of residential soils is likely rare.

- *Variations in soil ingestion rates with age.* Citing his own research, one panelist indicated that the percentage of children in his study who ingested soils, as reported by their parents, was 3% for 6-month-old children, 30% for 12-month-old children, 31% for 18-month-old

[2] At this point, an observer clarified that the author of the publication apparently extrapolated the results of a 2-week analytical study to soil ingestion rates over the course of the year. This extrapolation reportedly assumed that the variability of soil ingestion rates over a year is greater than that which was observed in 2 weeks—an assumption the observer questioned given that the study of concern was conducted during the summer, when soil ingestion rates would likely be greatest and perhaps most variable.

children, and gradually lower percentages for older children (BL). (Note: this research did not ask about "pica behavior," but rather asked parents whether their children ingest soils.) Somewhat consistent with this finding, another panelist added that he believes intentional soil ingestion behaviors decrease as children reach roughly the age of 3 (DV). He attributed this apparent decrease to the observation that parents try to control certain behaviors (including soil ingestion) as children reach ages when they can reason, while they overlook these behaviors when children are younger. One panelist indicated that the available data on this topic are extremely limited (NF).

- *Implications of the prevalence of soil-pica behavior.* The panelists offered various opinions on the implications of soil-pica behavior, regardless of not knowing the exact extent to which it occurs. One panelist, for example, believed that a significant number of children exhibit soil-pica behavior, but added that an insignificant number of children might develop adverse health effects (NF). She noted that ATSDR ultimately needs to consider many factors other than the prevalence of soil-pica behavior (e.g., the nature and extent of contamination and bioavailability) to put the health concerns into perspective. This panelist added, however, that ATSDR should err on the side of possibly overestimating the prevalence of soil-pica behavior, given that it might be associated with adverse health effects. Another panelist agreed, noting that his research has found soil ingestion, as reported by parents, to be a significant risk factor for childhood lead poisoning (BL). The panelists agreed that ATSDR should continue to evaluate the public health implications of soil-pica behavior, despite the uncertainties associated with the nature and extent of soil-pica. Most panelists agreed that ATSDR should try to validate the public health significance of soil-pica behavior through site-specific studies.

3.5 Temporal Factors

The next question was: "What temporal factors in the prevalence of soil-pica behavior should ATSDR consider (e.g., does soil-pica behavior generally occur once a week, three times a week, etc.)?" After a brief discussion, the panelists agreed that the existing soil ingestion studies—nearly all of which evaluated children's behavior for durations of 2 weeks or shorter—are inadequate for determining the frequency of, and seasonal variations in, soil-pica behavior.

Before reaching this conclusion, several panelists commented on the extent to which temporal variations have been considered in previous soil ingestion studies. One panelist noted that his surveys of parents in Rochester, New York, did not ask them how frequently their children ingest

soils (BL). Another panelist said her surveys also focused on whether children ingest soils, but not how often (NF). Reiterating a comment made earlier, this panelist found that surveys are poor methods for accurately quantifying detailed information about children's behavior, such as how often they ingest soils. Thus, the panelists suggested that the available soil ingestion survey data do not characterize the frequency of soil ingestion.

Other panelists commented that analytical data do not adequately characterize temporal variations in soil ingestion. For instance, two panelists indicated that none of the analytical studies examined soil ingestion for durations longer than 4 months and that most studies lasted only 2 weeks or less (SD, DM). Another panelist noted, however, that Ed Calabrese's analytical study does demonstrate considerable day-to-day variability in soil ingestion rates, but he questioned how representative this variability is of children nationwide (RW). Overall, panelists agreed that the analytical studies do not address seasonal variations in soil ingestion—a factor they thought would be important in evaluating soil ingestion, particularly for regions with cold winters. Consistent with this argument, one panelist indicated that blood lead levels among children he has studied in Rochester, New York, tend to peak during the summer (BL).

3.6 Prevalence of Soil-pica Among Various Subpopulations

The panelists only briefly discussed the extent geophagy and soil-pica vary across various subpopulations within a given age group. Citing his own research, one panelist found the prevalence of soil ingestion among white children to be higher than that among black children, but he thought this finding is likely due to factors (e.g., coverage of yard space with bare soils, time spent outdoors) other than a fundamental difference in soil ingestion behaviors among ethnic groups (BL). Another panelist cautioned, however, that data on soil ingestion collected in studies of children in the northeastern United States might not be representative of soil ingestion rates for children in other parts of the country (NF).

Also citing his research, another panelist indicated that geophagy in Mississippi did not appear to vary with socio-economic class (DV). Finally, earlier in the workshop, this panelist noted that consumption of geophagical materials by some Hispanics may be tied to religious traditions both in Mexico and Honduras. No other panelists commented on these topics.

3.7 The Need for ATSDR to Consider Soil-Pica Children

When discussing the prevalence of soil-pica behavior (see Section 3.4), the panelists also responded to the question, "Should ATSDR evaluate soil-pica behavior as an exposure scenario for hazardous waste sites or is soil-pica behavior too rare to be a public health concern?" The panelists unanimously agreed that ATSDR should evaluate the public health implications of all types of soil ingestion behavior, despite the uncertainties that currently surround this issue. Two panelists noted that ATSDR is rightly concerned about soil-pica behavior, because soil ingestion has already been shown to be a significant risk factor for increased blood lead levels (BL) and exposure to soil-transmitted parasites (PS). Some panelists noted that ATSDR's current approach to evaluating the health implications of soil-pica behavior is reasonable, despite the fact that extensive soil ingestion data are not available; however, they repeatedly recommended that the agency gather additional data on soil ingestion to provide confidence in their current approaches.

3.8 Observers' Comments and Additional Topics on the Prevalence of Soil-Pica Behavior

After addressing the questions on the prevalence of soil-pica behavior, observers had the opportunity to comment on the panelists' discussions. The panelists, in turn, responded to several issues raised by the observers. Following is a summary of these discussions.

- *Risk management implications of soil-pica behavior.* The observers and panelists debated at length how basing public health evaluations on soil-pica behavior can have great implications on risk management decisions. Three observers addressed this issue before the panelists responded. The first observer argued that the prevalence of pica behavior is too low to form the basis for extensive remedial decisions. Using a Superfund site in Denver as

an example, this observer argued that even though several thousand homes have contaminated soils, only a very small subset of these homes have levels of contamination that might be of concern for soil-pica children. Assuming that pica occurs rarely, the observer stressed that soils at very few, if any, homes might actually present health risks. Another observer disagreed, and argued that remedial actions should be taken at sites such as the one in Denver, even if only a small number of children—or even just one child—is at risk. Finally, a third observer stressed that basing risk assessments on soil-pica behavior can lead to excessively expensive remediation projects at sites across the country, including potentially massive remediation activities at the Denver site. This observer wondered if health risks to pica children are sufficient to warrant such extensive remedial actions and whether actions other than soil removal might address these risks.

The panelists also discussed risk management implications of soil-pica behavior and offered different perspectives on the issue. Several panelists recommended that additional studies be performed (see Section 6.0) to reduce uncertainties in the current approaches to evaluating potential health risks to soil-pica children (SD, BL, RW). Some thought these studies should examine the prevalence of soil-pica behavior and the distribution of soil ingestion rates, while others thought they should measure biomarkers and identify adverse health effects. Regardless of the type of study, the panelists thought that more detailed information was needed to give greater confidence in decisions based on risks to soil-pica children. One panelist suggested that ATSDR recommend remediation for properties where levels of soil contamination might pose a risk to soil-pica children, as predicted by the current tools for estimating exposures (NF). This panelist noted that such an approach is already often taken when public health officials identify childhood lead poisoning.

- *Public health implications of geophagy versus soil-pica.* Reflecting on the observer comments and discussions earlier at the workshop, one panelist highlighted an important difference between geophagy and soil-pica (PS). Specifically, he noted that geophagy is an institutionalized practice in which the processed clays or other geophagical materials do not seem to have any adverse health effects. However, he also stressed that soil-pica can lead to various health effects, whether due to consumption of environmental contaminants or parasites. Accordingly, he recommended that future discussions acknowledge the important difference in the disease-causing potential of these two behaviors.

- *Whether soil-pica is "abnormal" behavior.* One panelist argued that geophagy is far too common around the world to be considered abnormal behavior (DV). Another panelist noted that incidental ingestion of soils among children—not just those with unusually high intakes—is associated with increased blood lead levels (BL). The same panelist pointed out that soil ingestion at levels of potential health concern is too common to be labeled "abnormal."

- *The possibility of geophagy being an inherited trait.* One observer asked the panelists if geophagy might be a genetic trait (i.e., mothers can pass the urge to consume clays to their children). In response, one panelist noted that no studies have addressed this issue, but he suspected that cultural influences alone would probably lead to geophagy being most prevalent among families where it is practiced and least prevalent among families where it is not (PS).

4. TOPIC #2: INGESTION RATES FOR SOIL-PICA

This section summarizes the panelists' responses to the three charge questions pertaining to ingestion rates for soil-pica. The panelists' comments are organized into three subject areas: ingestion rates for an incident of soil-pica (Section 4.1), applying ingestion rates to acute, intermediate, and chronic exposure durations (Section 4.2), and ingestion rates for adults who exhibit soil-pica behavior (Section 4.3). The Executive Summary presents the panelists' key findings on these subjects, and a record of the discussion that led to these findings follows. Observers offered no comments during this discussion.

4.1 Ingestion Rates for an Incident of Soil-Pica

The first charge question pertaining to ingestion rates for soil-pica children was: "ATSDR currently assumes children who exhibit soil-pica behavior, on average, ingest 5,000 mg of soil per day. Based on your review of the literature on soil-pica behavior, is this soil ingestion rate scientifically defensible? Does this represent plausible exposures for children (i.e., is this soil ingestion rate unrealistically high or unrealistically low)? What soil ingestion rate would you recommend?" The panelists agreed that ATSDR's assumption that soil-pica children may ingest 5,000 mg of soil per day appears to be supported by only a few subjects in soil ingestion studies (i.e., two incidents in Massachusetts and several children in Jamaica). Referring to the distribution of soil ingestion rates published in the literature, some panelists thought ATSDR's assumed ingestion rate for soil-pica children seems high. Other panelists thought the available data might be inadequate for characterizing the distribution of soil ingestion rates among children. Tables 4-1 and 4-2, at the end of this section, present some of the findings published in the literature that formed the basis of the panelists' discussions.

The panelists also agreed that ATSDR should err on the side of being protective when examining exposures to soil contaminants. Following is a summary of the discussions that led to these key findings.

- *Review of data on maximum daily ingestion rates.* The panelists first reviewed the maximum soil ingestion rates reported in the literature. Citing data reported in the background documents, one panelist commented that evidence of gram-level soil ingestion has only been observed in two incidents in Massachusetts and in six children in Jamaica, with the highest daily soil ingestion rate reported being 50,000 mg (JM). After someone else noted that the 50,000 mg ingestion rate was observed for a developmentally disabled child (DM), this panelist said the next highest daily soil ingestion rate reported is 20,000 mg. She questioned ATSDR's use of a soil ingestion rate (5,000 mg per day) that is consistent with the most extreme soil ingestion rate ever reported (JM). Another panelist agreed, noting that nearly every child that has been considered in analytical studies has had ingestion rates considerably lower than 5,000 mg per day, though he acknowledged that the design of these studies might not be able to capture rare peaks in soil ingestion (SD).

  One panelist indicated that a statistical analysis of the existing soil ingestion data (Calabrese and Stanek, 1998) estimates that 42% of children will ingest 5,000 mg of soil on 1 or 2 days a year—a finding he thought supports ATSDR's use of this soil ingestion rate (PS). Other panelists argued, however, that this finding should be viewed as an estimate since it is based on a statistical analysis of very limited data; they suspected that the available soil ingestion data are not sufficient to characterize the distribution of soil ingestion rates among children (SD, NF).

- *Comments on the distribution of soil ingestion rates.* Despite their concerns about whether the available data adequately characterize this distribution, two panelists noted that data presented in EPA's *Exposure Factors Handbook* suggest that children who ingest 5,000 mg of soil a day are well above the 95th percentile of soil ingestion rates (NF, RW). Citing Table 4-1 in the *Exposure Factors Handbook*, for example, one panelist indicated that a study conducted by Ed Calabrese and Ed Stanek reported a 95th percentile soil ingestion rate of 208 mg per day (RW). Commenting further on this table, another panelist noted that the 95th percentile soil ingestion rate calculated for seven of the eight tracers considered ranged from 117 to 518 mg/day; she added that only by considering manganese as a tracer did the study report 95th percentile soil ingestion rates greater than 5,000 mg per day (NF). Given the great differences among the tracers, this panelist questioned the validity of the analytical method for characterizing soil ingestion rates. Nonetheless, based on the presentation of these 95th percentile soil ingestion rates, two panelists thought a case could be made for using a soil ingestion rate lower than 5,000 mg per day for soil-pica children.

  When discussing the implications of the analytical studies, some panelists noted that Ed Calabrese and Ed Stanek not only observed a 95th percentile soil ingestion rate of 208 mg/day based on the 64 children they studied, but also reported a 95th percentile soil

ingestion rate of 1,751 mg/day based on a statistical analysis of this same data (see Table 4-2 in EPA's *Exposure Factors Handbook*) (DM). Another panelist stressed that this higher soil ingestion rate was not actually observed, but was based on various assumptions made when extrapolating data collected over less than 2 weeks to soil ingestion behavior over an entire year (JM). Nonetheless, some panelists noted that the more recent findings reported by Ed Calabrese and Ed Stanek are more consistent with ATSDR's estimated soil ingestion rate.

- *Suggested approaches to defending a soil ingestion rate for pica children.* Without knowing how ATSDR derived its soil ingestion rate for pica children, the panelists ultimately found it difficult to critique the validity of this parameter. The panelists suggested that ATSDR should consider two approaches for deriving a defensible soil ingestion rate. First, ATSDR should conduct a comprehensive soil ingestion study that uses multiple methods to characterize the prevalence of pica behavior and to quantify the distribution of soil ingestion rates (NF, BL, RW). Second, until a more comprehensive study is performed, ATSDR should defend its soil ingestion rate by conducting statistical analyses of the various analytical studies reported in the literature[3] (DC, SD, NF). These panelists acknowledged, however, that such analyses will continue to be limited because the available data are sparse and possibly not representative of all geographic areas, cultures, and seasons. Given these uncertainties, the panelists stressed the importance of validating any conclusions drawn from the soil ingestion data currently available. Recommendations for validating these conclusions included measuring biomarkers, identifying adverse health effects, and conducting a multi-faceted study that relies on different approaches for characterizing soil ingestion.

4.2 Applying Ingestion Rates to Acute, Intermediate, and Chronic Exposure Durations

The second charge question pertaining to soil ingestion rates, was: "When evaluating children's exposure, ATSDR currently applies the soil ingestion rate of 5,000 mg per day for the entire duration of acute (<14 days), intermediate (14–365 days), and chronic exposures (>365 days) to develop screening levels. However, when evaluating site-specific residential exposures, ATSDR may alter the frequency of the behavior depending on the duration of expected exposure. For example, ATSDR may assume a one time exposure or 3 days of exposure per week for several

[3] Some panelists thought Ed Calabrese and Ed Stanek may have already performed such a statistical analysis, as documented in Table 4 of his publication in the Environmental Law Reporter (Calabrese and Stanek, 1998).

weeks, depending on site-specific conditions and toxicology of the contaminant of concern. Is this approach valid? What would you recommend in varying the amount and frequency of soil ingested over time? Are data available to support use of age-specific ingestion rates for soil-pica children?"

Because most of the analytical studies of soil ingestion spanned 2 weeks or less and none lasted over 4 months, the panelists agreed that soil ingestion rates over intermediate and chronic exposure durations have yet to be characterized. One panelist noted that extrapolations of short-term analytical studies to long-term exposure scenarios suggest that few children likely ingest 5,000 mg of soil a day throughout a year (PS). Specifically, he explained that a statistical review of an analytical study has suggested that the likelihood of children ingesting 5,000 mg of soil every day of the year is extremely low (<1%) (Calabrese and Stanek, 1998). However, this panelist and others stressed that no long-term studies have been conducted to verify this finding.

The panelists did not explicitly answer the question of whether or not assuming children ingest 5,000 grams of soil, 3 days a week, was a reasonable assumption, because there is limited data upon which to base this assumption.

4.3 Ingestion Rates for Adults Who Exhibit Soil-Pica Behavior

The final charge question on soil ingestion rates was: "Are sufficient data available for establishing a scientifically defensible soil ingestion rate for adults who exhibit soil-pica behavior? If so, what soil ingestion rate do you recommend?" Referring to their earlier discussions on geophagy among adults, the panelists noted that adults who consume large quantities of soils or clays tend to obtain these materials from known, uncontaminated sources. Having heard anecdotal accounts of a small number of adults who might consume soils from contaminated sources, however, the panelists recommended that ATSDR view soil-pica among adults as an extremely rare behavior, but not so rare as to be ruled out of consideration. The

panelists recommended that ATSDR investigate soil-pica in adults when that behavior has been shown to occur in people who live on or near a site that the agency is investigating. The panelists unanimously agreed that soil ingestion rates among pica adults have never been characterized.

Table 4-1
Data on Soil-Pica Discussed by the Panelists

Evidence of Soil-Pica Published by Ed Calabrese and Ed Stanek
During a study of 64 preschool children in Amherst, Massachusetts, soil-pica was observed on two occasions: • A 2 ½- year-old girl was observed for 4 days. On two of these days, she ingested 20,000 mg and 22,000 mg of soil. • A young girl ingested between 1,000 mg and 2,000 mg of soil on 4 days of a 7-day period.
Evidence of Soil-Pica Published by Michael Wong
During a 4-month study of 24 children (average age 3.1 years) living in a long-term government supervised institution in Jamaica, soil-pica was observed in five children: • Child #1 ingested 1,447 mg of soil on 1 day • Child #2 ingested 7,924 mg of soil on 1 day • Child #3 ingested 1,016 mg of soil, 2,690 mg of soil, and 898 mg of soil on different days • Child #4 ingested 10,343 mg of soil, 4,222 mg of soil, and 1,404 mg of soil on different days • Child #5 ingested 5,341 mg of soil on 1 day. In addition, during a study of 28 older children (average age 7.2 years), soil-pica was observed in one child who was developmentally disabled. This child ingested 48,300 mg of soil, 60,692 mg of soil, 51,422 mg of soil, and 3,782 mg of soil on different days.

Note: Of the soil ingestion rates listed in this table for preschool children, the median soil ingestion rate is 2,000 mg and the average value is 5,000 mg. One panelist noted that the soil ingestion study published by Michael Wong does not clearly state the nature and severity of the developmental disability in the child who ingested large quantities of soil (NF). As a result, she was not sure if this child's behavior would be expected to occur among other individuals who have various types of developmental disabilities.

Table 4-2
Estimated Percent of Children with Soil Ingestion Exceeding Daily Rates for Given Time Periods Per Year

Estimated Number of Days per Year with Soil Ingestion Rate	Daily Rate of Soil Ingestion (in mg)				
	> 200	> 500	> 1,000	> 5,000	> 10,000
1–2	86	72	63	42	33
7–10	72	53	41	20	9
35–40	42	31	16	1.6	1.6

Note: Data reproduced from Table 4 in Calabrese and Stanek, 1998.

5 TOPIC #3: MEANS FOR IDENTIFYING SOIL-PICA BEHAVIOR

This section summarizes the panelists' responses to the charge questions addressing how ATSDR can best identify people with soil-pica behavior. The discussion included a presentation by Dr. Natalie Freeman (Section 5.1) and the panelists' specific responses to the questions (Section 5.2). Observers did not comment on the panelists' discussions on this topic.

5.1 Activities Contributing to Exposure and Ingestion of Soil/Dust: Dr. Natalie Freeman

Dr. Freeman opened the discussion on how to identify soil-pica children by showing video footage from her observational studies on how children come into contact with soils and household dusts. The video showed children engaging in various behaviors that contribute to exposures, such as putting objects in their mouths, playing with pets, handling food, eating after playing outdoors, sucking thumbs, cleaning fingernails, playing in sandboxes, and engaging in other hand-to-mouth activities. Dr. Freeman explained that the extent of exposure depends on many factors, such as where children play, what they wear, and how often they wash their hands. She noted further that the number of times a day children wash their hands is often less than parents think, primarily because parents often do not oversee this behavior. Dr. Freeman added that exposures can occur even when children are relatively inactive. Specifically, she stated that mouthing behavior was often greatest during periods of "down time," such as just before children take naps or while they watch television.

Dr. Freeman acknowledged that this particular research project did not attempt to quantify the amounts of soil ingested by the various activities, but she indicated that exposures may be significant. Citing a research project from the 1980s as an example, she noted that as much as 10,000 mg of soil can adhere to certain types of candies, when dropped outdoors (reference not provided). In conclusion, she emphasized that the various activities that contribute to exposures to soil and dust are typical children's behavior, and do not involve direct consumption of soils. Though she has not quantified these exposures, Dr. Freeman suspected that the cumulative effect

of the various behaviors can lead to substantial ingestion of soils in some children (e.g., those who play vigorously outdoors, and who frequently engage in mouthing behavior, and who rarely wash their hands).

5.2 Responses to Charge Questions

The third topic on the agenda had only the following charge question: "ATSDR has reviewed studies that employed analytical, observational, and questionnaire techniques for identifying children who exhibit soil-pica behavior. What are the strengths and weaknesses of these methods? Are there other methods available to identify people with soil-pica behavior? Considering the pros and cons of each method, which method do you think ATSDR should use to identify people with soil-pica behavior?"

When addressing these issues, the panelists referred to their earlier responses (Section 3.3) on the utility of the different methods for characterizing the prevalence of soil-pica behavior. In summary, because analytical, observational, and questionnaire approaches all have their limitations, the panelists recommended that future studies use multiple approaches to identify soil-pica children. The panelists added that ATSDR needs to validate the findings of these approaches with epidemiologic studies that measure biomarkers of exposure to give the greatest degree of confidence in the results.

The panelists' other comments on means for identifying soil-pica children focused on how to conduct effective surveys. Following are their comments.

- *Behaviors to consider in survey questions.* Several panelists recommended that ATSDR review the existing literature on soil ingestion questionnaires before developing their own surveys (SD, NF, BL). For instance, one panelist indicated that his research on children living in Midvale, Utah, has found no association between the frequency of hand washing, as reported by parents, and blood lead levels (BL). Another panelist added that his research found soil ingestion rates to be essentially uncorrelated with several behaviors, such as

thumb sucking, hand washing, and use of pacifiers (SD). Both panelists thought that ATSDR could select survey questions judiciously by reviewing the results of these and other studies on soil ingestion.

Illustrating the utility of this suggestion, the panelists debated the need for including questions about hand washing on soil ingestion surveys. One panelist recommended that surveys address this topic, but two others noted that their own research found hand washing to be uncorrelated with other metrics of soil ingestion (i.e., analytical data from a tracer study and blood lead levels) (SD, BL). Given this precedent, another panelist questioned the utility of including detailed questions about personal hygiene on a soil ingestion survey, particularly since questions are directed at parents whose responses might be unreliable (NF).

- *Specific suggestions for survey questions.* The panelists offered several suggestions for specific survey questions that can help ATSDR identify soil-pica children. One panelist, for instance, suspected that ATSDR can adequately characterize parents' perceptions of soil ingestion among their children by asking just five carefully crafted questions (NF). She recommended using staged questions that start by focusing on general information (e.g., "does your child eat soil or dirt?") and end by addressing more specific information (e.g., "is this a weekly event?"). Another panelist recommended that surveys use questions and response options that are unambiguous (BL), (e.g., "how often have you observed your child put soil or dirt in his or her mouth?", with response options of "never," "once a month," "once a week," "once a day," or "several times a day.") He thought such descriptive response options are needed to derive semi-quantitative accounts of soil-pica. Another panelist agreed with the approach of using specific, unambiguous questions (SD). He explained that his research has found responses to direct and specific questions about a child eating dirt and soil to be associated with higher levels of soil ingestion as determined analytically, while responses to indirect questions were essentially unrelated to analytic measures of soil ingestion.

  Another panelist provided two more suggestions on developing specific questions (NF). First, to avoid recall bias, she recommended that ATSDR ask parents to remember recent events, as opposed to events that occurred months or years earlier (e.g., "how often have you observed your child put soil or dirt in his or her mouth in the last week?" rather than "have you ever seen your child put soil or dirt in his or her mouth?") Second, this panelist cautioned that using surveys to derive information on soil ingestion rates would be challenging. She thought asking parents about behaviors that lead to dramatically different ingestion rates (e.g., eating with fingers as compared to putting handfuls of soil into their mouth) might help identify the children who likely ingest the greatest quantities of soils, but she stressed that surveys are not the best approach for getting quantitative data on soil ingestion rates.

- *Other considerations for surveys.* The panelists listed several other suggestions for ATSDR to consider when developing soil ingestion surveys. First, one panelist noted that face-to-face interviews conducted by properly trained individuals typically generate the most detailed information, though she acknowledged that this approach is very time consuming and expensive (NF). This panelist added that ATSDR should draft soil ingestion surveys to assess the frequency of specific behaviors, and not to determine simply if these behaviors occur. Other recommendations included noting on surveys that the questions pertain to typical children's behavior (BL), ensuring that surveys are not too long (BL), and having trusted and respected individuals (e.g., community leaders or pediatricians) administer surveys (DV).

6. TOPIC #4: ADDITIONAL TOPICS

The panelists raised several issues when responding to the following final set of charge questions: "What critical research needs should be addressed to provide ATSDR greater insight into the public health implications of soil-pica behavior? What is known about the causes of soil-pica behavior? Does the bioavailability of metals in soil change with the amount of soil that is ingested? Is soil-pica behavior "normal"? Please bring to ATSDR's attention any other topics relevant to soil-pica behavior that are not addressed by the aforementioned questions."

When responding to these questions, the panelists referred to their earlier discussions on the causes of soil-pica behavior and whether this behavior is considered "normal." Following is an overview of the panelists' comments on research needs and bioavailability.

- *Critical Research Needs.* Several panelists thought the most critical data gap currently is the lack of a convincing account of the distribution of soil ingestion rates for various age groups, geographic regions, and selected subpopulations (SD, PS). The panelists thought that future research can best fill this gap, through a multi-faceted approach, possibly one that uses questionnaires, analytical studies, biomarkers, and observational studies to generate multiple lines of evidence of the distribution of soil ingestion rates. The panelists said that research is needed to validate the data currently reported in the literature and to generate additional data. Some panelists commented further on detailed study protocols that might help achieve this goal. These suggestions are not summarized here, but the panelists emphasized that research on the distribution of soil ingestion rates is needed so that ATSDR and other agencies can base their public health evaluations on more rigorously validated assumptions.

  The panelists identified other data gaps, including the lack of soil ingestion data for older children (aged 7 and higher) and adults (JM), and the need for data characterizing long-term variations in soil ingestion (RW). One panelist also recommended that ATSDR determine whether the National Health and Nutrition Examination Survey (NHANES) is collecting data that can be used to characterize soil ingestion rates (RO). Another panelist noted that this survey is measuring blood lead levels and analyzing floor-wipe samples in certain homes, but he was not sure how these data might relate to soil-pica. Lastly, wondering if analytical studies that measure isotopic ratios of various tracers can generate robust estimates of soil ingestion rates, some panelists recommended that ATSDR investigate the feasibility of conducting such a study.

- *Bioavailability of metals in ingested soils.* None of the panelists knew of studies showing that bioavailability of metals in soils decreases as soil ingestion rates increase, all other factors (e.g., particle size distribution) considered equal. Noting that pharmaceutical research has shown that humans absorb a smaller percentage of drugs when they are administered at higher doses, one panelist thought that bioavailability of metals in soils might decrease to a certain, but unknown, extent with higher doses (RW). He and other panelists (NF, DV) listed several other factors that likely play a greater role in bioavailability, such as alkalinity, particle size distribution, and composition of the soils, and the exposed individual's age, nutritional status, and dietary composition. One panelist added that bioavailability can vary considerably from metal to metal.

  An observer noted that the issue of bioavailability varying with ingestion rates has important implications on how ATSDR evaluates acute health risks among soil-pica children. In such cases, a panelist thought the best approach to validate assumptions about bioavailability would be to conduct health studies to examine the prevalence of specific acute health outcomes (BL). The observer asked the panelists if they saw a need to research how bioavailability might vary with soil ingestion rate, possibly using recently developed *in vitro* models or EPA's swine *in vivo* models. A panelist recommended that ATSDR research bioavailability first by reviewing the results of soil ingestion tracer studies that collected biomarker data before considering conducting the modeling studies suggested by the observer (BL).

- *The need for reporting soil ingestion on a body-weight basis.* One panelist asked if future research on soil ingestion should measure soil intake normalized to body weight (e.g., reporting "x milligrams of soil ingested per x kilogram of body weight"), consistent with how EPA is currently characterizing food and water ingestion rates (JM). Some panelists thought normalizing intakes to body weight would be consistent with other exposure metrics (BL), but others did not think this new approach added any insight to soil ingestion, especially considering that ATSDR already accounts for body weights in its exposure dose calculations (RO).

7. CONCLUSIONS

In summary, the panelists reached the following conclusions and recommendations.

- Soil-pica is the repeated consumption of soil (either intentional or unintentional) and geophagy is the intentional ingestion of earths that is usually associated with cultural practices.
- Soil-pica behavior exists. ATSDR should evaluate the public health significance of all types of soil ingestion, including soil-pica.
- Groups at risk of soil-pica behavior include children aged 6 years and younger as well as developmentally delayed individuals.
- For now ATSDR should use 5,000 mg as an estimate of soil intake for children with soil-pica behavior.
- Geophagy typically involves consumption of clay from known (and usually uncontaminated) sources at depth rather than consumption of surface soil from residential properties. ATSDR should investigate geophagy when the agency identifies this practice in a community.
- ATSDR should conduct a multicomponent investigation into soil-pica behavior.

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APPENDIX A

EXPERT PANELISTS

ATSDR

Agency for Toxic Substances & Disease Registry
Division of Health Assessment & Consultation

ATSDR Soil-Pica Workshop

Lenox Inn Buckhead
3387 Lenox Road, NE
Atlanta, GA

June 7-8, 2000

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APPENDIX B

CHARGE TO THE PANELISTS

CHARGE TO THE PANELISTS

The Agency for Toxic Substances and Disease Registry (ATSDR) scheduled this workshop to assess the current state of the science on soil-pica behavior—an issue that is relevant to ATSDR's ongoing work at sites with human exposure to contaminated soils. ATSDR intends to use the findings of this workshop to ensure that the agency continues to provide meaningful and scientifically defensible analyses of the potential health threats for individuals who exhibit soil-pica behavior.

During this workshop, ATSDR seeks expert opinions on several key questions, which are outlined below. Further, ATSDR welcomes insights on additional topics relevant to soil-pica behavior not explicitly addressed in the questions (see topic #4). Following the workshop, ATSDR will prepare a summary report to document the panelists' responses to these questions.

The workshop discussions will focus on answering the questions that pertain to the following four topics:

Topic #1: The prevalence of soil-pica behavior. A key aspect of preparing public health assessments and consultations pertaining to soil-pica behavior is having a sense of the prevalence of this behavior among different groups. A review of the literature shows several types of methods used to characterize soil-pica behavior, such as analytical, observational, and questionnaire. Some studies were provided to you prior to the workshop that used these methods. Using these and other studies, ATSDR seeks the expert panel's inputs on the following questions:

- What observational, questionnaire, and analytical studies are most valid for characterizing the extent of soil-pica behavior?
- What is the prevalence rate of soil-pica behavior among children, especially preschool children? among adults? among pregnant women?
- What temporal factors in the prevalence of soil-pica behavior should ATSDR consider (e.g., does soil-pica behavior generally occur once a week, three times a week, etc.)?
- Within the various age categories, has the prevalence of soil-pica behavior been shown to be more common among any groups (e.g., urban or rural populations, ethnic groups, people of different socio-economic status)?
- Should ATSDR evaluate soil-pica behavior as an exposure scenario for hazardous waste sites or is soil-pica behavior too rare to be a public health concern?

Topic #2: Ingestion rates for soil-pica. The expert panelists were provided several scientific papers as well as the chapter from EPA's *Exposure Factors Handbook* that summarizes soil ingestion rates that have been reported for soil-pica children. The soil ingestion rates ATSDR uses are a critical input to the agency's public health evaluations. Please be prepared to respond to the following questions pertaining to soil ingestion rates:

- ATSDR currently assumes children who exhibit soil-pica behavior, on average, ingest 5 mg of soils per day. Based on your review of the literature on soil-pica behavior, is this soil ingestion rate scientifically

defensible? Does this represent plausible exposures for children (i.e., is this soil ingestion rate unrealistically high or unrealistically low)? What soil ingestion rate would you recommend?

- When evaluating children's exposure, ATSDR currently applies the soil ingestion rate of 5 mg per day for the entire duration of acute (<14 days), intermediate (14–365 days), and chronic exposures (>365 days) but may alter the frequency of the behavior depending on the duration of expected exposure. For example, ATSDR may assume a 1 time exposure or 3 days of exposure per week for several weeks depending on site-specific conditions and toxicology of the contaminant of concern. Is this approach valid? What would you recommend in varying the amount and frequency of soil ingested over time? Are data available to support use of age-specific ingestion rates for soil-pica children?

- Are sufficient data available for establishing a scientifically defensible soil ingestion rate for adults who exhibit soil-pica behavior? If so, what soil ingestion rate do you recommend?

Topic #3: Means for identifying people with soil-pica behavior. An important element of ATSDR's public health mission is to prevent unhealthy exposures to hazardous chemicals. Thus, the agency is interested in how health professionals and parents can identify children who exhibit soil-pica behavior. More specifically:

- ATSDR has reviewed studies that employed analytical, observational, and questionnaire techniques for identifying children who exhibit soil-pica behavior. What are the strengths and weaknesses of these methods? Are there other methods available to identify people with soil-pica behavior? Considering the pros and cons of each method, which method do you think ATSDR should use to identify people with soil-pica behavior?

Topic #4: Additional topics. What critical research needs should be addressed to provide ATSDR greater insight into the public health implications of soil-pica behavior? What is known about the causes of soil-pica behavior? Does the bioavailability of metals in soil change with the amount of soil that is ingested? Is soil-pica behavior "normal"? Please bring to ATSDR's attention any other topics relevant to soil-pica behavior that are not addressed by the aforementioned questions.

When discussing the charge questions, please submit citations for references that ATSDR should consider when evaluating soil-pica behavior.

APPENDIX C

WORKSHOP AGENDA

ATSDR Agency for Toxic Substances & Disease Registry
Division of Health Assessment & Consultation

ATSDR Soil-Pica Workshop

Lenox Inn Buckhead
3387 Lenox Road, NE
Atlanta, GA

June 7–8, 2000

Agenda

WEDNESDAY, JUNE 7, 2000

Introduction and opening comments

8:00 AM	Registration	
8:30 AM	Welcome, introductions, and logistics	*Catherine McKinney*
8:45 AM	Goals and charge to workshop	*Henry Falk*
9:00 AM	Overview of ATSDR's Child Health Initiative	*Rob Amler*
9:15 AM	Purpose of meeting; review of charge	*Catherine McKinney*
9:30 AM	Definition of soil-pica, overview of soil-pica in ATSDR assessments, and site-specific example	*David Mellard*
9:45 AM	Community perspectives on soil-pica behavior	*Michael Maes* *Anthony Thomas*
10:00 AM	B R E A K	

Discussion on the prevalence of soil-pica

10:15 AM	Incidental influences on total dust/soil ingestion	*Natalie Freeman*
10:30 AM	Geophagical clays: extraction, preparation, and distribution	*Don Vermeer*
10:45 AM	Open discussion on prevalence of soil-pica	*Panelists*
12:00 PM	L U N C H	
1:00 PM	Continued discussion on prevalence of soil-pica	*Panelists*

ERG

W E D N E S D A Y , J U N E 7 , 2 0 0 0 (c o n t i n u e d)

1:30 PM Comments from observers

1:45 PM Conclusions about prevalence of soil-pica ..... *Panelists*

Discussion on soil ingestion rates for pica children

2:00 PM Optional presentation by panel member on soil-pica ingestion rates ..... *TBD*

2:45 PM B R E A K

3:00 PM Open discussion on soil-pica ingestion rates ..... *Panelists*

4:30 PM Comments from observers

4:45 PM Conclusions about prevalence of soil-pica ingestion rates ..... *Panelists*

5:00 PM A D J O U R N

T H U R S D A Y , J U N E 8 , 2 0 0 0

Discussion on identifying soil-pica children

8:30 AM Activities contributing to exposure and ingestion of soil/dust .... *Natalie Freeman*

9:00 AM Open discussion on identifying soil-pica behavior ..... *Panelists*

10:15 AM B R E A K

10:30 AM Continued discussion on identifying soil-pica behavior ..... *Panelists*

11:00 AM Comments from observers

11:15 AM Conclusions about identifying soil-pica behavior ..... *Panelists*

11:45 AM L U N C H

Discussion on additional topics

1:00 PM Discussion on additional topics ..... *Panelists*

Closing discussion

2:00 PM Revisit key findings ..... *Panelists*

3:00 PM A D J O U R N