APPENDIX 2

SOIL INGESTION RATE

CTUIR Soil Ingestion Rate = 400 mg/d (all ages)

SUMMARY

Soil ingestion includes consideration of direct ingestion of dirt, mud, or dust, swallowing inhaled dust, mouthing of objects, ingestion of dirt or dust on food, and hand-to-mouth contact. The CTUIR soil ingestion rate is based on a review of EPA guidance, soil ingestion studies in suburban and indigenous settings, pica and geophagia, and dermal adherence studies. It is also based on Plateau subsistence lifestyles with their higher environmental contact rates, local climatic and geologic conditions, and the frequency of dust storms in the Columbia Plateau[1].

The soil ingestion rate of 400 mg/d for all ages is the upper bound for suburban children (EPA), and within the range of outdoor activity rates for adults. Subsistence lifestyles were not considered by the EPA guidance, but are generally considered to be similar in soil contact rates to construction, utility worker or military soil contact levels. However, it is lower than 480 mg/d to allow for some low-contact days and balanced with many 1-gram days and events such as root gathering days, tule and wapato gathering days, pow wows, rodeos, horse training and riding days, sweat lodge building or repair days, grave digging, and similar activities. There are also likely to be many high or intermediate-contact days, depending on the occupation (e.g., wildlife field work, construction or road work, cultural resource field work).

1.0 EPA Guidance

EPA has reviewed the studies relevant to suburban populations and has published summaries in its Exposure Factors Handbook (1989, 1991, and 1997). In the current iteration of the Exposure Factors Handbook[2], EPA reviewed the available scientific literature for children and identified seven key studies that were used to prepare recommended guidelines for evaluating the amount of soil exposure. The mean daily values in these studies ranged from 39 mg/day to 271 mg/day with an average of 146 mg/day for soil ingestion and 191 mg/day for soil and dust ingestion. Based on these studies, EPA originally recommended a value of 200 mg/day. EPA now recommends 100 mg/d as a mean value for children in suburban settings, 200 mg/day as a conservative estimate of the mean, and a value of 400 mg/day as an “upper bound” value (exact percentile not specified). Most state and federal guidance uses 200 mg/d for children.

[1] WA Department of Ecology (2003) Columbia Plateau Windblown Dust Natural Events Action Plan. Publication 03-02-014. Website: http://www.ecy.wa.gov/pubs/0302014.pdf

[2] Environmental Protection Agency. 1997. Exposure Factors Handbook. Volumes I, II, III. U.S. Environmental Protection Agency, Office of Research and Development. EPA/600/P-95/002Fa.

For adults, the USEPA now suggests a mean soil ingestion rate in suburban settings of 50 mg/day for adults (USEPA, 1997), which has been decreased from 100 mg/d as recommended in earlier guidance. However, EPA says that this rate is still highly uncertain and has a low confidence rating due to lack of data. An adult soil ingestion rate of 100 mg/day is most commonly used for residential or agricultural settings.

Other EPA guidance such as the Soil Screening Level Guidance[3] recommends using 200 mg/d for children and 100 mg/d for adults, based on RAGS HHEM, Part B (EPA, 1991) or an age-adjusted rate of 114 mg/d assuming 30 years of exposure averaged over 70 years of life.

A value for an ingestion rate for outdoor activities is no longer given in the 1997 Exposure Factors Handbook for adults as "too speculative." However, the soil screening guidance still recommends 330 mg/d for a construction or other outdoor worker, and risk assessments for construction workers typically use a rate of 480 mg/d.

Other recommended values are also used by risk assessors. For example, some states recommend the use of 1 gram per acute soil ingestion event[4] to approximate a non-average day for children, such as an outdoor day.

2.0 Military Guidance

The US military assumes 480 mg per exposure event[5] or per field day. For military risk assessment, the US Army uses the Technical Guide 230 (TG) as the tool to assist deployed military personnel when assessing the potential health risks associated with chemical exposures.[6] No database is available to estimate incidental soil ingestion for adults in general or for military populations either during training at continental U.S. facilities or during deployment. Department Of Defense (2002)[7] recommendations for certain activities such as construction or landscaping which involve a greater soil contact rate is a soil ingestion rate of 480 mg/day. This value is based on the assumption that the ingested soil comes from a 50 µm layer of soil adhered to the insides of the thumb and the fingers of one hand. DOD assumed that the deployed military personnel would be exposed at both the high ingestion rate and a mean ingestion rate throughout the

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[3] EPA (1996) Soil Screening Guidance: Technical Background Document, EPA/540/R-95/128, July 1996 (http://www.epa.gov/superfund/resources/soil/toc.htm#p2), and EPA (2002) Supplemental Guidance For Developing Soil Screening Levels For Superfund Sites. OSWER 9355.4-24 (http://www.epa.gov/superfund/resources/soil/ssg_main.pdf),

[4] MADEP (1992). Background Documentation For The Development Of An "Available Cyanide" Benchmark Concentration. http://www.mass.gov/dep/ors/files/cn_soil.htm

[5] http://www.gulflink.osd.mil/pesto/pest_s22.htm, citing US Environmental Protection Agency, Office of Research and Development, Exposure Factors Handbook, Volume I, EPA/600/P-95/002a, August 1997 as the basis for the 480 mg/d.

[6] USACPPM TG 230A (1999). Short-Term Chemical Exposure Guidelines for Deployed Military Personnel. U.S. Army Center for Health Promotion and Preventive Medicine.
Website: http://www.grid.unep.ch/btf/missions/september/dufinal.pdf

[7] Reference Document (RD) 230, "Exposure Guidelines for Deployed Military" A Companion Document to USACHPPM Technical Guide (TG) 230, "Chemical Exposure Guidelines for Deployed Military Personnel", January 2002. Website: http://chppm-www.apgea.army.mil/desp/; and http://books.nap.edu/books/0309092213/html/83.html#pagetop.

year. The two ingestion rates were averaged (half the days were spent at 480 and half at 50 mg/d) for a chronic average rate of 265 mg/d.

The UN Balkans Task Force assumes that 1 gram of soil can be ingested per military field day[8].

3.0 Studies in suburban or urban populations

Written knowledge that humans often ingest soil dates back to the classical Greek era. Soil ingestion has been widely studied from a perspective of exposure to soil parasite eggs and other infections. More recently, soil ingestion was recognized to be a potentially significant pathway of exposure to contaminants, and risk assessments initially used a high inadvertent, based on studies of pica children (e.g., Kimbrough, 1984). This triggered a great deal of research with industry (e.g., the Calabrese series) or federal funding (e.g., the DOE-funded studies of fallout and bomb test contamination).

Some of the key studies are summarized here. Other agencies (including the EPA[9] and California OEHHA) have reviewed more studies and provide more detail. To quote form OEHHA:

> "There is a general consensus that hand-to-mouth activity results in incidental soil ingestion, and that children ingest more soil than adults. Soil ingestion rates vary depending on the age of the individual, frequency of hand-to-mouth contact, seasonal climate, amount and type of outdoor activity, the surface on which that activity occurs, and personal hygiene practices. Some children exhibit pica behavior which can result in intentional ingestion of relatively large amounts of soil."[10]

In general, two approaches to estimating soil ingestion rates have been taken. The first method of involves measuring the presence of (mostly) non-metabolized tracer elements in the feces of an individual and soil with which an individual is in contact, generally in controlled (largely indoor) situations. The other method involves measuring the dirt adhered to an individual's hand and observing hand-to-mouth activity. Results of these studies are associated with large uncertainty due to their somewhat qualitative nature, but some studies include specific activities relevant to outdoor lifestyles.

3.1 Studies in Children

Early studies in children focused on pica (see below) and unique food-related events. In particular, one study of soil ingestion from "sticky sweets" was estimated at 10 mg to 1 g/d (Day et al, 1975).

Hawley (1985) estimated that the amount ingested by young children during outdoor activity between May and October is 250 mg/d. For outdoor activities from May through

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[8] UNEP/UNCHS Balkans Task Force (BTF) (1999). The potential effects on human health and the environment arising from possible use of depleted uranium during the 1999 Kosovo conflict. www.grid.**un**ep.ch/btf/missions/september/dufinal.pdf

[9] http://www.epa.gov/ncea/pdfs/efh/sect4.pdf.

[10] California Office of Environmental Health Hazard Assessment, Technical Support Document for Exposure Assessment and Stochastic Analysis, Section 4: Soil Ingestion. http://www.oehha.ca.gov/air/hot_spots/pdf/chap4.pdf

October, Hawley estimated the ingestion amount as 480 mg per active day, assuming that 8 hours is spent outdoors per day, 2 d/week.

Other early tracer studies in American children (Binder, et al., 1986) resulted in large ranges of estimates of soil ingestion for several reasons. In the Binder study (as in all subsequent studies), the particular tracer element makes a large difference in soil ingestion estimates. Clausing et al. (1987) followed basically the same approach for Dutch rather than American children. Neither study included the trace minerals from food or medicine. A third study (Van Wijnen et al., 1990) used the same approach, and was the first to include a consideration of camping and the presence or absence of gardens.

Thompson and Burmaster (1991) reanalyzed the original data on children from Binder et al. (1986) to characterize the distribution of soil ingestion by children. In studies with large numbers of children, pica children may be present, but most studies did not try to diagnose pica. On the other hand, not all children with high ingestion rates are pica children, so caution must be exercised when identifying pica children merely on the basis of high soil ingestion. The reanalysis indicates a mean soil ingestion rate of 91 mg/d, and a 90th percentile of 143 mg/d.

Davis et al. (1990), in Calabrese's laboratory, included an evaluation of food, medicine, and house dust as a better approximation of a total mass balance. As with the earlier studies, using titanium as the tracer results in estimates of large soil ingestion rates, while Al and Si tracers resulted in a narrower range of soil ingestion rates. Ti, however, is problematic because of its variability in food, Al is difficult to control since it is the third most abundant soil mineral and present in many household products, and Si is widespread and an essential trace element for plants and animals (although apparently not for humans). This illustrates the difficulty of using mineral tracers to calculate mass balance and soil ingestion, but trace studies provide the most quantitative estimates.

Calabrese et al. (1989) based estimates of soil ingestion rate in children in a home and university daycare setting on measurements of eight tracer elements (aluminum, barium, manganese, silicon, titanium, vanadium, yttrium, and zirconium). The study population consisted of 64 children between one and four years old in the Amherst, Massachusetts. They used a method similar to Binder et al. (1986) but included an improved mass balance approach. They evaluated soil ingestion over eight days rather than three days, and collected duplicate samples of food, medicine, and house dust. In addition, the children used tracer-free toothpaste and ointment. The adult (n = 6) validation portion of the study indicated that study methodology could adequately detect soil ingestion at rates expected by children. Recovery data from the adult study indicated that Al, Si, Y, and Zr had the best recoveries (closest to 100%). Zirconium as a tracer was highly variable and Ti was not reliable in the adult studies. The investigators conclude that Al, Si, and Y are the most reliable tracers for soil ingestion. This was also the first study to evaluate whether pica children were present in the sampled population; one diagnosed pica child was found.

Stanek and Calabrese (1995a) adjusted their 1989 data for the 64 children. The primary adjustment was related to intestinal transit time, which allowed an adjustment for clearance of minerals on days when fecal samples were not collected. They concluded that daily intake based on the "overall" multi-tracer estimates is 45 mg/day or less for 50 percent of the children and 208 mg/day or less for 95 percent of the children. When extended to an annual estimate, the range of average daily soil ingestion in the 64 children was 1 – 2268 mg/d; the median (lognormal) was 75 mg/d, the 90^{th} % was 1190 mg/d, and the 95^{th}% was 1751 mg/d. The known pica child was not included, and individual “outlier” results for individual tracers were also omitted. Even so, the range of rates is so large that it is evident that there are still methodological difficulties.

Stanek and Calabrese (1995a) also evaluated the number of days a child might have excessive soil ingestion events. An estimated 16% of children are predicted to ingest more than 1 gram of soil per day on 35-40 days of the year. In addition, 1.6% would be expected to ingest more than 10 grams per day for 35-40 days per year.

Stanek and Calabrese (1995b) published a separate reanalysis combining the data from their 1989 study with data from Davis et al. (1990) and using a different methodology. This methodology, the Best Tracer Method (BTM), is designed to overcome intertracer inconsistencies in the estimation of soil ingestion rates. The two data sets were combined, with estimates as follows: 50^{th} = 37 mg/d, 90^{th} = 156mg/d, 95^{th} = 217mg/d, 99^{th} = 535mg/d, mean = 104mg/d □758. Even with this method, they conclude that the large standard deviation indicates that there are still large problems with “input-output misalignment.” They also says that soil ingestion cannot even be detected, in comparison to food, unless more than 200 mg/d is ingested, rather than lower rates as they indicated in 1989.

Stanek et al. (2000) conducted a second study of 64 children aged 1-4 at a Superfund site in Montana, using the same methods as they did in their earlier study, with 3 additional tracers. Soil, food and fecal samples were collected for a total mass balance estimate. The home or daycare settings were not described, nor were the community conditions or the typical daily activities of the children, and 32% of the soil ingestion estimates were excluded as outliers. In addition, only soil with a grain size of 250 um or less was used; no explanation of concentration differences between large and small grain sizes were given (see discussion on dermal adherence) and no concentration data were included.

3.2 Studies in Adults

Only a few soil ingestion studies in adults have been done because the attention has been focused on children, who are known to ingest more soil and are more vulnerable to toxicity of contaminants. Stanek, Calabrese and co-authors (1997) conducted a second adult pilot study (n = 10) to compare tracers. This study was done as a method validation, and was “not designed to estimate the amount of soil normally ingested by adults.” Each adult was followed for 4 weeks. The median, 75th percentile, and 95th percentile soil ingestion estimates were 1, 49, and 331 mg/day, with estimates calculated as the median of the three trace elements Al, Si, and Y.

4.0 Studies in Indigenous Populations

Studies of soil ingestion in indigenous populations have largely centered on estimates of past exposure (or dose reconstruction) of populations affected by atomic bomb tests such as the Marshall Islands (tropical island) and Maralinga (Australian desert) evaluations.

Haywood and Smith (1992) evaluated potential doses to aboriginal inhabitants of the Maralinga and Emu areas of South Australia, where nuclear weapons tests in the 1950s and 1960s resulted in widespread residual radioactive contamination. Annual doses to individuals following an aboriginal lifestyle could result in an annual effective dose equivalents of several mSv within contours enclosing areas of several hundred square kilometers. The most significant dose pathways are inhalation of resuspended dust and ingestion of soil by infants. Haywood and Smith constructed a table showing hours per week sleeping, sitting, hunting or driving, cooking or butchering, and other activities. The authors state that in this climate

> "virtually all food, whether of local origin or purchased, has some dust content by the time of consumption due to methods of preparation and the nature of the environment. A total soil intake in the region of 1 gpd was estimated based on fecal samples of nonaboriginals during field trips. This must be regarded as a low estimate of soil ingestion by aboriginals under camp conditions. In the absence of better information, a soil intake of 10 gpd has been assumed in the assessment for all age groups."

They noted a "very high occurrence of cuts and scratches with a high percentage being classified as dirty...puncture wounds on the feet were frequent. "

The Marshall Island indigenous peoples have also been studied. In a study of the gastrointestinal absorption of plutonium, Sun and Meinhold (1997) assumed a soil ingestion rate of 500 mg/d. This was based on the primary work of Haywood and Smith who "reported an average soil intake of 10,000 mg/d in dose assessments for the Emu and Maralinga nuclear weapons testing sites in Australia." The authors state that:

> "Haywood and Smith specifically discussed the effects of lifestyle on plutonium ingestion for the Australian aboriginal people: an average soil intake of 1,000 mg/d was established from the fecal samples of the investigators who made field trips to the affected areas."
>
> "It is difficult to quantitatively compare the amount of soil ingested by the Marshall Islanders and the Aboriginal people because of their different lifestyles. However, both societies live in close contact with their natural environment, although the Australian aboriginal people are nomadic, while the Marshallese have a lifestyle nearly like to that of industrial nations. LaGoy (1987) reported a maximum intake of 500 mg/d for adults in developed nations who do not exhibit habitual pica. This value, then, was taken to be a reasonably conservative average for the Marshallese people. Therefore, this work adopts 500 mg/d as the average life-time intake of soil by the Marshallese."

Simon (1998) reviewed soil ingestion studies from a perspective of risk and dose assessment. Certain lifestyles, occupations, and living conditions will likely put different individuals or different groups at risk to inadvertent soil ingestion. Because of their high dependence on the land, indigenous peoples are at highest risk for inadvertent ingestion, along with professions that may bring workers into close and continual contact with the soil. Most of the studies that Simon reviewed were related to geophagia (intentional soil ingestion; see below), which is relatively common worldwide. Simon recommends using a soil ingestion rate for indigenous people in hunters/food gathering/nomadic societies of 1g/d in wet climates and 2 g/d in dry climates. He recommends using 3 g/d for all indigenous children. Geophagia is assumed not to occur; if geophagia is common, Simon recommends using 5 g/d. These are all geometric means (lognormal) or modes (triangular distribution), not maxima.

These estimates are supported by studies of human coprolites from archaeological sites. For instance, Nelson (1999) noted that human coprolites from a desert spring-fed aquatic system included obsidian chips (possibly from sharpening points with the teeth), grit (pumice and quartzite grains from grinding seeds and roots), and sand (from mussel and roots consumption). Her conclusions are based on finding grit in the same coprolites as seeds, and sand in the same coprolites as mussels and roots. She concludes that "the presence of sand in coprolites containing aquatic root fibers suggests that the roots were not well-cleaned prior to consumption. Charcoal was present in every coprolite examined."

5.0 Geophagia

Despite the limited awareness of geophagia in western countries, the deliberate consumption of dirt, usually clay, has been recorded in every region of the world both as idiosyncratic behavior of isolated individuals and as culturally prescribed behavior (Abrahams, 1997; Callahan, 2003; Johns and Duquette, 1991; Reid, 1992). It also routinely occurs in primates (Krishnamani and Mahaney (2000). Indigenous peoples have routinely used montmorillonite clays in food preparation to remove toxins (e.g., in acorn breads) and as condiments or spices (in the Philippines, New Guinea, Costa Rica, Guatemala, the Amazon and Orinoco basins of South America). Clays are also often used in medications (e.g., kaolin clay in Kaopectate). But the most common occasion for eating dirt in many societies, especially kaolin and montmorillonite clays in amounts of 30g to 50g a day, is pregnancy. In some cultures, well-established trade routes and clay traders make rural clays available for geophagy even in urban settings. Clays from termite mounds are especially popular among traded clays, perhaps because they are rich in calcium (Callahan, 2003; Johns and Duquette, 1991).

There are two types of edible clays, sodium and calcium montmorillonite[11]. Sodium montmorillonite is commonly known as bentonite; the name is derived from the location of the first commercial deposit mined at Fort Benton, Wyoming USA. Bentonite principally consists of sodium montmorillonite in combination with 10 to 20% of various mineral impurities such as feldspars, calcite, silica, gypsum, and others. Calcium montmorillonite, the second type of montmorillonite, is also known as "living clay" for it principally consists of nutritionally essential minerals.

Geophagia has long been viewed as pathological by the western medical profession. However, this practice is so widespread and physiologically significant that is presumed to be important in the evolution of human dietary behavior due to its antidiarrheal, detoxification, and mineral supplementation potentials (Reid, 1992; Krishnamani and Mahaney, 2000).

Krishnamani and Mahaney (2000) propose several hypotheses that may contribute to the prevalence of geophagy:

(1) soils adsorb toxins.

(2) soil ingestion has an antacid action.

[11] http://www.the-vu.com/edible_clay.htm

(3) soils act as an antidiarrheal agent.

(4) soils counteract the effects of endoparasites.

(5) geophagy may satiate olfactory senses.

(6) soils supplement nutrient-poor diets. Some clays release calcium, copper, iron, magnesium, manganese, or zinc in amounts of nutritional significance (Johns and Duquette, 1991). This is especially important in pregnancy and at high altitudes.

Several studies of geophagia in pregnancy have been done. In countries such as Uganda where modern pharmaceuticals are either unobtainable or prohibitively expensive, ingested soils may be very important as a mineral supplement, particularly iron and calcium during pregnancy (Abrahams, 1997). One widely held theory suggests that iron deficiency is a major cause of geophagia[12]. Several reports have described an extreme form of geophagy (pica) in individuals with documented iron deficiency, although there has been uncertainty as to whether the iron deficiency was a cause of pica or a result of it. Some studies have shown that pica cravings in individuals with iron deficiency stop once iron supplements are given to correct the deficiency, suggesting that iron deficiency induces pica (and other) cravings during pregnancy. In addition, low blood levels of iron commonly occur in pregnant women and those with poor nutrition, two populations at higher risk for pica.

Edwards et al. (1994) studied 553 African American women who were admitted to prenatal clinics in Washington, D.C.. Serum ferritin concentrations of pica women were significantly lower during the second and third trimesters of pregnancy; the average values for three trimesters of pregnancy for both ferritin and mean corpuscular hemoglobin were significantly lower in pica women than their nonpica counterparts. Although not significantly different, the iron (66 vs. 84% RDA) and calcium (60 vs. 75% RDA) contents of the diets of pica women were less those of nonpica women.

A further hypothesis is presented by Callahan (2003). Regular consumption of soil might boost the mother’s secretory immune system. Monkeys that regularly eat dirt have lower parasite loads. In some cultures, clays are baked before they are eaten, which could boost immunity from previous exposures. For decades aluminum salts, like those found in clays, have been used as adjuvants in human and animal vaccines. Adjuvants are compounds that nonspecifically amplify immune response. Aluminum compounds make effective adjuvants because they are relatively nontoxic; the charged surfaces of aluminum salts absorb large numbers of organic molecules. Note that Al was one of Calabrese’s preferred tracers due to the assumption that it is not adsorbed and inert at trace levels (it is quite toxic at high levels).

6.0 Acute Soil Ingestion and Pica

There is a gradient between geophagy and pica, and there is not a clear distinction between the conditions. Pica is an obsessive-compulsive eating disorder typically defined as the persistent eating of nonnutritive substances for a period of at least 1

[12] http://www.ehendrick.org/healthy/001609.htm

month at an age in which this behavior is developmentally inappropriate. The definition also includes the mouthing of nonnutritive substances. Individuals presenting with pica have been reported to mouth and/or ingest a wide variety of nonfood substances, including, but not limited to, clay, dirt, sand, stones, pebbles, hair, feces, lead, laundry starch, vinyl gloves, plastic, pencil erasers, ice, fingernails, paper, paint chips, coal, chalk, wood, plaster, light bulbs, needles, string, and burnt matches.

Pica is generally thought of as a pediatric condition, but pica diagnoses include psychiatric conditions like schizophrenia, developmental disorders including autism, and conditions with mental retardation. These conditions are not characterized by iron deficiency, which supports a psychological component in the cause of pica.

Pica is seen more in young children than adults, with 10-32% of children aged 1 to 6 may exhibit pica behavior at some point[13]. LaGoy (1987) estimated that a value of 5 gpd is a reasonable maximum single-day exposure for a child with habitual pica. In June 2000, the U.S. Agency for Toxic Substances and Disease Registry appointed a committee to review soil pica. The committee settled on a threshold of pathological levels as consumption of more than 500 mg of soil per day but cautioned that the amount selected was arbitrary[14]. With this criterion, studies in the literature estimate that between 10 and 50% of children may exhibit pica behavior at some point. While this threshold may be appropriate in relatively clean suburban settings, it may not be appropriate for defining the pica threshold in rural settings where average soil ingestion is likely to be higher.

The occurrence of pica has been discussed with respect to risk assessment, especially for acute exposures. Calabrese et al. (1997) recognized that some children have been observed to ingest up to 25-60 g soil during a single day. When a set of 13 chemicals were evaluated for acute exposures with a pica exposure rate, four of these chemicals would have caused a dose approximating or exceeding the acute human lethal dose.

Regulatory guidance recommends 5 or 10g/d for pica children. Some examples are:

(1) EPA (1997) recommends a value of 10g/d for a pica child.

(2) Florida recommends 10g per event for acute toxicity evaluation[15].

(3) ATSDR uses 5 g/day for a pica child[16].

7.0 Data from dermal adherence

Dermal adherence of soil is generally studied in relation to dermal absorption of contaminants, but soil on the hands and face can be ingested, as well. Although this

[13] http://www.nlm.nih.gov/medlineplus/ency/article/001538.htm#Causes,%20incidence,%20and%20risk%20factors
[14] Summary report for the ATSDR Soil-Pica Workshop, Atlanta, Georgia, 2000. Available from: URL: http://www.atsdr.cdc.gov/NEWS/soilpica.html
[15] Proposed Modifications To Identified Acute Toxicity-Based Soil Cleanup Target Level, December 1999, www.dep.state.fl.us/waste/quick_topics/ publications/wc/csf/focus/csf.pdf .
[16] For Example: El Paso Metals Survey, Appendix B, www.atsdr.cdc.gov/HAC/PHA/**elpaso**/epc_toc.html.

body of literature is not typically used to estimate a quantitative contribution to soil ingestion, it can give relative estimates of soil contact rates between activities.

Two relevant papers from Kissel's laboratory are summarized here. Kissel, et al. (1996) included reed gatherers in tide flats. "Kids in mud" at a lakeshore had by far the highest skin loadings, with an average of 35 mg/cm^2 for 6 children and an average of 58 mg/cm^2 for another 6 children. Reed gatherers were next highest at 0.66 mg/cm^2 and an upper bound for reed gatherers of >1 mg/cm^2. This was followed by farmers and rugby players (approximately 0.4mg/cm^2) and irrigation installers (0.2mg/cm^2). Holmes et al. (1999) studied 99 individuals in a variety of occupations. Farmers, reed gatherers and kids in mud had the highest overall skin loadings. The next highest skin loadings on the hands were for equipment operators, gardeners, construction, and utility workers (0.3 mg/cm^2), followed by archaeologists, and several other occupations (0.15 – 0.1 mg/cm^2). Since reed gatherers, farmers, and gardeners had higher skin loadings, this is supporting evidence that these activities also have higher than average soil ingestion rates.

One factor that has not received enough attention is the grain size of adhering and ingested soil. Stanek and Calabrese (2000) said that variability in estimating soil ingestion rates using tracer elements was reduced when a grain size less than 250 um were excluded in order to reduce variability. Driver et al. (1989) found statistically significant increases in skin adherence with decreasing particle size. Average adherences of 1.40 mg/cm^2 for particle sizes less than 150 µm, 0.95 mg/cm^2 for particle sizes less than 250 µm and 0.58 mg/cm^2 for unsieved soils were measured (see EPA, 1992[17] for more details).

A consideration of grain size could affect the estimation of soil ingestion rates because the mineral and organic composition within a particular soil sample can vary with particle size and pore size. If soil adherence studies are conducted in a manner wherein sand is brushed off the hands while smaller grain sizes remain adhered, then tracer ratios could be altered, and would be different from the original unsieved soil. Soil loading on various parts of the body is collected with wipes, tape, or rinsing in dilute solvents, which would generally collect the smaller particle sizes[18].

8.0 Data from washed or unwashed vegetables.

Direct soil ingestion also occurs via food, for example from dust blowing onto food (Hinton, 1992), residual soil on garden produce or gathered native plants, particles on cooking utensils, and so on. However, there is very little quantitative data about soil on vegetation as-gathered, as-prepared, or as-eaten, which is a separate issue from root uptake of soil contaminants into edible materials. However, there is information on interception rate of dust particles deposited onto leafy surfaces, and information on soil

[17] EPA (1992). Interim Report: Dermal Exposure Assessment: Principles And Applications. Office of Health and Environmental Assessment, Exposure Assessment Group. /600/8-91/011B

[18] Soils are classified according to grain size (1mm = Very coarse sand; 0.5mm = Coarse sand; 0.25mm = Medium sand; 0.10mm = Fine sand; 0.05mm = Very fine sand; 0.002mm = Silt; <0.002mm = Clay). The Wentworth scale classifies particle sizes as ranges: sand = 1/16 to 2 mm; silt = 1/256 to 1/16 mm; clay = <1/256 mm.

ingestion by pasture animals. For example, Beresford and Howard (1991) found that soil adhesion to vegetation was highly seasonal, being highest in autumn and winter, and is important source of radionuclides to grazing animals. Palacios et al. (2002) evaluated lead levels in the aerial part of herbage near a Superfund site. A water washing pre-treatment of the vegetal samples considerably diminished the concentration of lead.

Kissel et al. (2003) evaluated concentrations of arsenic and lead in rinsed, washed, or peeled garden vegetables. He found that concentrations of lead and arsenic in washed or peeled potatoes or lettuce were generally lower, as expected, although the concentration of lead in peeled potatoes was higher than in rinsed or washed potatoes.

9.0 Subsistence lifestyles and rationale for soil ingestion rate

The derivation of the soil ingestion rate is based on the following points:

- The foraging-subsistence lifestyle is lived in close contact with the environment.
- Plateau winds and dust storms are fairly frequent. Incorporated into overall rate, rather than trying to segregate ingestion rates according to number of high-wind days per year because low-wind days are also spent in foraging activities.
- The original Plateau lifestyle – pit houses, caches, gathering tules and roots - includes processing and using foods, medicines, and materials. This is considered but not as today's living conditions.
- The house is assumed to have little landscaping other than the natural conditions or xeriscaping, some naturally bare soil, a gravel driveway, no air conditioning (more open windows), and a wood burning stove in the winter for heat.
- All persons participate in day-long outdoor group cultural activities at least once a month, such as pow-wows, horse races, and seasonal ceremonial as well as private family cultural activities. These activities tend to be large gatherings with a greater rate of dust resuspension and particulate inhalation. These are considered to be 1-gram events or greater.
- 400 mg/d is based on the following:
    1. 400 mg/d is the upper bound for suburban children (EPA); traditional or subsistence activities are not suburban in environs or activities
    2. This rate is within the range of outdoor activity rates for adults (between 330 and 480); subsistence activities are more like the construction, utility worker or military soil contact levels. However, it is lower than 480 to allow for some low-contact days.
    3. The low soil-contact days are balanced with many 1-gram days and events (as suggested by Boyd et al., 1999) such as root gathering days, tule and wapato gathering days, pow wows, rodeos, horse training and riding days, sweat lodge building or repair days, grave digging, and similar activities. There are also likely to be many high or intermediate-contact days, depending on the occupation (e.g., wildlife field work, construction or road work, cultural resource field work).
    4. This rate is lower than Simon estimate of 500 mg/d and lower than the recommendations of 3 g/d for indigenous children and 2 g/d for indigenous adults in arid environments. It is also lower than the 5 or 10 grams he estimated for purely aboriginal lifestyles. For original housing

conditions a higher rate would be clearly justified; for today's housing conditions, a lower rate is adequate.

5. This rate does not account for pica or geophagy
6. Primary data is supported by dermal adherence data in gatherers and 'kids in mud'. Tule and wapato gathering are kid-in-mud activities
7. This rate includes a consideration of residual soil on roots (a major food category) through observation and anecdote, but there is no quantitative data.
8. This rate includes a consideration of the number of windy-dusty days, but without further quantification of air particulates.

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