Exposure Scenario for CTUIR Traditional Subsistence Lifeways

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Outline

1. Introduction

This report presents the updated exposure factors for the CTUIR exposure scenario. Some of the exposure factors in the original reference (Harris and Harper, 1977) were updated in the Spokane Tribe's scenario (Harper et al., 2002). The present report includes those updated exposure factors and further research.

1.1 Basis

The scenario reflects a traditional cultural subsistence lifestyle. Information on the CTUIR eco-cultural lifestyle has been presented previously, and is summarized as follows.

> The CTUIR culture, which has co-evolved with nature through thousands of ecological education, has provided its people with their traditional environmental knowledge. Throughout the year, when the CTUIR traditional American Indian participates in activities such as hunting and gathering for foods, medicines, ceremonies, and subsistence, the associated activities are as important as the end product. All of the foods and implements gathered and manufactured by the traditional American Indian are interconnected in at least one, but more often in many ways. The people of the CTUIR community follow cultural teachings brought down through history from the elders. Our individual and collective well-being is derived from membership in a healthy community that has access to ancestral lands and traditional resources and from having the ability to satisfy the personal responsibility to participate in traditional community activities and to help maintain the spiritual quality of our resources. This is an ancient oral tradition of cultural norms. The material or fabric of this tradition is unique, and is woven into a single tapestry that extends from far in the past to long into the future. In order to encompass the wide range of factors directed tied to the traditional American Indians of the CTUIR, a risk assessment has to be designed and scaled appropriately (Harris, 1998).

EPA is required to identify populations who are more highly exposed; for example, subsistence populations and subsistence consumption of natural resources (Executive Order 12898[1]). EPA is also required to protect sensitive populations.[2] Some of the factors known to increase sensitivity include developmental stage, age (very young and very old), gender, genetics, and health status[3], and this is part of EPA's human health research strategy.[4]

> "The Superfund law requires cleanup of the site to levels which are protective of human health and the environment, which will serve to minimize any disproportionately high and adverse environmental burdens impacting the EJ community"[5].

CERCLA ARARs include Treaties such as the Migratory Bird Treaty Act of 1918, 16 U.S.C. § 703 et seq. Therefore, CTUIR believes that other Treaties, including the Treaty of 1855, are ARARs as well. In addition, the situation that existed when Hanford was established

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[1] White House, 1994. Federal Actions To Address Environmental Justice In Minority Populations And Low income Populations: Feb. 11, 1994; 59 FR 7629, Feb. 16, 1994.
[2] *Superfund Exposure Assessment Manual*. EPA/540/1-88/001 OSWER directive 9285.5-1. U.S. Environmental Protection Agency Office of Remedial Response, U.S. Environmental Protection Agency, Washington, D.C. 1988.
[3] http://www.epa.gov/nheerl/research/childrens_health.html
[4] EPA/600/R-02/050, September 2003 (posted at http://www.epa.gov/nheerl/publications/).
[5] http://www.epa.gov/region02/community/ej/superfund.htm

included CTUIR members living in permanent fishing villages along the Hanford Reach. This scenario reflects that fact.

> Section 120(a)(2) of CERCLA provides that all guidelines, rules, regulations, and criteria for preliminary assessments, site investigations, National Priorities List (NPL) listing, and remedial actions are applicable to federal facilities to the same extent as they are applicable to other facilities. No federal agency may adopt or utilize any such guidelines, rules, regulations, or criteria that are inconsistent with those established by EPA under CERCLA.[6]

CTUIR believes that this CERCLA language means that DOE and USFWS cannot abrogate the Treaty of 1855 by developing land use plans that do not include the exercise of Treaty rights where they existed before Hanford was established, or do not recognize case law such as fishing and hunting rights cases.

1.2 Scenario Construction

This scenario was developed in a manner consistent with CERCLA guidance[7] and the EPA Exposure Factors Handbook.[8] Constructing these scenarios requires a basic understanding of the subsistence (or traditional) lifestyle. What do "subsistence" and "tradition" mean with respect to exposure scenarios? Traditional lifestyles are often misunderstood to be a recreational (e.g. sport hunting) supplement to an otherwise suburban scenario, rather than being an entire cultural/spiritual lifestyle inextricable from the environment. Another misconception is that some activities are 'cultural' or 'religious' while others are secular and optional. This leads to flawed concepts, for instance, that only ceremonial meals are cultural, while all others are merely nutritional and therefore a personal preference or lifestyle choice. To the contrary, in a traditional lifestyle all food has both nutritional and spiritual benefits, and all activities have practical survival as well as spiritual aspects. Therefore, our exposure scenarios do not separate exposure factors into cultural or residential subsets.

The exposure scenario reflects a traditional subsistence lifestyle. "Subsistence" refers to the hunting, fishing, and gathering activities that are fundamental to the way of life of many indigenous peoples. Subsistence utilizes traditional, small-scale technologies for harvesting and preserving foods as well as for distributing the produce through communal networks of sharing and bartering. Because it is often misinterpreted, an explanation of "subsistence" is taken from the National Park Service:

> "While non-natives tend to define subsistence in terms of poverty or the minimum amount of food necessary to support life, native people equate subsistence with their culture. Among many tribes, maintaining a subsistence lifestyle has become the symbol of their survival in the face of mounting political and economic pressures. It defines who they are as a people. To Native Americans who continue to depend on natural resources, subsistence is more than eking out a living. While it is important to the economic well-being of their communities, the subsistence lifestyle is also the basis of cultural existence and survival. It is a communal activity. It unifies communities as cohesive functioning units through collective production

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[6] 40CFR300 National Oil and Hazardous Substances Pollution Contingency Plan, Preamble http://www.epa.gov/superfund/action/guidance/remedy/pdfs/ncppreamble61.pdf

[7] EPA Risk Assessment Guidance for Superfund, several volumes at http://www.epa.gov/superfund/programs/risk/toolthh.htm.

[8] EPA (1997). *Exposure Factors Handbook,* EPA/600/P-95/002Fa, http://www.epa.gov/ncea/pdfs/efh/sect5.pdf

> and distribution of the harvest. Some groups have formalized patterns of sharing, while others do so in more informal ways. Entire families participate, including elders, who assist with less physically demanding tasks. Parents teach the young to hunt, fish, and farm. Food and goods are also distributed through native cultural institutions. Most require young hunters to distribute their first catch throughout the community. Subsistence embodies cultural values that recognize both the social obligation to share as well as the special spiritual relationship to the land and resources. This relationship is portrayed in native art and in many ceremonies held throughout the year."[9]

In economic terms, a subsistence economy is one in which currency is limited because many goods and services are produced and consumed by the same families or bands. Today, currency (inedible symbols of specified quantities of useful resources) is limited, but important.

> "The modern-day subsistence family depends on the tools of the trade, most of which are expensive. Snowmobiles, gasoline, guns, fishing nets, and sleeping bags are necessities. Subsistence households also enjoy many of the modern conveniences of life, and are saddled with the economic demands which come with their acquisition. Today's subsistence family generates much-needed cash as wage-labourers, part-time workers and trappers, professional business people, traditional craftmakers, and seasonal workers. A highly-integrated interdependence between formal (cash-based) and informal (barter and subsistence-based) economic sectors has evolved."[10]

Once the activities comprising a particular subsistence lifestyle are known, they are translated into a format that is used for risk assessment. This translation captures the degree of environmental contact that occurs through activities and diet, expressed as numerical "exposure factors." Direct exposure pathways include exposure to abiotic media (air, water, and soil), which can result in inhalation, soil ingestion, water ingestion, and dermal exposure. Indirect pathways refer to contaminants that are incorporated into biota and subsequently expose people who ingest or use them. There are also unique exposure pathways that are not accounted for in scenarios for the general public, but may be significant to people with certain traditional specialties such as pottery or basket making, flint knapping, or using natural medicines, smoke, smudges, paints and dyes. These activities may result in increased dust inhalation, soil ingestion, soil loading onto the skin for dermal exposure, or exposure via wounds, to give a few examples. While the portals of entry into the body are the same (primarily via the lungs, skin, mouth), the amount of contaminants may be increased, and the relative importance of some activities (e.g., basketmaking, wetlands gathering), pathways (e.g., steam immersion or medicinal infusions) or portals of entry (e.g., dermal wounding) may be different than for the general population.

Together, this information is then used to calculate the direct and indirect exposure factors. This process follows the general sequence:

1. Environmental setting – identify what resources are available;
2. Lifestyle description – activities and their frequency, duration and intensity, and uses of natural resources;
3. Diet (indirect exposure factors);
4. Pathways and media;

[9] National Park Service: http://www.cr.nps.gov/aad/cg/fa_1999/Subsist.htm
[10] http://arcticcircle.uconn.edu/NatResources/subsistglobal.html

5. Exposure factors - Crosswalk between pathways and direct exposure factors; cumulative soil, water and air exposures.

Traditional or subsistence scenarios are similar in format to existing residential recreational, or occupational exposure scenarios, but reflect and are inclusive of tribal cultural and lifestyle activities. They are comprised of:

1. standard exposure pathways and exposure factors (such as inhalation or soil ingestion but with increased environmental contact rates),
2. traditional diets composed of native plants and animals possibly supplemented with a home garden, and
3. unique pathways such as the sweatlodge.

Tribal exposure scenarios pose a unique problem in that much of the specific cultural information about the uses of plants and animals for food, medicine, ceremonial, and religious purposes is proprietary. Therefore, the challenge to the scenario developer is to ensure that all human exposures received during the procurement and use of every resource are accounted for without revealing condifential information. Risk assessment methods are fairly qualitative and high-level. Risk assessment exposure equations require simple summary input parameters. For example, the dietary portion of CERCLA risk assessments is quite general (fish, meat, above-ground and below-ground vegetation, or root-fruit-leafy plants, sometimes with a little more detail), and typically uses generic soil-to-plant transfer factors that are not species specific. Therefore, the choices for the risk assessor are:

(1) to create an encyclopedia of activities and resources, and then perform thousands of exposure calculations based on the myriad of activities and the typical 200+ species used in a subsistence lifestyle, and then sum the exposures with the knowledge that the species and activity lists are inevitably incomplete and probably include proprietary information. Further, species-specific uptake information is lacking so generic assumptions are used.

(2) to sum intakes of long lists of species into single global intakes of above- and below-ground plants before applying generic uptake or bioconcentration factors, thus losing any detail that had been achieved by developing the long lists.

(3) using representative species and ignoring other members of each trophic level or feeding guild and the details of different uses, preparation methods, and so on (for example; using an estimate that a hunter obtains x number of deer per year while ignoring other large and small game, the different parts consumed, and losing the whole-diet and multiple-uses concepts).

(4) asking a Tribe to identify a few areas and species that are particularly important, and doing the risk assessment only for those areas and species, thus losing all cumulative perspective of the lifestyle and the risks it could pose.

(5) ensuring that all potential species and their uses are accounted for by taking a top-down rather than bottom-up (inventory or encyclopedia) approach, with staple resources representing classes of resources such that a full-calorie diet is achieved and 24 hours per day are accounted for.

We have chosen the last option based on a decade of experience. This is the level of detail that a risk assessment can handle, does not waste time by constructing long lists of species that are simply rolled up into global sums, includes a consideration of all species and variations on their uses, and avoids revealing proprietary information. It is also comparable to the feeding guild approach to ecological risk assessments, and allows an easier use of the results of the ecological risk assessment as input to the native diet portion of the human risk assessment.

The process for ensuring a full accounting of species, uses, and environmental contacts are presented in the following sections. The summary exposure factors are then compared to literature and guidance for further documentation. Because the primary exposure factors are larger than EPA typically uses, extensive documentation is included in appendices.

2. Assumptions and Approach

This scenario reflects an active, outdoor lifestyle with a subsistence economic base. Subsistence food sources include gathering, gardening, hunting, pasturing livestock, and fishing. The forager relies all or in part on native foods and medicines, while the residential farmer relies on domesticated but self-produced foods. Thus, the CTUIR scenario is at the foraging end of the subsistence spectrum, while the residential farmer is at the domesticated end of the subsistence spectrum. Both are active, outdoor lifestyles, and are consistent with the reasonable maximum exposure (RME) approach to baseline risk assessment.

This is a full-time multipathway scenario, to be applied within each area being assessed, consistent with EPA guidance on performing baseline risk assessments. The purpose of CERCLA baseline risk assessments is to evaluate the risks that would occur to a person engaging in defined sets of activities *absent* land use restrictions. It reflects the activities that the person would engage in if the site were not contaminated. Therefore, a baseline risk assessment is applied irrespective of possible institutional controls or other restrictions that may be needed as part of the remedy in order to protect human health.

Unrestricted access is the typical baseline risk assessment “no action” scenario. This includes CTUIR residence, because permanent year-round fishing villages with resident CTUIR members were present along the Hanford Reach when Hanford was established. This scenario is not a visiting scenario like a recreational scenario. It is a full-time scenario. This means that the forager may obtain a site-specific percentage of his and her food from an irrigated garden to supplement the native plants in his or her diet. The ratio of gathered to grown plants will vary with the size and resources of the assessment area, as will the ratio of game to livestock, upland to riparian resources, and so on. The forager also uses a well and/or seep and/or river for drinking water, sweat lodge water, and irrigation, also consistent with the general CERCLA principles of evaluating reasonable maximum exposures.

Exposure factors for the traditional CTUIR lifestyle are presented below. One of the key misunderstandings is how a subsistence lifestyle can be applied to a constrained area. The risk assessment methodology uses an interface between lifestyle and contamination termed an exposure point concentration. The guidance for risk assessment is to assume that the RME individual is constrained to the area being assessed (for subsistence or residential scenarios), or receives exposures only during visits to the area being assessed (for recreational or occupational scenarios). The subsistence scenario is not to be divided into partial scenarios, such as upland hunting or localized gathering, unless those are also complete scenarios, accounting for a full life but with emphasis on a specialized activity (e.g., the subsistence person who specializes in fishing for himself and others and trades fish for game and plants, or the subsistence person who specializes in gathering food and medicinal plants and materials and trades those items for fish and game).

2.1 Major Activities

A description of activities for the purposes of developing exposure factors includes parameters describing:

- Frequency of activity
  - Daily, weekly, monthly
- Duration of activity
  - Hours at a time
  - Number of years
- Intensity of environmental contact and intensity of activity
  - For soil ingestion and dermal exposure, is the activity more than, less than, or equal to gardening, camping, construction/excavation, or sports?
  - For inhalation rates and calorie needs, is the activity level more than, less than, or equal to standard EPA activity levels for specific activities with known respiration rates and caloric expenditure?

A brief description of major activities in the subsistence lifestyle is presented here (Table 1). This table and the following material is presented to explain the complexity and variety of activities involved in each activity. It is not really possible to separate "hunting" from other activities, since hunting is simply part of living, just as going to the grocery store is part of suburban living. However, we have founf it useful to explain some aspects of the lifestyle because this sets the stage for developing exposure factors.

Table 1. Major Activity Categories

Activity Type	***General Description***
Hunting	Hunting includes a variety of preparation activities of low to moderate intensity. Hunting occurs in terrain ranging from flat and open to very steep and rugged. It may also include setting traplines, waiting in blinds, digging, climbing, etc. After the capture or kill, field dressing, packing or hauling, and other very strenuous activities occur, depending on the species. Subsequent activities include cutting, storing (e.g., smoking or drying), etc.
Fishing	Fishing includes building weirs and platforms, hauling in lines and nets, gaffing or gigging, wading (for shellfish), followed by cleaning the fish and carrying them to the place of use. Activities associated with smoking and constructing drying racks may be involved.
Gathering	A variety of activities is involved in gathering, such as hiking, bending, stooping, wading (marsh and water plants), digging, and carrying.
Sweatlodge Use	Sweatlodge building and repairing is intermittent, but collecting firewood is a constant activity.
Materials and Food Use	Many activities of varying intensity are involved in preparing materials for use or food storage. Some are quite vigorous such as pounding or grinding seeds and nuts into flour, preparing meat, and tanning hides, Many others are semi-active, such as basket making, flintknapping, construction of storage containers, cleaning village sites, sanitation activities, home repairs, and so on.

The following figure lists some of the activities involved in the major categoires. The purpose of this figure is to show that many activities are involved in major activity categories, and that resources and activities are interlinked. For instance, materials gathered in one area may be required to construct implements (such as baskets) used when gathering in a second location, or a hide must be brain-tanned to make a drum head to sing the songs required for ceremonies in preparation for fishing.

Figure 1. Traditional Lifeways – Typical activities in the activity categories.

Hunting	***Sweatlodge***	***Gathering***	***Fishing***
Learn skills, TEK	*Learn skills, songs*	*Learn skills, TEK*	*Learn skills, TEK*
Making tools	*Build lodge from natural materials*	*Previous gathering*	*Make nets, poles, platforms, tools*
Sweat Purify	*Gather rocks*	*Make baskets, bags*	*Travel to location*
Vigorous activity in hunting	*Chop firewood*	*Hike to areas*	*Catch fish, haul out*
Pack meat out	*Prepare for use, get water*	*Cut, dig, harvest*	*Clean, can, hard dry, soft dry, smoke, eat whole fish or fillet or liver or soup*
Process	*Use Lodge, sing, drink water, inhale steam and smudges*	*Carry out items*	*Return carcasses to ecosystem, use as fertilizer*
Scrape hides	*Close area & fire*	*Wash, peel, process, split, spin, dye*	
Tan, use other parts		*Cook and eat or make product or make medicine*	
Cook, smoke, dry, eat meat and organs			
Diff. habitats			

Table 2 shows the thought process in cross-walking activity categories with exposure pathways and media in order to develop exposure factors. Because exposure factors are specific to media and exposure pathways (via portals of entry into the body), they must sum across activities. The basic process is to sum inhalation rates according to the amount of time spent in each activity. The time or activity profile is presented in the next section; Table 2 shows the thought process and identifies some of the factors that must be considered to ensure that the complexity of activities and diversity of resources are accounted for.

Table 2. Examples of factors to consider within major activity categories.
This is not a complete listing; it is an example of the thought process used to cross-walk exposure pathways and categories of subsistence activities.

	Hunting and associated activities	***Fishing and associated activities***	***Gathering and associated activities***	***Sweatlodge and associated activities***	***Material and food use and processing***	***Totals for major exposure factor categories***
Indirect pathways - food, medicine, tea, other biota ingestion (diet)	*n* deer /yr diet; Total large-small game, fowl. Organs eaten	*n* fish /yr diet; Total pounds or meals/day-wk-yr; Organs eaten.	Includes foods, medicines, teas, etc.	No food, but herbal particulates are inhaled.	Both as-gathered and as-eaten forms; cleaning and cooking methods.	Must account for all calories and 100-200 plant species; parts eaten
Soil, sediment, dust, and mud ingestion	Terrain types; Degree of dermal contact; How much dirt and mud.	Sediment contact, dust and smoke if drying; weir construction in mud.	External soil on plants; cooking method such as pit cooking; ingestion when gathering.	Includes building the sweat lodge and getting materials..	Includes incidental soil remaining on foods; pit cooking	Must consider living area, roads, and gap identification.
Inhalation rates	Days per terrain; Exertion level; hide scraping; load & grade.	Exertion level – nets and gaffing methods; cleaning effort.	Exertion level for load and grade; or gardening. Include making items.	Includes building the lodge, chopping firewood, singing.	Exertion level for pounding, grinding, etc.	Must account for exertion levels; smokes and smudges.
Groundwater and Surface water pathways	Drinking water; wash water; water-to-game pathways.	Drinking water; incidental ingestion	Drinking water, cooking water, etc.	Steam in lodge; drinking water during sweat.	Soaking, possibly other uses.	Must account for climate, sweat lodge, ritual bathing.
Dermal exposure	Soil, air and water pathways, plus pigments etc.	Immersion considerations.	Same as hunting.	Immersion with open skin pores.	Includes basketmaking, wounds.	Must consider skin loading and habitat types.

2.2 The Family, The Day, and The Lifetime

This section describes a family-based exposure scenario based on traditional CTUIR lifestyles and diets. Only the fish-based diet is discussed here, since it is to be applied within 20 miles of a major fishing river. It is based on habits of members who live in the sagebrush steppe, gather native foods supplemented with a home garden, have a high rate of subsistence activities, have a regular schedule of other cultural activities, and work as field workers monitoring natural and cultural resources, taking environmental samples, and doing reclamation or restoration work. The lifestyles are moderately active outdoor lifestyles, with daily sweat lodge use.

2.2.1 Lifestyle of a Representative Traditional CTUIR Family

The families are intended to be reasonable composites. Each family includes an infant/child (age 0-2 years) who breastfeeds for two years and crawls and plays; a child (age 2-6) who plays in the house and outdoors, a youth (age 7-16) who attends school, plays outdoors near his/her residence, and is learning traditional practices; two adult workers (one male, one female, age 17-55; the female breastfeeds the infant) who work outdoors on reclamation and environmental and cultural activities and who also engage in subsistence activities; and an elder (age 56-75) who is partly at home and partly outdoors teaching and demonstrating traditional cultural practices. All members (except the infant from 0 - 2 years) partake in family sweat lodge use and in cultural activities throughout the year.

Location and Type of Residence. The residence is located within the assessment area. The family lives in a house with little or no landscaping other than the natural vegetation. Each house has its own well for domestic use and a garden irrigated with groundwater or surface water (whichever is more contaminated). This is not a fully traditional pit house or tule mat house, but a typical reservation-quality house, with seasonally open windows. The road and driveway are not paved.

2.2.2 Activity Patterns of Each Family Member

Infant. The infant breast-feeds for 2 years, and crawls on the floor (with housedust exposure) from age 6 months to 2 years. Infants ingest more fluid per body weight than children do, and toddlers (6 months to 2 years) are likely to have the highest of the children's exposures due to crawling and mouthing behaviors, and their higher food and water per capita ingestion rates.

Child (ages 2-6 years). Beginning at age 2, the child eats the same food as everyone else, participates in family sweat lodge, and spends some time accompanying the mother as she gardens and gathers.

Youth (ages 7-16). The adolescent is learning to hunt, gather, and fish (and spends equal time in each activity in their respective locations), plays outdoors, and attends school.

Adult Worker (ages 17-55). Workers are assumed to work for the Tribe collecting environmental samples, engaging in restoration/remediation or construction work, and caring for natural and cultural resources and tribal property. This type of activity is dusty in the summer and muddy in the winter. Both males and females are currently employed in this type of activity. Workers could be exposed to external irradiation, surface soil and dust, vegetation, surface water, sediments, seeps, and radon and daughter products in outdoor air and water. These workers have an average 8-hour workday.

Adult Hunter/Fisher/Gatherer. Each adult also hunts (male), fishes (male), or gardens and gathers plants (female). These activities are roughly analogous with respect to environmental contact, and therefore are assumed to result in the same amount of soil ingestion and so on for males and females. The additional time and contact during game processing, plant washing and preparation, and so on are also roughly equal. The location of hunting small game or fowl is in the same area as the residence, and the location of big game hunting covers a larger area, although the livestock are located in the same area as the residence. The time spent hunting of fishing versus livestock tending is proportional to the diet and the size of the assessment area. The garden is at the place of residence and uses the same water as the household, while the gathering occurs in a larger area, also proportional to the size of the assessment area. All of the hunters, gatherers and fishers spend some time near water, if it is present in the area, on activities such as washing plants or game, gathering aquatic plants and mollusks/crustacean, and so on, with concomitant exposure to mud or sediment.

Elder (ages 56-75). The elder gathers plants and medicines, prepares them, uses them (e.g., making medicines or baskets, etc.) and teaches a variety of indoor and outdoor traditional activities. The elder also provides childcare in the home.

Sweat Lodge Use (ages 2-75). The daily use of the sweat lodge is an integral part of the lifestyle that starts at age 2. Sweat lodge construction has been described in the open literature. Although the details vary among tribes and among individual families, they are generally round structures (6 feet in diameter for single-family use) constructed of natural materials (i.e. branches, moss, leaves with a dirt floor covered with mats or cedar boughs) near a source of surface or groundwater. A nearby fire is used to heat rocks that are brought into the sweat lodge. Water (4L) is poured over the rocks to form steam (a confined hemispheric space with complete evaporation of the water which is available for inhalation and dermal exposure over the entire skin area). Either groundwater or surface water may be used. Inhalation and heart rates may be higher depending on activities that occur during the sweat lodge ceremony (e.g. singing).

Cultural Activities. All persons participate in day-long outdoor community cultural activities once a month, such as pow-wows, horse races, and seasonal ceremonial and private cultural activities (together averaging about 0.5 hours/day). These activities tend to be large gatherings with a greater rate of dust resuspension and particulate inhalation. Individuals also tend to be active, resulting in a greater inhalation and water ingestion rates.

Seasonality. The changes in activity patterns over the annual seasonal cycle has been modified in modern times, but the ecological cycle has not, so people must still gather plants according to when they are ripe, hunt according to game and fowl patterns, and fish when the spawning runs occur. Items are gathered during a harvest season for year-round use. While specific activities change from season to season, they are replaced by other activities with a similar environmental contact rate. For instance, a particular plant may gathered during one month, while another month may be spent hunting, and a winter month may include cleaning and using the items obtained previously. Therefore, since we are assuming that all activities are roughly equal, there is no decrease in environmental contact rates during winter months.

Special Activities. It is recognized that there are special circumstances when some people may be highly exposed (and their exposure would be underestimated). For instance, some men hunt or fish for the general community, and many people provide roots and fish and game to elders in addition to their own families. Flintknappers may receive additional exposure through obtaining and working with their materials. Healers handle pharmacollogically active plants, some of which may differentially uptake contaminants. These type of activities may require special consideration with respect to exposures.

Basketmaking. Exposure specific to basketmakers is a well-recognized problem[11], but it has not been fully researched for this scenario. Gathering of some plants (e.g., willows, cattails, tules, reeds and rushes) can be very muddy, and river shore or lakeshore activities with sediment exposure may be underestimated. Washing, peeling, weaving rushes, and other activities results in additional exposure, such as dust deposited on leaves or soil adhered to roots. Some of the materials are held in the mouth for splitting, and cuts on the fingers are common. As more information becomes available, it will be evaluated to ensure that the exposure factors account for the particular exposure pathway.

2.2.3 Time allocation throughout the day

The time adds up to slightly more than 24 hours per day, as is typical for any exposure scenario, in order to allow specific pathways to drive the risk should they be contaminated. This also accounts for specialization by the person who spends more than an average amount of time in particular activities.

Identical Activities: From the age of 2 to 75 years, 15 hours of every day are similar: 8 hours sleep, 2.5 hours in other indoor activities, 2 hours in the sweat lodge, 1 hour in nearby outside activity such as small game hunting, 0.5 hour in community cultural activities, and 0.5 hour traveling on unpaved roads. These activities are referred to as "**common time**" because they are common to all individuals.

Infant: Standard infant exposure parameters are used. Housedust is assumed to have similar concentrations of contaminants as outside soil. The infant is breastfed for 2 years, assuming two different scenarios: (1) the mother has received 25 years of prior exposure from a contaminated area; and (2) the mother has not received such exposure. The issue of fetal exposure remains to be determined.

Child: The child, up through age 6, spends the same amount of common time in the same activities, and 4 hours indoors and 5 hours outdoors with the mother as she gardens and gathers.

Youth: "Common time" plus 6 hours at school 5 days/week (averaging 4.5 hours/day over a full week), 2.5 hours indoors, and 3 hours outdoors playing or accompanying an adult or elder learning traditional activities. It is assumed that the school is uncontaminated unless there is data about chemical usage or contamination, and it is also assumed that his or her

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[11] http://www.cdpr.ca.gov/docs/envjust/documents/basketweaver.pdf

near-residence outdoor time results in a higher amount of soil contact that at other ages, therefore, the youth's average contact rates are the same as the child and adult's.

Adult: "Common time" plus 8 hours working 5 days/week (about 5.5 hours/day), 0.5 hour at home, and 3 hours in one of the subsistence activities (hunting = 1 hour plus 2 hours processing, smoking, etc.; fishing = 2 hours plus 1 hour processing; gathering/gardening = 1 hour gathering in the assessment area, 1 hour gardening at home, and 1 hour washing, processing, etc.).

Elder: "Common time" plus 3 hours at home providing child care, 3 hours outdoors teaching, 1 hour gardening or gathering, and 2 hours at home processing materials and making items.

2.2.4 The Lifetime

Traditionally, daily tasks were somewhat different for males and females: males hunt and fish, while females gather and cook. However, upon consultation with traditional tribal members, it was determined that while the activities are different, the rates of environmental contact are probably similar. Today, both women and men are employed as environmental and construction workers, as well. Therefore, for the purposes of the exposure scenario, the genders have identical exposure factors, although a briefs description is provided here.

Male Lifetime. The male lifetime consists of the standard infancy, childhood, and youth. At age 17 he specializes in either hunting or fishing and begins working as a reclamation /restoration/environmental worker. These activities are specified solely to determine their locations, which may have different contaminant concentrations. As an elder he changes his activity patterns to teaching and demonstrating as described above.

Female Lifetime. The female lifetime consists of the standard infancy, childhood, and youth. At age 17 she engages in gathering and gardening and also works the same job as the male. During motherhood, the woman may remain at home, which is located in the same sparsely populated area, and she continues to garden and gather, so her exposure does not diminish. Her earlier exposure contributes to fetal development and breast milk.

2.3 Media, Pathways, and Exposure Factors

Contaminant transport and exposure pathways are generally presented as Conceptual Site Models or CSMs. The pathways that are described below are intended to highlight some of the pathways that should be reflected in conceptual site models, the RME, and the baseline and residual risk assessments.

Ground Water and/or Surface Water. Ground water and/or surface water are directly ingested as drinking water. Both are also used to create steam in the sweatlodge. Other uses of water include typical household use can result in aerosolization or vaporization (e.g. flushing, cooking, bathing, and showering), or can transfer contamination to biota through irrigation of crops and/or garden, and livestock.

Air and Dust. Inhalation of volatiles, aerosols, and particulates is associated with almost all of the aforementioned activities. Inhalation of fire smoke or smudge should be included because some of these pathways can be frequent and significant. Dust resuspension from unpaved road should be included as part of the inhalation exposure pathway.

Soil and Sediment. This pathway includes soil ingestion from hand to mouth activities associated with daily activities, gathering (e.g., digging roots) and gardening, food and material processing (e.g. grinding, scraping, pit cooking). This pathway also includes direct ingestion resulting from residual soil on roots and bulbs. The as-gathered and as-eaten condition of plants is important. Some vegetable foods are eaten raw on the spot after being brushed off. Grinding seeds and nuts also adds rock dust to the flour.

2.3.1 Exposure factors for direct exposure pathways.

Table 3 includes three adult scenarios: the suburban resident, the rural residential farmer-gardener, and the subsistence forager. Each scenario is intended to be physiologically "coherent," which means that the activity levels and inhalation rates match each other, and match the degree of environmental contact as reflected in soil and water ingestion rates as well as the proportion of grown or foraged food. We have included the rural residential farmer-gardener information as a suggestion to be considered, since this is a lifestyle intermediate between suburban and subsistence foraging.

Table 2 shows the thought process for considering the wide range and numerous activities associated with the major activity categories (hunting, fishing, gathering, and sweatlodge use). Figure 1 lists a number of individual activities within each major category; this is included because most non-Indians have not learned much about traditional lifestyles and the complexity of daily life.

Drinking Water.

Harper et al. (2002) estimated an average water ingestion rate of 3 L/day for adults, based on total fluid intake for an arid climate. In addition, each use of the sweatlodge requires an additional 1L for rehydration, for a total of 4L per day.

Inhalation Rate

An inhalation rate of 30 m^3/d is more accurate for the active outdoor lifestyle than the EPA default rate of 20 m^3/d (EPA, 1997). Using EPA guidance, an average rate of 26.2 m^3/d is obtained from 8 hours sleeping, 2 hours sedentary, 6 hours light activity, 6 hours moderate activity, and 2 hours heavy activity. This represents minimal heavy activity (construction, climbing hills, etc), and is an average rather than a reasonable maximum.

Soil Ingestion.

Soil ingestion by young children (0-6 years) is assumed to be 400 mg/day for 365 days/year. This is higher than the prior EPA default value of 200 mg/day (USEPA, 1989), and is the children's upper bound value. This rate reflects both indoor dust and continuous outdoor activities analogous to gardening or camping, but it is less than a single-incident sports or construction ingestion rate. For adults, the soil ingestion value is also 400 mg/day, reflecting an unspecified upper percentile (EPA, 1997).

Table 3. Exposure factors for direct pathways

Direct Pathway	Exposure Factors (Adults)		
	Default Suburban	***Rural Residential Gardener***	***Subsistence Forager***
Inhalation	20 m^3	25 m^3 While EPA does not have official exposure factors for this lifestyle, it is reasonable to assume that a person who farms, gardens, irrigates, and cares for livestock has an intermediate inhalation rate.	30 m^3/day. This rate is based on a lifestyle that is an outdoor active lifestyle, based on EPA activity databases, foraging theory and ethnographic description of the activities undertaken to obtain subsistence resources as well as allotment-based food (livestock and garden). It is higher than the conventional 20 m^3/day because the activities with associated respiration rates are higher than suburban activities.
Drinking water ingestion	2L/d	3L/day. This rate is based on water requirements in an outdoor, moderately arid environment.	3L/d plus 1 L for each use of the sweat lodge.
Soil ingestion	100 mg/d (conventional suburban); 50 mg/d (manicured suburban; less outdoor time).	300 mg/d.	400 mg/d. This rate is based on indoor and outdoor activities, a greater rate of gathering, processing, and other uses of natural resources, as well as on residual soil on grown and gathered plants. Episodic events (1 gram each) are considered, such as very muddy gathering, sports with higher soil contact, and so on. It does not specifically include geophagy or pica.
Other parameters			
Exposure frequency	Up to 365 days per year, but varies. Hours per day varies; typically 24 hrs/d.	Up to 365 days per year, but varies. Hours per day varies; typically 24 hrs/d.	365 days per year. Hours per day varies; typically 24 hrs/d.
Exposure duration	30 years	30 or 70-75 years	70-75 years
Body weight	70 kg	70 kg	70 kg

Sweat Lodge

Inhalation and dermal exposure in the sweat lodge are evaluated by assuming: (1) one hour of use daily; (2) 4 liters of water is poured on heated rocks resulting in instant vaporization; (3) the sweat lodge is a hemisphere 6 feet in diameter; and (4) dermal exposure is over the entire body surface area. More detail is given in the Appendix.

Children's Exposure Factors

Children's exposure factors are based on "Child-Specific Exposure Factors Handbook"[12] but scaled from the adult subsistence values for inhalation rate. Soil ingestion is 400 mg/d for all age groups.

[12] U.S. Environmental Protection Agency (EPA). (2002) Child-specific exposure factors handbook. National Center for Environmental Assessment, Washington, DC; EPA/600/P-00/002B. Available from: National Information Service, Springfield, VA; PB2003-101678 and <http://www.epa.gov/ncea>.

2.3.2 Summary of Exposure Factors

A summary of primary exposures are presented in Table 4. Further documentation is provided in appendices for the 3 major exposure factors: inhalation rate, soil ingestion rate, and the fish consumption rate. Additional detail on exposure factors or guidance on the application of the scenario to particular locations will be provided on request.

Table 4. Summary of Exposure Factors. This summary draws on the 1997 and 2004 references. All exposure duration and averaging times are daily for 70 years unless otherwise noted. Children's factors are scaled from adults except where noted.

Medium	***Exposure Pathway***	***Exposure Factor***	***Value***
Soil	Ingestion	Ingestion Rate	400 mg/d (all ages)
Soil	Dermal	Adherence rate (<150 um particle size)	1 mg/cm^2 (all ages)
Soil	Dermal	Skin surface area (head, hands, forearms, lower legs)	5700 cm^2 (adult) 2800 cm^2 child)
Air	Inhalation	Inhalation Rate	30 $m^{3/}$/day (adult)
Water	Dermal	Skin surface area	18,000 cm^2 (adult) 14,900 cm^2 (child)
Water	Dermal and Ingestion	Swimming	13 days /yr, 2.6 hrs/event, 50 ml/event.
Water	Ingestion	Ingestion Rate	4 L/d
Biota	Foodchain	Fish ingestion rate	500 lbs per capita per year, or 620 gpd
Biota		Game, meat, fowl	125 gpd
Biota		Fruit, greens (unprotected)	Berries – 125 gpd Greens – 300 gpd Other - 125 gpd
Biota		Below-ground roots	800 gpd
Biota		Milk	Use children's rate (children only)

Notes.

- Soil adherence rate is correlated to grain size; soil samples must be sieved, and data for particle size <0.044 cm (RAGSe, App. C, Table C-4) should be used for dose estimation. Inhalation is also related to particle size, so the dust resuspension estimate must also include particle size. The adherence rate of 1 mg/cm^2 is higher than most commercial rates but lower than the kid-in-mud rate (RAGSe, Ch.3, Table C-3) to account for longer events and more wet soil (riparian, wetlands) contact.
- Animal meats include organs, which have a bioconcentration potential. Assume that 10% of animal food is organs with 10x higher concentration.
- Sweatlodge parameters are included in the attached appendix.

2.3.3 CTUIR River-based Food Pyramid

Approximately 135 species of plants are used as foods, flavorings, or beverages; approximately 125 species are used in traditional technologies; nearly 120 species of medicinal plants are used by the southern plateau tribes and up to 200 by northern Plateau tribes (Hunn, 1990). This wide variety of plants is typical of foraging societies. For risk assessment, however, this is collapsed into a few food categories. This is because the simple risk equations cannot handle more detailed information, and data on species-specific soil-to-plant uptake is lacking. Further compounding this problem is the tendency of game to be treated like livestock, and native plants like domesticated plants. Many pathways such as medicines and teas are typically ignored altogether. For this reason, the upper bounds for food categories are evaluated in the same way that direct exposure factors are rounded up to account for the myriad of small and otherwise ignored pathways.

There are two distinct diets within the Umatilla Tribes: the game-focused diet and the fish-focused diet. Because this scenario is applied to Hanford and the Columbia River, only the fish-based diet is presented here (Table 5, Figure 2). After making appropriate simplifying assumptions, the general CTUIR 2500 kcal subsistence diet that is focused on the Rivers is estimated as follows (based on references by Hunn and Walker; see also DOE[13]). CTUIR can be contacted if more detail is needed (for instance, the ratio between tubers and bulbs, from different plant families, and so on).

Table 5. Dietary Food Categories for the Fish-based CTUIR Traditional Diet.

Food Category	Grams per day Wet wt.	Kcal per day	% of 2500 kcal	Comments
Fish - 75% anadromous - 25% resident	620	1000	40%	Consumption of parts with higher lipid content needs to be added to this total. The lipid content will vary with species; the ratio of species can be provided on request.
Game, fowl	125	150	6	Consumption of organs with higher contaminant concentration (10x) needs to be added to this total. If 10% is organ meat with 10X bioconcentration, the total is **250 gpd** equivalents.
Roots (unspeciated, including tubers, corms, bulbs)	800	800	32	Depending on the habitat, this needs to allocated among tubers and bulbs (different plant families) and terrestrial or aquatic species.
Berries, fruits	125	125	5	
Greens, medicinal leaves, tea, stems, pith, cambium	300	300	12	Above-ground plants may have contaminants translocated from the roots as well as dust deposited on the leaves.
Other: sweeteners, mushrooms, lichens.	125	125	5% combined	General assumption of 1 kcal per gram.
Total	***2095g***	***2500***	***100%***	This is 4.6 pounds of food per day; this includes a much higher fiber content than domesticated varieties, which were bred for lower fiber and easier commercial processing.

[13] www.hanford.gov/doe/culres/mpd/toc.htm

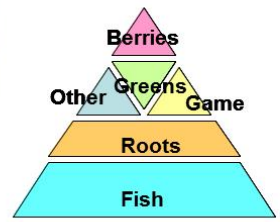
Figure 2. CTUIR Food Pyramids

Three CTUIR Tribes – Two basic habitat types

Food Category	Grams per day	Kcal per day	% of kcal
Fish	620 (Boldt decision)	1000	40
Game, Fowl, Eggs	225	400	16
Roots	500	500	20
Berries, fruits, nuts	125	125	7
Greens, medicines, tea, grain	300	300	12
Sweeteners, mushrooms, other	125	125	5

Cayuse (Upland peoples)

Walla Walla, Umatilla (River peoples)



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APPENDIX 1.

INHALATION RATE

Inhalation Rate = 25 m^3/d (adult)

SUMMARY

The inhalation rate in the indigenous scenarios reflects the active, outdoor lifestyle of traditional tribal members, including youth who are learning traditional subsistence skills, adult outdoor workers who also hunt, gather, and fish, and elders who gather plants and medicines, and prepare and use them (e.g., making medicines or baskets, etc.) and who teach a variety of indoor and outdoor traditional activities. Traditional tribal communities have no sedentary members except the frail elderly, whereas one-quarter of modern American adults of all ages report no leisure time physical activity at all.[14] We have estimated the activity levels associated with this lifestyle and diet using published anthropological studies, ethnographic literature on foraging theory, hunting-gathering lifestyles, and interviews with Tribal members. Using EPA guidance on hourly inhalation rates for different activity levels, a reasonable inhalation rate for an average tribal member's active lifestyle is an average rate of 26.2 m^3/d, based on 8 hours sleeping at 0.4 m^3/hr, 2 hours sedentary at 0.5 m^3/hr, 6 hours light activity at 1 m^3/hr, 6 hours moderate activity at 1.6 m^3/hr, and 2 hours heavy activity at 3.2 m^3/hr. Unlike most other exposure factors, which are upper bounds, the inhalation rate is an average rate. This could result in under-protection of children, the elderly, athletes, asthmatics, and the half of the population with above-average inhalation rates. However, to be consistent with national methodology, we have rounded the rate to 25 m^3/day.

1.0 Population-specific physiology

Perhaps the most relevant factors associated with ethnic specificity of metabolic and inhalation rates are the thrifty genotype(s), insulin use, and oxidation and adiposity patterns (Goran, 2000; Fox et al., 1998; Muzzin et al., 1999; Rush et al., 1997; Saad et al., 1991; Kue Young et al., 2002), as well as ethnic differences in spirometry (Crapo et al., 1988; Lanese et al., 1978; Mapel et al., 1997; Aidaraliyev et al., 1993; Berman et al., 1994). Research on the thrifty genotype suggests that there may be several stress response genes that enable indigenous populations to respond to environmental stresses and to the rapid transition between extremes, including feast and famine, heat and cold, disruption in circadian rhythms, dehydration, seasonality, and explosive energy output or rapid transitions between minimum and maximum exercise and $VO2_{max}$ (Kimm et al., 2002; Snitker et al., 1998). These genes "uncouple" several energy expenditure parameters (Kimm et al., 2002), and generally support the logic of using a higher inhalation rate for active, outdoor lifestyles, especially in Native American populations.

2.0 Short-term versus long-term inhalation rates.

[14] (http://www.cdc.gov/brfss/pdf/ 2001prvrpt.pdf and http://www.cdc.gov/brfss/pubrfdat.htm).

Most federal and state agencies either use the EPA default value of 20m^3/d or use activity levels to estimate short-term and long-term inhalation rates. For this exposure scenario, activity levels were evaluated through anthropological data (foraging theory and activity descriptions in the anthropological literature) and confirmatory interviews with Tribal elders, and used the CHAD-based EPA recommendations for ventilation rate for the different activity levels. Several examples of similar approaches are:

- EPA's National Air Toxics Assessment (homepage: http://www.epa.gov/ttn/atw/nata/natsa3.html) uses the CHAD database in its HAPEM4 model to estimate national average air toxics exposures even though "the lack of activity pattern data that extend over longer periods of times presents a challenge for HAPEM4 to predict the long-term (yearly) activity patterns that are required to determine chronic exposures." Therefore, "an approach of selection of a series of single day's patterns (from CHAD) to represent an individual's activity pattern for a year was developed."
- The California Air Resources Board (CARB, 2000) reviewed daily breathing rates based on activity levels and measured ventilation rates for many activities in the CHAD database. The average hourly rate for sleeping was 0.5 m^3/hr, light activities at 0.55 m^3/hr, moderate activities at 1.4 m^3/hr, and heavy rates of activity levels at 3.4 m^3/hr. The CARB concluded that 20 m^3/d represents an 85th percentile of typical adult sedentary/light activity lifestyles. This is based on 8 hours sleeping and 16 hours of light activity with no moderate or heavy activity, or 1 hour day of moderate and heavy activity each.
- In their technical guidance document, "Long-term Chemical Exposure Guidelines for Deployed Military Personnel," the US Army Center for Health Promotion and Preventive Medicine (USACHPPM) recommended an inhalation rate of 29.2 m^3/d for US service members. Deployed personnel were assumed to spend 6 hours sleeping at an inhalation rate of 0.4 m^3/hr, 4 hours in sedentary activities (at 0.5 m^3/hr), 6 hours in light duties (at 1.2 m^3/hr), and 8 hours in moderate duties (at 2.2 m^3/hr).[15]
- EPA used 30 m^3/day for a year-long exposure estimate for the general public at the Hanford Superfund site in Washington state, based on a person doing 4 hours of heavy work, 8 hours of light activity, and 12 hours resting.[16]
- The DOE's Lawrence Berkeley Laboratory also used 30 m^3/d: "the working breathing rate is for 8 hours of work and, when combined with 8 hours of breathing at the active rate and 8 hours at the resting rate, gives a daily equivalent intake of 30 m^3 for an adult."[17]
- The Rocky Flats Oversight Panel recommended using 30 m^3/d.[18]

3.0 The use of population-specific information rather than national averages.

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[15] http://www.gulflink.osd.mil/particulate_final/ particulate_final_s06.htm and http://www.gulflink.osd.mil/pm/pm_en.htm.

[16] "Report of Radiochemical Analyses for Air Filters from Hanford Area" Memorandum from Edwin L. Sensintaffar, Director of the National Air and Radiation Environmental Laboratory to Jerrold Leitch, Region 10 Radiation Profram Manager (http://yosemite.epa.gov/R10/AIRPAGE.NSF/webpage/Hanford+Environmental+Perspective)

[17] (www.lbl.gov/ehs/epg/tritium/TritAppB.html)

[18] RAC (Risk Assessment Corporation). 1999. *Task 1: Cleanup Levels at Other Sites. Rocky Flats Citizens Advisory Board, Rocky Flats Soil Action Level Oversight Panel.* RAC Report No. 3-RFCAB-RFSAL-1999' http://www.itrcweb.org/Documents/RAD-2.pdf

EPA instructs risk assessors to identify the receptor population and their activities or land use.[19] "Assessors are encouraged to use values which most accurately reflect the exposed population."[20] The OSWER Land Use Directive[21] requires the identification of land uses for the baseline risk assessment; when the affected resources are on reservations or areas where tribes retain usory rights, a subsistence/residential land use must be assumed if the Tribe so indicates. Executive Order 12898[22] requires the identification of subsistence consumption of natural resources, and for Indian Tribes this includes the activities required to obtain those resources.

EPA recognizes that inhalation rates may be higher in certain populations, such as athletes or outdoor workers, because levels of activity outdoors may be higher over long time periods. "If site-specific data are available to show that subsistence farmers and fishers have higher respiration rates due to rigorous physical activities than other receptors, that data may be appropriate."[23] Such subpopulation groups are considered 'high risk' subgroups.[24] EPA (1997) recommends calculating their inhalation rates using the following <u>average</u> hourly intakes for various activity levels (in m^3/hr): resting = 0.4, sedentary = 0.5, light activity = 1, moderate activity = 1.6, heavy activity = 3.2. EPA's average rate for outdoor workers is 1.3 m^3/hr, with an upper percentile of 3.3 m^3/hr, depending on the ratio of light, moderate and heavy activities during the observation time. Other EPA risk assessments typically use 2.5 m^3/hr for groundskeepers.[25]

Using EPA guidance on hourly inhalation rates for different activity levels, a reasonable inhalation rate for an average tribal member's active lifestyle is an average rate of 26.2 m^3/d, based on 8 hours sleeping at 0.4 m^3/hr, 2 hours sedentary at 0.5 m^3/hr, 6 hours light activity at 1 m^3/hr, 6 hours moderate activity at 1.6 m^3/hr, and 2 hours heavy activity at 3.2 m^3/hr. The resultant 26.2 m^3/d is rounded to 25 m^3/day.

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[20] Exposure Factor Handbook, Volume 1, page 5-23
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[22] White House, 1994. Federal Actions To Address Environmental Justice In Minority Populations And Lowincome Populations: Feb. 11, 1994; 59 FR 7629, Feb. 16, 1994.

[23] EPA (OSWER) "Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities, Support Materials Volume 1: Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities" page 6-4, at (http://www.epa.gov/earth1r6/6pd/rcra_c/protocol/volume_1/chpt6-hh.pdf)
[24] Exposure Factors Handbook, 1997, Volume 1. page 5-24
[25] For outdoor workers, see U.S. EPA 1991a. U.S. Environmental Protection Agency (U.S. EPA). Human health evaluation manual, supplemental guidance: "Standard default exposure factors". OSWER Directive 9285.6-03. An example of use is http://epa-dccs.ornl.gov/radionuclides/equations/outdoor_guide.shtml. Oregon uses 3.66 m^3/hr for penitentiary workers; http://64.233.167.104/search?q=cache:uQII54d5ioYJ:www.doc.state.or.us/fiscalservices/facilities/existing/osp_groundwater/tables/2000/table_5_4.pdf+%22construction+worker%22+%22inhalation+rate%22+epa&hl=en.

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APPENDIX 2

SOIL INGESTION RATE

Indigenous 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 indigenous 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, and local climatic and geologic conditions.

The soil ingestion rate of 400 mg/d for all ages is the upper bound for suburban children (EPA, 1997), 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[26], 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.

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

[26] 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.

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[27] 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-y/kg-d.

A value for an ingestion rate for adult 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 (EPA, 1997; Hawley, 1985).

Other soil ingestion rates are also used by risk assessors. For example, some states recommend the use of 1 gram per acute soil ingestion event[28] 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[29] 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.[30] 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)[31] 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 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.

[27] 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),

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

[29] 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.

[30] 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

[31] 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.

The UN Balkans Task Force assumes that 1 gram of soil can be ingested per military field day[32].

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[33] 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."[34]

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

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[32] 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.unep.ch/btf/missions/september/dufinal.pdf

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

[34] 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

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 90th % was 1190 mg/d, and the 95th% 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[35]. 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.

(3) soils act as an antidiarrheal agent.

(4) soils counteract the effects of endoparasites.

(5) geophagy may satiate olfactory senses.

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

(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[36]. 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. Because some substances, such as clay, are believed to block the absorption of iron into the bloodstream, it was thought that low blood levels of iron could be the direct result of pica. 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. Again, low ferritin and hemoglobin are hypothesized to result in pica.

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 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

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

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[37]. 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 5000 mg of soil per day but cautioned that the amount selected was arbitrary[38]. 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[39].

(3) ATSDR uses 5 g/day for a pica child[40].

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 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

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[37] http://www.nlm.nih.gov/medlineplus/ency/article/001538.htm#Causes,%20incidence,%20and%20risk%20factors

[38] Summary report for the ATSDR Soil-Pica Workshop, Atlanta, Georgia, 2000. Available from: URL: http://www.atsdr.cdc.gov/NEWS/soilpica.html

[39] 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 .

[40] For Example: El Paso Metals Survey, Appendix B, www.atsdr.cdc.gov/HAC/PHA/**elpaso**/epc_toc.html.

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, up to 27 mg/cm^2. 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, with particles above the sand-silt size division (0.075 mm) adhering less than smaller sizes. 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[41] for more details). Soil samples should be sieved and concentrations should be evaluated for sizes below 0.075 mm.

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[42]. Soil adherence rate is correlated to grain size; soil samples must be sieved, and data for particle size <0.044 cm (RAGSe, App. C, Table C-4) should be used for dose estimation. Inhalation is also related to particle size, so the dust resuspension estimate must also include particle size.

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 ingestion by pasture animals. For example, Beresford and Howard (1991) found that soil adhesion to vegetation

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

[42] 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.

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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APPENDIX 3

FISH CONSUMPTION RATE

CTUIR Fish Consumption Rate = 620 g/d or 500 pounds per year (adult) .

SUMMARY

Although many indigenous peoples living along coasts or major waterways originally had very high fish consumption rates, most are now suppressed due to destruction of fisheries, lost access to aboriginal lands, or awareness of contamination. Therefore, studies that assess the current fish consumption rates are not measuring the true subsistence rate, but a modern suppressed rate. Even so, a subset of tribal members remain heavily fish-dependent, creating a bimodal distribution that is missed in most conventional survey methods.

The Confederated Tribes (Cayuse, Umatilla, Walla Walla) have relied on resident and anadromous fish in the Columbia River and its tributaries for at least 10,000 years. Salmon and the people are inseparable, and people will and must continue to partake in the circle of life with salmon as a partner. We regard current fish numbers as a temporary decline, with continued improvement through concerted efforts in watershed restoration. Therefore, since Hanford cleanup must remain protective for thousands of years, we are using our subsistence consumption rate, not the current average suppressed consumption rate.

The subsistence consumption rate is an average of 620 grams per day for adults. This is known through anthro-historical data, anecdotal information by early observers such as Lewis & Clark, nutritional analysis, and documentation from the era of dam construction (1920-1950), interviews of current subsistence fishers, and literature review. Table 1 shows examples of the range of consumption rates that were reviewed.

Table 1. Summary of selected fish ingestion rates.

Fish Ingestion Rate	***Derivation***
6.5 g/day	Previously used in federal promulgations based on national food consumption surveys of the general non-tribal population; now superceded by 17.5 g/d.
17.5 g/day	EPA's new recommendation for the general non-tribal population and recreational fishers
48.5 g/day	EPA and FDA recommendations for adults to eat two 6-ounce meals per week.
54 g/d	Model Toxics Control Act (Washington State) and OSWER (Combustor risk assessment guildelines).
63.2 g/day (about 1 pound/week)	CRITFC (1994) average for current tribal fish consumers, excluding subsistence fishers. See commentary below.
142.4 g/day	EPA proposed average rate for tribal subsistence fishers and 99th % of the general non-tribal population
389 g/day	CRITFC 99th percentile of non-subsistence fish consumers plus non-consumers, minus 7 "outliers." The 90th percentile was between 97 and 130 g/day, and the 95th percentile was between 170 and 194 g/day.
454 g/day (1 pound/day)	Anecdotal subsistence estimate, commonly cited during interviews with traditional and subsistence people..
540 g/day	Harris & Harper (1997), based on averages for traditional CTUIR fishing families, and the lower end of the Treaty-based range; approved by BOT for use at Hanford and Columbia River. The authors sought out and interviewed traditional and subsistence fishing members.
620 g/day	Cited in the Boldt decision ("Salmon, however, both fresh and cured, was a staple in the food supply of these Indians. It was annually consumed by these Indians in the neighborhood of 500 pounds per capita.") U.S. District Judge George Boldt, U.S. v. Washington, February 12, 1974, note 151. *Note: Boldt was referring to Columbia mainstem fishers when he wrote this. This does not include resident fish.*
650 g/day	Walker (1999) mid-range of top third of Yakama members using the Columbia River during the 1950s and 1960s (both resident and anadromous fish). This is based on interviews of tribal fishermen, fish market records, nutritional analysis, archaeological and ethnographic evidence, and literature reviews. Walker cites other studies that support this number. Walker estimated that minimal river users ate 80 g/d, and the median river user ate 350 g/d. The BOT endorsed the numbers in this paper.
1000 g/day	Walker (1985) estimate of pre-dam rates for Columbia Plateau Tribes, accounting for calorie loss as fish migrate upriver and other documentation.
To convert from ounces to grams, multiply by 28.35. There are 3.53 ounces in 100 grams. To convert from pound to gram, multiply by 453.6 There are 16 ounces in a pound. 100 grams or 3.5 ounces is about the size of a deck of cards. Meal sizes are generally assumed to be 8 ounce portions for adults	

1.0 Approach and Assumptions

Within the Confederation of Cayuse, Walla Walla and Umatilla Tribes, there are different family natural resource uses according to the specific area that a family is from. Nevertheless, while the Cayuse Tribe emphasized hunting more than fishing and the Walla Walla and Umatilla Tribes emphasized fishing more than hunting, both diets are "subsistence" diets because they provide all the food and medicine that a family needs to survive and thrive. However, in this scenario we are using the term "subsistence fisher" to refer to original consumption rates along the Columbia River and its major tributaries, and which the Treaty of 1855 was intended to protect.

The development of the CTUIR fish consumption rate was based on the following premise:

- Subsistence consumption rates were practiced by many or all members of a Tribe, but today are practiced by a subset of tribal members;

- Within tribes or confederations of tribes there may be distinct patterns of natural resource use that are obscured by statistical cross-sectional surveys. Therefore, cross-sectional fish consumptions surveys in tribal communities may not be able to identify subsistence fishers;

- In order to develop a subsistence consumption rate, subsistence fishers must be specifically identified and interviewed, and existing studies must be reviewed to determine whether they are suitable for developing true subsistence rates, or combined/ suppressed consumption rates.

Our goal was to identify the subsistence consumption rate because that is the rate that the Treaty of 1855 was designed to protect and which is upheld by case law. It also reflects tribal fish restoration goals and healthy lifestyle goals.

As other investigators have done (Walker, in particular), the CTUIR fish consumption rate was developed using multiple lines of evidence: literature review of ethnohistorical evidence, review of cross-sectional fish consumption surveys (a combination of subsistence and non-subsistence fishers), interviews of current subsistence fishers, and caloric and nutritional analysis.

2.0 Current Federal and State Guidance

The EPA Office of Water provides guidance for setting ambient water quality standards for surface water, and includes a consideration of fish consumptions rates. The prior national fish consumption rate for the general population [6.5 gpd] was based on the mean national per capita (both consumer and non-consumers) consumption rate of freshwater and estuarine finfish and shellfish from 3-day diary results that were reported in the 1973-74 National Purchase Diary Survey (Javitz, 1980).

The EPA Office of Water[43] now recommends a default fish intake rate of 17.5 grams/day to adequately protect the general population of fish consumers including sport fishers, and 142.4 grams/day for subsistence fishers. The basis for the fish intake rates is the 1994-96 Continuing Survey of Food Intake by Individuals and 1998 Continuing Survey of Food Intakes by Individuals *(*CSFII) conducted by the U.S. Department of Agriculture.

When Tribes develop ambient water quality standards, EPA[44] recommends using either an upper percentile of a cross-section or an average rate specific for a higher fishing group, according to the policies of the Tribe. EPA says that the two numbers should be compared to ensure that the higher fishing group (if one is present within a general tribal population) is protected. In the case of CTUIR, these two numbers are quite different (see discussion below), so the CTUIR rate is based on the average rate specific to the higher fishing group rather than the average for the whole Tribe.

The U.S. EPA Office of Solid Waste and Emergency Response (OSWER) also considers fish consumption in the Superfund program. OSWER's policy is to assume an ingestion rate of 54g/day for high recreational consumers of locally caught fish [OSWER directive 9285.6-03]. This number is based on recreational, not Native American data. Region 10 of the U.S. EPA recommends the use of results from local or regional seafood intake surveys for use in the regional Superfund program[45]. If Tribal-specific or local information is not available, EPA-OSWER recommends using the U.S. EPA Exposure Factors Handbook, which recommends a mean and 95th percentile for the general U.S. population of 20.1 g/day and 63 g/day, respectively (U.S. EPA, 1997). For Native American subsistence populations the recommended value for mean intake is 70 g/day and the recommended 95th percentile is 170 g/day.

The Washington State Department of Ecology recently recommended a *draft* statewide default of 177g/day to protect all Washington residents including the highest consumers, subsistence fishers. The draft report recommends "final default consumption values of approximately 178 and 175 g/day for marine and freshwater areas, respectively. These values represent approximately the 90th percentile of the fish consumption rate distribution from the Toy et al. study and the 95th percentile from the CRITFC study, respectively[46]. State-wide criteria may use the mid-point between these values, or 177 g/day as a reasonably protective default. Shellfish may be separated out from the marine values. Shellfish estimates are recommended as 68 g/day based on the Toy et al. study."

The Washington Department of Ecology's 1997 standards for surface water refer to WAC 173-340-730 (Model Toxics Control Act), which includes a "placeholder" for fish consumption of 54 gpd.

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[43] Estimated Per Capita Fish Consumption in the United States. (EPA-821-C-02-003) (August 2002). http://www.epa.gov/waterscience/fish/consumption_report.pdf; *and* Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (2000) EPA-822-B-00-004, October 2000. http://www.epa.gov/waterscience/humanhealth/method/chapter4.pdf

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[46] Washington Department of Ecology, Analysis and selection of fish consumption rates for Washington State risk assessments and risk-based standards, external review draft, March 1999. http://www.ecy.wa.gov/biblio/99200.html

3.0 Fish Consumption Surveys of Current Suppressed Rates

Several studies have evaluated current Tribal fish consumption rates in the Pacific Northwest in order to evaluate current exposures and risks (Table 2). None of them addressed the issue of original fish consumptions rates which are protected by Treaty or by judicial decisions, and none addressed the current tribal conditions which forced many people off the River and away from their hereditary or Usual and Accustomed fishing sites. Additionally, none of them specifically consider the range of lifestyles within tribal communities, but assumed that Tribes are all composed of a homogeneous population even if Tribes with different histories and homelands and even languages were forced onto the same reservation. This results in bimodal or more distributions within many tribes. In the case of the Confederated Umatilla Tribes, there is a subset of tribal members who maintain high fishing rates and consumption rates (see next section). The studies summarized in Section 3 assumed that Tribes were homogeneous in their activities and lifestyles, and therefore took a statistical cross-section approach. In contrast, the studies summarized in Section 4 specifically focused on the subset of tribal members who maintain a true subsistence lifestyle, and on documenting original consumption rates.

Table 2. Major Pacific Northwest cross-sectional studies of current suppressed fish consumption rates.

	Mean (converted to g/person/d)			**95th**	**99th**
Survey	**finfish**	**shellfish**	**combined**	**Fish + shellfish**	
CRITFC	63.2	-	63.2	170-194	389
Suquamish	81.8	132.7	213.9	798	ND
Toy - Tulalip/Squaxin	48.8	22.3	72.9	177	ND
Sechena - Asian / Pac Isl.	-	-	119.3	?	?
CRITFC – outliers were eliminated from the database (implies a presumption of not valid). Suquamish – no labeling of high end consumers as outliers; says they were assumed to be accurate reports. Tulalip – recoded outliers (implies a presumption that these were valid but mistaken)					

3.1 CRITFC (1994)

CRITFC (1994). "A Fish Consumption Survey of the Umatilla, Nez Perce, Yakama, and Warm Springs Tribes of the Columbia River Basin." CRITFC Technical Report No. 94-3, Portland, OR.

The CRITFC fish consumption survey was designed in a way that is conventionally used in typical suburban populations. It used statistical rather than ethnographic research methods. Both methods are "scientific" in that they are systematic, repeatable, and verifiable, but they are suitable for different populations and situations. The CRITFC survey was a random cross-section of tribal members (names were randomly selected from enrollment lists), with ultimate surveys of 126 Warm Springs, 133 Nez Perce, 131 CTUIR, and about 130 Yakama members. The mean age of respondents was 39 years old (less than 10% were elders 60 years old or older). Tribal members were contacted by phone, mail, or in person. They were asked to drive to a central location on a particular day, and answer a lengthy set of questions read from a script (for consistency) by an interviewer. The overall response rate was 69% (31% of selected people either refused, could not be located, or did not participate for unknown reasons). It is likely that traditional members were under-represented due to refusal, lack of a phone, car, or permanent address, or inability to respond for the small amount of payment ($40).

Seven individuals reported that they ate more than 389 g/day, or more than 99% of the amount eaten by fish consumers (4 people ate 486 g/day, and one person each ate 648 g/d, 778 g/d, and 972 g/d). These values were treated as statistical outliers and were eliminated from the database. No follow-up was done to find out whether these higher rates were accurate or not, but we assume that these people are true subsistence fishers. Because these numbers are based on a reported meal frequency and size, we assume that the underlying answers by the interviewees were accurate, because people can provide information about meal frequency more easily than poundage.

During the research for the Harris & Harper paper (1977) traditional members who had been included in the CRITFC survey were asked if they gave accurate information, and several said no. Some traditional fishers said they simply refused to participate, or reported lower consumption rates than reality, due to a fear of law enforcement or fear of being accused of knowingly eating contaminated fish. Other factors are unknown, such as whether traditional members were away from home during a fishing season, or otherwise engaged in activities that prevented them from participating. The personal experiences of the people we are most interested in (elders and subsistence fishing families) make them less likely to answer questions, even when posed by a member of the community. Fishing families often have a family history of having to fish clandestinely and being persecuted by authorities or jailed as a result of fishing in their own rivers to feed their families.

The point of this discussion is that the makeup and history of the community must be understood before conducting a conventional survey. In addition to the above items, we know that elders tend to eat more traditionally (including people who return to traditional ways as they get older). Within the Umatilla and Walla Walla membership there are people who lost access to their hereditary fishing sites, or who have full-time day jobs or other family circumstances that prevent them from designating a family member as a fish provider.

Arithmetic mean = 63.2 grams/day
50^{th} percentile = 38.9 to 40.5 gpd
90^{th} percentile = 127 gpd (Table 10 says the weighted 90^{th} = 97 – 130 gpd).
95^{th} percentile = 182 (Table 10 says the weighted 95^{th} = 170 – 194 gpd. The 95^{th} % is also cited as 175 from Table 18 by the same author in her discussion of the Portland Harbor workplan)
98^{th} percentile = 317 gpd
99^{th} percentile = 389 gpd
Average serving size = 8.42 oz +/- 0.13 oz.

3.2 TOY et al. (1996).

Toy KA, Polissar NL, Liao S, and Mittelstaedt GD. (1996) "A Fish Consumption Survey of the Tulalip and Squaxin Island Tribes of the Puget Sound Region." Tulalip Tribes, Department of the Environment, 7615 Totem Beach Road, Marysville, WA 98721.

This survey was designed to focus on frequency (daily, weekly, monthly, annually) and portion size of fish and shellfish, both fresh and frozen. Commercial fishing and shellfishing is an important source of income for both tribes, but for the Tulalip, “at present, the consumption of shellfish is limited to a personal-use activity.” Sample size goals were developed by assuming a homogeneous (not bimodal) population and a certain standard deviation. Random names were generated, and children were evaluated if a parent was included (limited to one child per family). The final sample sizes were 73 Tulalip and 117 Squaxin adults over 18 and 68 children. A scripted questionnaire with food models was used.

52 edible species were divided into anadromous, pelagic, bottom fish, shellfish, and other (canned tuna or trout) categories. Consumption per body weight was recorded (average weight = 81 kg). Participants were paid $25. There was no correlation of consumption with income (i.e., low income did not drive people to eat more fish; high income did not allow more fish as a luxury purchase; or the two factors balanced each other).

“Outliers” were recoded to the 3 SD value. “The distribution of consumption rates was skewed toward large values.” At least 25 people (out of 190, or 13% of participants) ate more than the 95th % of total finfish. This suggests that there is an underlying bimodal distribution of higher consumers, rather than being a single homogeneous population.

The weighted means of total finfish and shellfish consumption rates for both Tribes combined were:

Shellfish = 0.272 g/kg/d
Finfish = 0.596 g/kg/d
Total fish = 0.890 g/kg/d

Table 3. Combined Tulalip and Squaxin Island results (from Toy, Table A2). Results are given in grams per kg body weight per day and grams per person (assumed to weigh 70 kg) per day.

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	Finfish (g/70kg/d)	***Shellfish (g/70kg/d)***	***Total fish (g/70kg/d)***
50th %	22.2	8.1	37.2
90th	122.5	58.8	161.8
95th	153.2	91.6	205.5
99th	Not calculated	Not calculated	Not calculated

3.3 Suquamish (2000).

Suquamish Tribe (2000). “Fish Consumption Survey of the Suquamish Indian Tribe of The Port Madison Indian Reservation, Puget Sound Region.” Suquamish Tribe, Fisheries Department, PO Box 498, Suquamish, WA.

This study used a questionnaire with food models, as well as maps, pictures, and interviews. The study used scripted statistical methods for the questionnaire and ethnographic methods for oral history and elders’ interviews. There were 3 special interest groups: children under 6, women between 16 and 42, and elders 55 and over.

“Despite degraded water quality and habitat, tribal members continue to rely on fish and shellfish as a significant part of their diet. All species of seafood are an integral component of the cultural fabric that weaves people, the water, and the land together in an interdependent linkage which was been experienced and passed on for countless generations."

Given a SD of 1.26 (from the span of ingestion rates for the Toy study), and a target precision of +/-20%, the target sample size was *n = 150*, indicating that one-quarter of the adults should be sampled. The final sample size was 92 adults (out of 425 eligible) and 31 children. Participants were paid $25. The participation rate was 65%.

Consumption rates "have very little correlation with body weights among adults," but people did not want to report their weights or be weighed. The average weight (males and females combined) was 79 kg. As with the Tulalip study, some people report eating more for health benefits, but twice as many people ate less now than 20 years ago due to contamination and restricted access.

Outliers were not recoded because high values were believed to reflect actual high consumption. When tested, it was found that recoding outliers had "virtually no effect" on results. The distribution graph again appears bimodal, with a group of people eating 9-10 g/kg/d (750 g/d), but the "best fit" line obscures this. One respondent reported an ingestion of 1 kg/d, which is nutritionally possible, although it may also have reflected a short-term seasonal availability – it is known that people tend to overestimate whatever is seasonally available and underestimate whatever is out of season.

Adults total mean finfish and shellfish = 2.7 g/kg/d.
Average finfish = 1.03 g/kg/d; shellfish = 1.68 g/kg/d.
90^{th} percentile = 2.5 finfish, 4.6 shellfish, 6.2 total (all in g/kg/d)
(or 175, 322, 434 in g/70kg/d)
95^{th} percentile = 3.4 finfish, 7.75 shellfish, 10.1 total (all in g/kg/d)
(or 238, 542.5, 707 in g/70kg/d)
99^{th} percentile = not calculated

3.4 Sechena et al. (1999)

R Sechena, C Nakano, S Liao, N Polissar, R Lorenzana, S Truong, and R Fenske (1999) "Asian and Pacific Islander Seafood Consumption Study," (EPA 910/R-99-003). Seattle: EPA Region 10; http://www.epa.gov/r10earth/offices/oea/risk/a&pi.pdf

Sechena R, Liao S, Lorenzana R, Nakano C, Polissar N, and Fenske R. (2003) "Asian American and Pacific Islander seafood consumption -- a community-based study in King County, Washington." J Expo Anal Environ Epidemiol. 13(4):256-66.

This paper describes and quantifies seafood consumption rates and acquisition and preparation habits of 202 first- and second-generation Asian American and Pacific Islanders (AAPI) from 10 ethnic groups (Cambodian, Chinese, Filipino, Hmong, Japanese, Korean, Laotian, Mien, Samoan, and Vietnamese) in King County, Washington in 1997.

A sample size of 200 fish consumers was the target, and 202 people actually participated, with 5-30 interviews per ethnic group. Because it was not possible to pre-identify first and second generation A/PI for random name generation, half the participants were invited to participate from rosters provided by community leaders for random contact, and half were volunteers who had previously been recruited for a Dietary Habits Study. The interviewee pool was adjusted to reflect age and gender of the populations (from census and other information), so the participants had to fit the ethnic, age and gender profiles before inclusion in the study. If groups were still too small, relatives of participants were actively recruited. The sample size of some ethnicities was deliberately larger than others, according to a judgment about how well established that group was in the Seattle area (e.g., they knew where and how to get fish, etc.). The majority of the 202 respondents (89%) were first generation (i.e., born outside the United States). There were slightly more women (53%) than men (47%), and 35% lived under the 1997 Federal Poverty Line. Participants were paid $25 or given a store voucher

In general, the A/PI members consumed seafood at a very high rate. The average overall consumption rate for all seafood combined was 1.891 grams/per kilogram body weight/day (g/kg/day), with a median consumption rate of 1.439 g/kg/day (or a mean of 117.2 and a median of 89 g/70kg/day). Seafood consumption based on gender, age, income, and “fishermen” status did not differ significantly. However, mean consumption rates varied significantly between ethnic groups with Vietnamese (2.63 g/kg/day) and Japanese (2.18 g/kg/day) having the highest average consumption rates, and Mien (0.58 g/kg/day) and Hmong (0.59 g/kg/day) the lowest.

The predominant seafood consumed was shellfish (46% of all seafood). The most frequently consumed finfish and invertebrates were salmon (93% of respondents), tuna (86%), shrimp (98%), crab (96%), and squid (82%). Fish fillets were eaten with the skin 55% of the time, and the head, bones, eggs, and/or other organs were eaten 20% of the time. Crabmeat including the hepatopancreas was consumed 43% of the time.

Outliers (more than 3 SD from the mean) had “large but uncertain” ingestion rates. They were recoded to 3 SD. Again, fish consumption rates were skewed considerably for all fish groups. The skewed distribution indicates that a few respondents had a larger consumption rate than other respondents. Because outliers had already been recoded within each fish group, these large consumption rates reflected the fact that some API members were, indeed, higher consumers of seafood.

People over 55 ate more fish (131 gpd) than younger people (111 gpd). There was no correlation with income. Volunteer participants ate very slightly more than roster recruits (random contact from lists). Fishermen and non-fishermen did not show any statistical difference, and there was little or no difference between first generation (foreign born) and second generation (bore here).

TABLE 4. Consumption Rates of Asian/Pacific Islanders in King County (From Sechena et al., 1999, Table R-1). [LCI= lower confidence interval; UCI = upper confidence interval]

Category	**N**	**Median g/kg/d**	**Mean g/kg/d**	**Percentage of consumption**	**S.E.**	**95% LCI g/kg/d**	**95%UCI g/kg/d**	**90% g/kg/d**
Anadromous Fish	202	0.093	0.201	10.6%	0.008	0.187	0.216	0.509
Pelagic Fish	202	0.215	0.382	20.2%	0.013	0.357	0.407	0.829
Freshwater Fish	202	0.043	0.110	5.8%	0.005	0.101	0.119	0.271
Bottom Fish	202	0.047	0.125	6.6%	0.006	0.113	0.137	0.272

Shellfish Fish	202	0.498	0.867	45.9%	0.023	0.821	0.913	1.727
Seaweed/ Kelp	202	0.014	0.084	4.4%	0.005	0.075	0.093	0.294
Miscellaneous Seafood	202	0.056	0.121	6.4%	0.004	0.112	0.130	0.296
All Finfish	202	0.515	0.818	43.3%	0.023	0.774	0.863	1.638
All Fish	202	1.363	1.807	95.6%	0.042	1.724	1.889	3.909
All Seafood	202	1.439	1.891	100.0%	0.043	1.805	1.976	3.928
All Seafood, converted to g/70kg person/d		100.7	132.4			126.4	138.3	274.5

4.0 Studies of subsistence fishers and Treaty-based Consumption Rates

In order to document original fish consumption rates, as well as to evaluate the subset of tribal members who maintain a subsistence level of fish consumption, a combination of historical documentation, literature review, and additional ethnographic interviews were used. These three lines of evidence indicate that the range of original rates (also referred to as a Treaty-protected rate) is 540 to 1000 gpd. Interviews confirm that there are quite a few people who consume fish two to three times a day in various forms (whole filet, soup, powdered thickener or flavoring, dried or smoked as snacks). Some of the primary references are summarized below, with citations of other literature included. It should be noted that these rates persist to the present despite the decimation of salmon runs by canneries and dams, and knowledge of contamination.

4.1 Harris and Harper (1997)

Harris, S.G. and Harper, B.L. (1997) "A Native American Exposure Scenario." Risk Analysis, 17(6): 789-795.

Harris interviewed 75 people in order to identify members of the special interest group (the higher fishing group). A subset of 35 traditional fishers, including many elders, were then interviewed in detail using ethnographic methods. The ethnographic interview is actually a process (Schensul et al., 1999a,b; Spradley, 1979; Emerson et al., 1995; Fetterman, 1998; Thornton, 1998; Mihesuah, 1998). It involves establishing community standing and personal credibility, and demonstrating cultural sensitivity and an understanding of what information is proprietary. Without this process, information collected from interviews or questionnaires with Native Americans risks being inaccurate. Interviewees were asked how the accuracy of their responses compared to other studies, including the CRITFC study, and many stated that they do not try to provide accurate information (or actively seek to avoid revealing information) unless they know the person and know how the information could be used or misused. The authors consider this to be an essential part of the bioethics and informed consent safeguards, even if this takes considerably more time than simply asking people to answer questions.

Interviewees reported eating fish daily, with fresh and dried fish in equal weights. This amount reflects one 4-ounce portion of fresh fish and 4 ounces of dried fish, which is equivalent to 12 ounces of wet weight. Since these interviews, more research has been done which indicates that several forms of fish consumption were overlooked, including use as a thickener and flavoring, and the use of whole fish and eggs were probably underestimated. In addition, the CRITFC (1994) results indicates that half of the interviewees ate less than they did twenty years previously. The resulting number is 540 grams per day.

Anecdotally, people are now eating more fish as the salmon runs are being restored in the Umatilla and Walla Walla Rivers. The Umatilla Tribes have invested a large amount of money, time, and effort to restore these runs, with the goal of regaining subsistence fishing capabilities.

4.2 Walker (1967).

> **Walker DE (1967. Mutual Cross-Utilization of Economic Resources in the Plateau: from aboriginal Nez Perce Fishing Practices. Washington State University Laboratory of Anthropology, Report of Investigations, No. 21, Pullman WA.**

Walker estimated that fish consumption rates before dam construction ranged from 365 to 800 pounds per year.

4.3 Walker (1985)

> ***cited in:*** **Scholtz A, O'Laughlin K, Geist D, Peone D, Uehara J, Fields L, Kleist T, Zozaya I, Peone T, and Teesatuskie K, (1985), "Compilation of information on salmon and steelhead total run size, catch, and hydropower related losses in the Upper Columbia River Basin, above Grand Coulee Dam." Fisheries Technical Report No. 2., Upper Columbia United Tribes Fisheries Center, Eastern Washington University, Department of Biology, Cheney, WA 99004.**

Walker reviewed the ethno-historical and scientific literature to estimate the pre-dam fish consumption rates of Tribes along the Columbia River. He estimated that total fish consumption (not harvest) was 1000 lbs per capita for lower Columbia Tribes, of which 75% were salmon (Umatilla and Yakama estimates), and the Nez Perce also ate 1000 lbs per capita of which 90% were salmonids (including trout and whitefish). Other early estimates are very close to this. Hewes (1947, 1973) originally estimated from 50 to 900 pound per year for Plateau Tribes by estimating a total catch, subtracting an estimate of the amount of salmon that was trade, used as dog food, and other uses, and adding additional 1/3 of the weight of salmon to account for resident fish consumption during the 1/3 of the year that salmon are not running, (but considering the dried, pounded (pemmican or powder) fish are eaten in the winter).

Walker improved on Hewes' estimate by using actual historical observational counts of the Indian catch, rather than a global estimate of a Tribe's entire catch for a season. The median annual per capita consumption of salmonids for the Columbia Plateau Tribes derived by Walker was 585 pounds per capita. "Walker's figures provide a more accurate picture of the catch..." based on direct observation and ethnographic fieldwork."

Other authors were also cited in this reference. “Schalk (1985) pointed out that the early caloric estimates were for salmon flesh in the ocean. Since salmon lose calories as they migrate upstream, tribes living upriver would actually have to take more fish than tribes living downriver to obtain an equivalent amount of calories.” He estimated that 1.5 pounds of wet weight are equivalent to 1 pound dried, and that 20% of a whole fish is entrails. Schalk estimated that a family needs 250 to 500 dried fish per family, or 2000 pounds per family.

Walker also cited Swindell (1942), who interviewed 55 family heads from Yakama, Umatilla and Warm Springs (not specifically fishing families) for an average of 322 pounds/yr in 1941 (the time when the canneries were taking a large percentage of the fish, leaving fewer for the Indians). Hewes estimated that Cayuse ate 365 pounds per capita, while Umatilla and Walla Walla ate 500 pounds per capita. Yakama, Klickitat, Wanapum, and Palus were estimated to eat 400 lbs, and Nez Perce were estimated to eat 300 lbs.

Hudson Bay records from 1827, 1829, and 1830 indicated that the company supplemented the regular supplies that were shipped to them by purchasing about 535 lbs of fish per person (about 30 people were housed at the Colville Post), as well as around 100 lbs dried venison (for the 30 men), 1500 pounds of fresh venison, 10 beavers, 275 ducks, 200 geese, 10 cranes, 75 dogs, 50 grouse, and a few swans, beaver tails, and small fish.

4.4 Walker (1992)

> **Walker, D.E. (1992). Productivity of Tribal Dipnet Fishermen at Celilo Falls: Analysis of the Joe Pinkham Fish Buying Records. Northwest Anthropol. Res. Notes. 26(2):123-135.**

Walker review an earlier reference (Anastasio, 1972), who reviewed historical accounts of early explorers, as well as thoroughly reviewing ethnographic and ethnohistoric research. Archaeological research indicates that this region has been the scene of relatively continuous anadromous fishing activity for at least 10,000 years. Walker reviewed fish buying records in 1945, a time when fish runs were declining rapidly, continuing a trend begun with the canneries. Over the years, packing house and cannery records support statements that salmon runs have been 99% decimated.

4.5 Walker (1999)

> **Walker, D.E. and Pritchard, L.W.(1999). “Estimated Radiation Doses to Yakama Tribal Fishermen: An Application of the Columbia River Dosimetry Model for the Hanford Environmental Dose Reconstruction Project.” Boulder, CO: Walker Research Group.**

This study relied on the use of officially recorded fishing sites along the Columbia River mainstem, and interviews with the individuals who actually used those sites between 1950 and 1971. Fishermen were grouped as maximum, median, or minimum river users according to how many fishing sites they held. Minimum river users used between 1 and 9 fishing sites, and ate 64 pounds per year (29 kg/yr or 80 gpd). Median river users used between 10 and 19 sites and ate 282 pounds per year (128 kg or 350 gpd). Maximum river users “would be considered subsistence fishermen,” and used 20 or more fishing sites. They ate 522 pounds per year (237 kg or 650 gpd). 75% of fish were caught between April 1 through October 31; of this 75%, 90% was anadromous and 10% was resident. Between

November 1 and March 31, 25% of the annual catch was caught; of this 75% were resident and 25% anadromous.

4.6 Hunn (1990)

Hunn ES (1990). Nch'i-Wana, The Big River: Mid-Columbians and Their Land. Seattle: University of Washington Press.

Hunn estimated that 30-40% of caloric needs supplied by salmon. Table 13 (Hunn, 1990, page 150) provides estimates of salmon consumption per capita from Hewes (not including resident fish during the winter quarter): Wishram Tribe (400 pounds per year), Tenino Tribe (500 pounds), Umatilla Tribe (500 pounds), and Nez Perce Tribe (382 pounds from Hewes estimate and 582 pounds from Walker's estimates), including the adjustment for caloric loss as fish move upstream.

4.7 Ray (1977)

Ray, V.E. (1977). "Ethnic Impact of the Event Incident to Federal Power Development on the Colville and Spokane Indian Reservations." Prepared for the Confederated Tribes of the Colville Reservation and the Spokane Tribe of Indians, Port Townsend, WA. Available at Eastern Washington State Historical Society, Spokane WA.

Ray provided expert testimony of the amount of fish consumption of the upper Columbia River Tribes during the discussions of the impact of the Grand Coulee Dam. . Ray estimates 1.25 pound per person per day based on 50 years of observation and research, including fish counts, catch rates, early observers. This is also supported by contemporaneous observations at Celilo during the late 1940s.

> "The salmon and other fish taken from the rivers provided around half of the native subsistence, and the lands immediately adjacent to the rivers supplied a significant part of the game which was taken."
>
> "Apart from fish and game, the most important component of the Indian diet was roots."
>
> "Salmon was the staple food for both the Colvilles and the Spokanes. The fish were taken during the long fishing seasons – May to October – but during the same period great quantities were dried to serve and the basic item of subsistence during the winter."

4.8 Boldt (1994) case law

Judge Boldt stated that "Salmon, however, both fresh and cured, was a staple in the food supply of these Indians. It was annually consumed by these Indians in the neighborhood of 500 pounds per capita."[47] Boldt was referring to Columbia mainstem fishers when he wrote this. This does not include resident fish.

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[47] U.S. District Judge George Boldt, U.S. v. Washington, February 12, 1974, note 151.

4.9 Bimodality in Tribal communities

In the above discussion, we have suggested that the cross-sectional tribal surveys summarized in Section 3 revealed a bimodal distribution, with a cluster of people consuming high amounts of fish. We believe that these are accurate reports from members of a distinct group of subsistence consumers, and that most of this group is missed in cross-sectional surveys because they decline to participate in conventional surveys. However, this raises the question of how a tribal or tribal confederation should be stratified, and whether this reflects simply a high end tail of a normal distribution defined by an arbitrary upper percentile or standard deviation, or whether there is a discernible subset of tribal members with a distinct lifestyle and/or a statistically detectable consumption rate.

- In the Sechena study, respondents were divided into low (<75th percentile) or higher (> 75th percentile) consumers; the basis for this is not given.
- In the Walker (1999) study, Columbia River mainstem fishers were divided into three groups according to how many fishing sites were used by a fisherman; the basis for this was not given.
- In the three tribal cross-sectional studies, there appear to be clusters of high consumers; since no follow-up was done to investigate the characteristics or accuracy of these individuals, we conclude (as others have concluded) from indirect evidence that these people are members of a subsistence subset that is otherwise obscured by poor study design, and that their reports were indeed accurate.
- In our review of subsistence and cross-sectional studies, we have concluded that a threshold for subsistence consumption rates is roughly 1 pound per day, without regard to the shape of a distribution curve.

The Confederated Umatilla Tribes have distinct subsets of natural resource use according to the original Tribe's homeland; Cayuse emphasized upland hunting more than fishing, while Walla Walla and Umatilla Tribes emphasized fishing more than hunting. During ethnographic interviews, several subsistence consumers confirmed our supposition that traditional subsistence fishers generally decline to participate in surveys by people they don't know, or who give information that they assume is "correct" rather than accurate.

5.0 SUMMARY

We conclude that the subsistence consumption rate for the Confederated Tribes is in the range of 540 to 650 gpd or more (particularly at permanent fishing villages such as Celilo). Within this range, we have concluded that the best estimate is 500 pounds per year (or 620 gpd) as the central tendency of subsistence fish consumption, as well as being recognized in a widely-cited legal decision.

- The CRITFC study (1994) is judged to reflect the median river user (350 gpd from Walker) and minimum river users (80 gpd from Walker). This is comparable to the CRITFC 95th and 99th percentiles (175-182 gpd and 389 gpd) and the CRITFC median (63 gpd), further indicating that the CRITFC study captured data for the minimum and median river users, not the maximum river users.
- The CRITFC "outliers" (reporting a consumption rate of 486-972 gpd) are comparable to Walker's maximum river users (650 gpd), which reflect subsistence use.

- Most per capita estimates of fish consumption rates for subsistence fishers are approximately 500 pounds per year, or 620 gpd as a mean value. These results are based on direct observation of early observers, fish buying records, interview with current members, caloric and nutritional calculations, and ecological and archaeological information.
- Salmon supplied 30% to 40% of the total calories in the river-based subsistence diet. At an average of 175 kcal per 100g of raw fish weight, 620 gpd would provide roughly 1000 kcal daily, which is 40% of a 2500 kcal diet. This conforms with the estimates of Hunn and others that salmon provide 30-40% of the subsistence diet.
- The number of people in the high consumer or maximum river user group diminished as runs were decimated, dams were constructed, and awareness of contamination increased. However, the existence of the subsistent or maximum river user clearly persists to this day, and in fact may be increasing recently as runs are restored and health benefits of eating fish are emphasized.

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Appendix 4.

Native American Sweat Lodge Exposure Scenario – Exposure Equations

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Inhalation in Sweat Lodge

In this analysis it is assumed that the internal temperature of the sweat lodge is maintained at a constant 150 °F [339 °K] (personal communication). It is further assumed that the geometry of the lodge can be estimated as a hemisphere of radius *r* so that the internal volume is equal to:

$$V_{lodge} = \frac{2}{3} \cdot \pi \cdot r^3 \qquad (1)$$

where:

V_{lodge} = Internal volume of the sweat lodge (m^3)
r = radius of sweat lodge (m)
π = the constant *pi* (unitless); $\pi \approx 3.14159$

Finally, contaminants, termed Compounds of Potential Concern (COPC), are assumed to be introduced into the sweat lodge predominately through the water used to create steam.

Volatile and Semi-Volatile Compounds

For the purpose of the following analysis, volatile and semi-volatile compounds are defined as those with a boiling point less than, or equal to, 339 °K. Intake of COPCs via inhalation are typically estimated as:

$$I_{inh} = \frac{C_v \cdot IR \cdot ET \cdot EF \cdot ED}{BW \cdot AT \cdot CF} \qquad (2)$$

where:

I_{inh} = inhalation exposure to COPCs in the sweat lodge (mg/kg-day)
C_v = vapor phase COPC concentration (mg/m^3)
IR = inhalation rate (m^3/hr)
ET = exposure time (hr/event)
EF = exposure frequency (events/yr)
ED = exposure duration (yr)
BW = body weight (kg)
AT = averaging time for carcinogens (AT_C) or noncarcinogens (AT_N) (yr)
CF = units conversion factor of 365 (day/yr)

For compounds that preferential partition to the air phase it is assumed that a negligible quantity deposit on surfaces or partition into condensed liquid. Thus, the bulk of contaminants added in the water will remain in the vapor phase throughout the sweat and the vapor concentration of an individual COPC is given by:

$$C_v(t) = C_{dw}\left(\frac{V_w(t)}{V_{lodge}}\right) \tag{3}$$

where:

- C_{dw} = dissolved surface water concentration of the COPC (mg/L); calculated according to EPA 1998a, Appendix B
- $C_v(t)$ = time dependent vapor phase concentration of the COPC in the sweat lodge (mg/m^3)
- $V_W(t)$ = cumulative volume of water used in the sweat at time *t*; see the discussion of $V_W(t)$ below (L)

Combing Equations 1 through 3 and recognizing that the total inhalation exposure for a single sweat requires integration of the volume function over the duration of the sweat then the following equation for inhalation exposure results:

$$\int_0^{ET} I_{inh}(t)\cdot dt = I_{inh} = \frac{C_{dw}\cdot\left(\frac{1}{\frac{2}{3}\cdot\pi\cdot r^3}\right)\cdot IR\cdot EF\cdot ED}{BW\cdot AT\cdot CF}\cdot\int_0^{ET} V_w(t)\cdot dt \tag{4}$$

If it is assumed that water is poured over heated rocks at a constant rate throughout the sweat, then the volume function would be described by the following linear equation:

$$V_w = \frac{V_{w,total}}{ET}\cdot t \tag{5}$$

Where $V_{w,total}$ is the total amount of water that will be used in the sweat to create steam in units of liters (L).

Noting that:

$$\int_0^{ET} V_w(t)\cdot dt = \frac{V_{w,total}}{ET}\cdot\int_0^{ET} t\cdot dt = \frac{V_{w,total}}{2}\cdot ET \tag{6}$$

then the intake by inhalation is described by the following equation:

$$I_{inh} = \frac{C_{dw} \cdot \left(\frac{V_{w,total}}{2}\right) \cdot \left(\frac{1}{\frac{2}{3} \cdot \pi \cdot r^3}\right) \cdot IR \cdot ET \cdot EF \cdot ED}{BW \cdot AT \cdot CF} \qquad (7)$$

If more water is poured over the heated rocks during the first part of the sweat, then the following form would be more appropriate:

$$V_w(t) = \frac{V_{w,total} \cdot t}{k + t} \qquad (8)$$

where $V_{w,total}$ is the maximum amount of water poured over the heated rocks during a sweat and k indicates the time when half of the water has been used. Integration of the above equation between the limits of 0 and ET results in the following expression for intake via inhalation:

$$I_{inh} = \frac{C_{dw} \cdot \left(\frac{V_{w,total}}{\frac{2}{3} \cdot \pi \cdot r^3}\right) \cdot \left(ET + k \cdot \ln\left(\frac{k}{ET + k}\right)\right) \cdot IR \cdot EF \cdot ED}{BW \cdot AT \cdot CF} \qquad (9)$$

The assumptions regarding the mathematical representation of water volume in the sweat lodge are an uncertainty in estimating intake via inhalation for the Native American adult. For simplicity, the linear assumption represented by Equations 5 and 7 is a reasonable approximation for intake via inhalation of volatile and semivolatile compounds in the sweat lodge. Table 1 provides a list of typical values for the parameters used in Equation 7.

Table 1: Typical Parameter Values for Calculating I_{inh} for Volatile and Semi-volatile compounds

Parameter	Typical Value	Unit
Volume of water used in a sweat ($V_{w,total}$)	4	L
Radius of a hemispherical sweat lodge (*r*)	1	m
Inhalation rate (*IR*)	30	m^3/day
Length of a sweat event (*ET*)	1	hr/event
Number of sweats per year (*EF*)	365	events/yr
Number of years a person sweats in a life time (*ED*)	64	yr
Average body weight (*BW*)	70	kg
Averaging time (*AT*)	70 (carcinogen) ED (noncarcinogens)	yr
Conversion factor (*CF*)	365	day/yr

Nonvolatile Compounds
For the purpose of the following analysis nonvolatile compounds are defined as those with a boiling point greater than 339 °K. The sweat lodge vapor concentration for nonvolatile compounds can be estimated by assuming that:

- Nonvolatile COPC become airborne as an aerosol as the water they were carried in vaporizes.
- Once airborne, nonvolatile compounds deposit onto solid surfaces with aqueous condensation.
- The ideal gas law can be applied to air and water vapor at the temperature and pressure of the sweat lodge.

With these assumptions the quantity of nonvolatile constituents in the air phase is limited to that which is carried into the air phase by the volume of liquid water needed to create saturated conditions in the lodge. Numerically this can be expressed as:

$$C_v = \left(\frac{V_{w,sat}}{V_{lodge}}\right) \cdot C_{dw} \tag{10}$$

where $V_{w,sat}$ represents the volume of liquid water needed to create a saturated vapor in the sweat lodge in units of liters (L). From the ideal gas law and the properties of liquid water, $V_{w,sat}$ can be determined from:

$$V_{w,sat} = \left(\frac{p \cdot V_{w,air}}{R \cdot T}\right)\left(\frac{MW_w}{\rho_w}\right) \tag{11}$$

where:

$V_{w,air}$	=	volume of air space in sweat lodge occupied by water vapor (m^3)
p	=	ambient pressure (mmHg)
ρ_w	=	density of liquid water (g/L)
T	=	temperature of the sweat lodge (K)
R	=	ideal gas law constant (0.06237 ($mmHg \cdot m^3$)/($gmole \cdot K$))
MW_w	=	molecular weight of water (AMU)

The volume of water vapor in the sweat lodge air can be estimated from the vapor pressure of water at the temperature of the sweat lodge (assumed constant at 339 °K), the ambient pressure, and the internal volume of the lodge.

$$V_{w,air} = \left(\frac{p^*}{p}\right) \cdot V_{lodge} \tag{12}$$

where p^* represents the vapor pressure of water at temperature T (mmHg). The vapor pressure of water as a function of temperature is given by the Antoine equation as follows (Himmelblau, 1982):

$$\ln(p^*) = 18.3036 - \frac{3816.44}{T - 46.13} \quad (13)$$

Combining Equations 10 through 13 allows the concentration of nonvolatile COPC in the air to be determined as follows:

$$C_v = C_{dw} \cdot \left(\frac{MW_w}{R \cdot T \cdot \rho_w} \right) \cdot EXP\left(18.3036 - \frac{3816.44}{T - 46.13} \right) \quad (14)$$

Application of Equation 14 to the definition of vapor inhalation exposure given in Equation (2) yields the following result for nonvolatile compounds:

$$I_{inh} = \left(\frac{IR \cdot ET \cdot EF \cdot ED}{BW \cdot AT \cdot CF} \right) \cdot C_{dw} \cdot \left(\frac{MW_w}{R \cdot T \cdot \rho_w} \right) \cdot EXP\left(18.3036 - \frac{3816.44}{T - 46.13} \right) \quad (15)$$

Table 2 provides a list of typical values for the parameters used in Equation 15.

Table 2: Typical Parameter Values for Calculating I_{inh} for Nonvolatile compounds

Parameter	Typical Value	Unit
Temperature of the sweat lodge (T)	339 (150)	K (F)
Ideal gas law constant (R)	0.06237	(mmHg·m^3)/(gmole·K)
Inhalation rate (*IR*)	30	m^3/day
Length of a sweat event (*ET*)	1	hr/event
Number of sweats per year (*EF*)	365	events/yr
Number of years a person sweats in a life time (*ED*)	64	Yr
Average body weight (*BW*)	70	Kg
Averaging time (*AT*)	70 (carcinogen) ED (noncarcinogens)	Yr
Conversion factor (*CF*)	365	day/yr
Molecular weight of water (MW_w)	18	g/gmole
Density of liquid water (ρ_w)	1000	g/L

Dermal Exposure in Sweat Lodge

Dermal exposure to COPC in a sweat lodge can come from skin contact with contaminates in both the air and in water that condenses on the skin. Calculation of dermal exposure to COPC from water contacting the skin is typical represented by the following equations:

$$I_{d,l} = \frac{C_{dw} \cdot SA \cdot f_{SA,l} \cdot Kp_l \cdot ET \cdot EF \cdot ED \cdot CF_3}{BW \cdot AT \cdot CF_2} \quad (16)$$

where:

- $I_{d,l}$ = intake of COPCs from dermal absorption to liquid within the sweat lodge (mg/kg-day)
- C_{dw} = dissolved-phase surface water concentration (mg/L); calculated according to EPA 1998a, Appendix B
- SA_l = body surface area available for contact (m^2)
- $f_{SA,l}$ = Fraction of skin area (SA) in contract with liquid (unitless)
- Kp_l = COPC-specific water to skin permeability constant (cm/hr)
- ET = exposure time (hr/event)
- EF = exposure frequency (events/yr)
- ED = exposure duration (yr)
- CF_2 = units conversion factor of 365 (day/yr)
- CF_3 = units conversion factor of 10 (L/m^2-cm)
- BW = body weight (kg)
- AT = averaging time for carcinogens (AT_C) or noncarcinogens (AT_N) (yr)

Dermal exposure resulting from skin contact with contaminants in the air is calculated as:

$$I_{d,v} = \frac{C_v \cdot SA \cdot f_{SA,v} \cdot Kp_v \cdot ET \cdot EF \cdot ED \cdot CF_1}{BW \cdot AT \cdot CF_2} \quad (17)$$

where:

- $I_{d,v}$ = intake of COPCs from dermal absorption to vapor within the sweat lodge (mg/kg-day)
- C_v = vapor-phase concentration for a COPC (mg/m^3)
- $f_{SA,v}$ = Fraction of skin area (SA) in contract with vapor (unitless)
- Kp_v = COPC-specific vapor to skin permeability constant (cm/hr)
- CF_1 = units conversion factor of 0.01 (m/cm)

Volatile and Semi-Volatile Compounds

Dermal exposure should be calculated using the same assumptions described for inhalation exposure. For volatile and semivolatile compounds (defined as those with a boiling point less than or equal to 339 °K), 100% volatilization with a hemispherical sweat lodge was assumed. Hence, the primary exposure pathway will be from vapor and exposure from condensed water can be neglected. The vapor concentration of COPC causing dermal exposure is identical to the inhalation concentration and is given by Equations 3 and 5. Combining Equations 3 and 5 with Equation 17 and integrating between the limits of 0 and ET results in the following prediction from dermal exposure to volatile and semi-volatile compounds.

$$I_{d,total} = I_{d,v} = \frac{C_{dw} \cdot \left(\frac{V_{w,total}}{2} \right) \cdot \left(\frac{1}{\frac{2}{3} \cdot \pi \cdot r^3} \right) \cdot SA \cdot f_{SA,v} \cdot Kp_v \cdot ET \cdot EF \cdot ED \cdot CF_1}{BW \cdot AT \cdot CF_2} \quad (18)$$

where $I_{d,total}$ is the total dermal exposure rate for volatile and semi-volatile compounds. Table 3 provides a list of typical values for the parameters used in Equation 18.

Table 3: Typical Parameter Values for Calculating $I_{d,total}$ for Volatile Semi-volatile compounds

Parameter	Typical Value	Unit
Volume of water used in a sweat ($V_{w,total}$)	4	L
Radius of a hemispherical sweat lodge (r)	1	m
Body surface area available for contact (SA)	1.8	m^2
Fraction of skin area (SA) in contact with vapor ($f_{SA,v}$)	0.0 - 1.0	unitless
COPC-specific permeability constant for vapor exposure (Kp_v)	1 to 1E-5	cm/hr
Length of a sweat event (ET)	1	hr/event
Number of sweats per year (EF)	365	events/yr
Number of years a person sweats in a life time (ED)	64	yr
Average body weight (BW)	70	kg
Averaging time (AT)	70 (carcinogen) ED (noncarcinogens)	yr
Conversion factor (CF_1)	0.01	m/cm
Conversion factor (CF_2)	365	day/yr

Nonvolatile Compounds

For non-volatile compounds (defined as those with a boiling point greater than 339 °K), the dermal exposure assumptions would result in a concentration in condensed water equal to that of the water added to the heated rocks and a vapor concentration as described by Equation 14. Thus, exposure through dermal contact resulting from water condensing on the skin would be calculated using the following equation:

$$I_{d,l} = \frac{C_{dw} \cdot SA \cdot f_{SA,l} \cdot Kp_l \cdot ET \cdot EF \cdot ED \cdot CF_3}{BW \cdot AT \cdot CF_2} \qquad (19)$$

The dermal exposure to COCP in the vapor phase is represented by combining Equations 17 and 14 as follows:

$$I_{d,v} = \left(\frac{(SA \cdot f_{SA,v} \cdot Kp_v \cdot ET \cdot EF \cdot ED \cdot CF_1}{BW \cdot AT \cdot CF_2} \right) \cdot C_{dw} \cdot \left(\frac{MW_w}{R \cdot T \cdot \rho_w} \right) \cdot \ldots$$
$$\ldots EXP\left(18.3036 - \frac{3816.44}{T - 46.13} \right) \qquad (20)$$

In this equation $f_{SA,v}$ and Kp_v represents the fraction of skin area (SA) in contact with vapor and the COPC-specific permeability coefficient for a contaminant from vapor to the skin.

The total dermal exposure for nonvolatile compounds is thus represented by the sum of $I_{d,v}$ and $I_{d,l}$. That is:

$$I_{d,total} = I_{d,v} + I_{d,l} \qquad (21)$$

It should be noted that at the temperature conditions assumed for a sweat lodge it is acceptable to neglect the vapor component of dermal exposure since it will always be less than 0.2% of the liquid exposure value. This can be demonstrated by computing the ratio of the vapor to liquid exposure rates. In this calculation it should be recognized that, in a sweat lodge, more of the body surface area will be covered with a layer of liquid water (condensation and perspiration) than would be dry and so available for only vapor contact (i.e. $f_{SA,l} > f_{SA,v}$). In addition the vapor permeability coefficient is generally within an order of magnitude of the corresponding liquid coefficient (EPA, 1992). With these assumptions the ratio of vapor to liquid dermal exposure is given by:

$$\frac{I_{d,v}}{I_{d,l}} = \frac{CF_1 \cdot MW_w}{CF_3 \cdot \rho_w \cdot R \cdot T} \cdot \frac{f_{SA,v}}{f_{SA,l}} \cdot \frac{Kp_v}{Kp_l} \cdot EXP\left(18.3036 - \frac{3816.44}{T - 46.13} \right) \leq 1.6 \times 10^{-3} \qquad (22)$$

Hence, for the purposes of this evaluation the dermal exposure to nonvolatile compounds can be represented by:

$$I_{d,total} = I_{d,l} \qquad (23)$$

Table 4 provides a list of typical values for the parameters used in Equations 19 through 23.

Table 4: Typical Parameter Values for Calculating $I_{d,total}$ for Nonvolatile compounds

Parameter	Typical Value	Unit
Volume of water used in a sweat ($V_{w,total}$)	4	L
Radius of a hemispherical sweat lodge (*r*)	1	m
Body surface area available for contact (*SA*)	1.8	m^2
Fraction of skin area (SA) in contact with liquid ($f_{SA,l}$)	0.0-1.0	unitless
Fraction of skin area (SA) in contact with vapor ($f_{SA,v}$)	1.0-$f_{SA,l}$	unitless
COPC-specific permeability constant from vapor contact with skin (Kp_v)	1 to 1E-5	cm/hr
COPC-specific permeability constant from water contact with skin (Kp_l)	1 to 1E-5	cm/hr
Length of a sweat event (*ET*)	1	hr
Number of sweats per year (*EF*)	365	events/yr
Number of years a person sweats in a life time (*ED*)	64	yr
Average body weight (*BW*)	70	kg
Averaging time (*AT*)	70 (carcinogen) ED (noncarcinogens)	yr
Molecular weight of water (MW_w)	18	g/gmole
Density of liquid water (ρ_w)	1000	g/L
Temperature of the sweat lodge (T)	389 (150)	K (F)
Ideal gas law constant (R)	0.06237	$(mmHg \cdot m^3)/(gmole \cdot K)$
Conversion factor (CF_1)	0.01	m/cm
Conversion factor (CF_2)	365	day/yr
Conversion factor (CF_3)	10	L/m^2-cm

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