Proposition 65

Interpretive Guideline No. 2008-001

Guideline for Hand-to-Mouth Transfer of Lead through Exposure to Fishing Tackle Products

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Reproductive and Cancer Hazard Assessment Branch
Office of Environmental Health Hazard Assessment
California Environmental Protection Agency

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Request for Hand-to-Mouth Transfer for Lead

This interpretive guideline was developed by the Office of Environmental Health Hazard Assessment (OEHHA) in response to a request from the Sports Fishing Coalition for guidance on calculating the transfer of lead to the mouth from the handling of fishing tackle products during recreational fishing under regulations implementing the Safe Drinking Water and Toxic Enforcement Act of 1986 (Health and Safety Code Section 25249.5 et seq., commonly known as Proposition 65). OEHHA responded to this request by developing this guideline for calculating the hand-to-mouth transfer of lead for use in estimating lead exposure from the use of fishing tackle in recreational fishing (Title 22, Cal. Code of Regs., section 12204(h)(4)[1]). Thus, this guideline does not address lead exposure to retail workers or consumers during other activities such as sale or purchase, or non-fishing uses of these products and it does not apply to exposures to lead that may occur from other products such as artwork, jewelry or other forms of ornamentation.

Scope of Interpretive Guideline

Lead may be present in fishing tackle products made of metal alloys or polyvinyl chloride plastics, or coated with lead-containing paints. The method for calculating the hand-to-mouth transfer of lead discussed in this guideline document only addresses the transfer to the mouth of lead on the hands accrued from handling fishing tackle products. It does not address the transfer of lead from fishing tackle directly to the mouth. Also, this interpretive guideline covers lead transfer in the context of the use of fishing tackle and does not apply to the handling of other products containing lead (e.g., power cords, crystal glassware). The hand-to-mouth transfer is intended for use only in the context of calculating lead exposure from the use of fishing tackle for purposes of compliance with Proposition 65.

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[1] All further regulatory references are to Title 22 of the California Code of Regulations, unless indicated otherwise.

Proposition 65 Listings for Lead and Safe Harbor Levels

Lead has been listed under Proposition 65 as a chemical known to cause cancer since October 1, 1992 and reproductive toxicity (i.e., developmental and male and female reproductive toxicity) since February 27, 1987. For reproductive effects, the Maximum Allowable Dose Level for lead is 0.5 µg/day (Section 12805); for carcinogenic effects the No Significant Risk Level for lead is 15 µg/day (Section 12705(d)).

Lead Exposure from Hand-to-Mouth Transfer during Fishing

The activity of fishing involves repeated and frequent handling of fishing tackle (e.g., rod, reel, swivels, lures, hooks). Fishing in the non-occupational context may commonly involve multiple and frequent hand-to-mouth activities, such as touching the mouth and nail-biting, and those associated with the consumption of foods and beverages *al fresco*. Lead transferred from fishing tackle to the hands during fishing is therefore expected to result in incidental ingestion of lead through hand-to-mouth transfer.

The importance of this route of exposure for lead has been demonstrated in occupational settings in several studies. For example, Far *et al.* (1993) reported that blood lead levels in lead-acid battery workers in Singapore correlated more closely with lead levels on the hands than with airborne lead concentrations in the workplace. Culturally-based eating practices (i.e., eating with bare hands vs. utensils) explained the bulk of the variation in blood lead levels observed among the workers, with higher blood lead levels associated with eating with bare hands. A workplace education program reinforcing hand-washing and mouth-rinsing practices resulted in an 11.5% reduction in blood lead levels. In another study of lead battery workers, Chuang *et al.* (1999) reported that two personal hygiene habits, eating and smoking at the work site, were most closely related to blood lead levels in workers in Taiwan. Matte *et al.* (1989) reported that the blood lead levels of workers in lead-acid battery shops in Jamaica were significantly higher among smokers than non-smokers, and among workers who did not always wash their hands before eating. Finally, researchers in the Netherlands reported that the frequency of hand-to-mouth and hand-to-nose activity in the workplace was significantly associated with total blood lead levels in workers (Ulenbelt *et al.*, 1990). Taken together these studies indicate significant exposure to lead can result from hand-to-mouth contact for adults.

Definition of Hand-to-Mouth Transfer Factor

Transfer of lead from the hand to the mouth can occur directly by handling the product and then touching the mouth with the hand, nail biting, finger sucking, or other hand-to-mouth contact. It may also occur indirectly by handling the fishing tackle product and then eating food, smoking cigarettes, drinking from a straw, or through other handling of materials that ultimately contact or otherwise make their way into the mouth. Indirect transfer may involve one or more intermediate steps. Examples of indirect transfer are given in Figure 1.

Figure 1. Examples of Indirect Hand-to-Mouth Transfer of Lead

Cigarette Smoking Handle tackle $\Rightarrow$ Handle cigarette $\Rightarrow$ Smoke Snacking Handle tackle $\Rightarrow$ Pick Up Tortilla Chip $\Rightarrow$ Eat Chip Snacking Handle tackle $\Rightarrow$ Wipe hands on pants $\Rightarrow$ Wipe an apple on pants $\Rightarrow$ Eat the apple

Here two hand-to-mouth transfer factors are defined. The *direct* hand-to-mouth lead transfer factor (f_{direct}) is defined as the lead mass transferred to the mouth divided by the lead mass that is on the surface area of that part of the hand that is in contact with the mouth (not the whole hand), per contact between the hand and mouth. Similarly, the *indirect* hand-to-mouth lead transfer factor ($f_{indirect}$) is the fraction of lead mass on the portion of the hand that is in contact with the intermediate object that ultimately reaches the mouth. Similar terms like "transfer efficiency" or "transfer coefficient" have been used to describe chemical transfer from one surface to another (e.g., residue-to-skin transfer efficiency).

Lead Intake from Hand-to-Mouth Activity

Intake from direct hand-to-mouth contact

The intake of lead from one direct hand-to-mouth contact during a fishing event is a function of:

- $L_{hand\text{-}D}$ the lead loading on the part of the hand touching the mouth (e.g., not the loading on the whole hand), in units of weight per surface area (e.g., mass of lead per surface area of the fingertip or palm, $\mu g/cm^2$);
- SA_D the surface area of the part of the hand in direct contact with the mouth (e.g., cm^2);
- f_{direct} the direct hand-to-mouth transfer factor, presented as a fraction or percentage.

The intake can be calculated from the following equation:

$$Intake_{HM\ direct} = L_{hand\text{-}D} \times SA_D \times f_{direct}$$

There can be multiple hand-to-mouth contacts during fishing. Thus the direct lead intake during fishing will be the sum of intake from each contact *i* during fishing:

$$Intake_{HM\,direct} = \sum_{i=1}^{n} Intake_{HM\,direct\;i}$$

$$= \sum_{i=1}^{n} L_{hand\text{-}D\;i} \times SA_{D\;i} \times \mathrm{f}_{direct\;i.}$$

It is acknowledged that the surface area of the hand in contact with the mouth, the lead loading on the hand, and the fraction of lead on the part of the hand in contact with the mouth that is transferred can be different each time a person contacts the product or his/her mouth. In addition, there are person-to-person differences, that is, inter-individual variability, for each of those variables. This interpretive guideline uses the following equation to calculate lead intake from direct hand-to-mouth contact:

$$Intake_{HM\,direct} = L_{hand\text{-}D} \times SA_D \times \mathrm{f}_{direct} \times \lambda_D \times t \qquad \text{(Eq. 1a)}$$

where

- λ_D the rate of direct hand-to-mouth contact, e.g., the number of contacts per hour; and
- t the number of hours per fishing event.

For applications of the above equation, this interpretive guideline will provide values for SA_D, λ_D and f_{direct} that can be considered as representative and account for the range the values can potentially take on.

Intake from indirect hand-to-mouth contact

Similarly, the intake of lead from indirect hand-to-mouth transfer during a fishing event is a function of t as defined above as well as

- $L_{hand\text{-}I}$ the lead loading on the part of the hand touching the intermediate object, in units of weight per surface area ($\mu g/cm^2$);
- SA_I the surface area of the hand in contact with material reaching the mouth;
- λ_I the rate of indirect hand to mouthed object contact, e.g., the number of contacts per hour;
- $\mathrm{f}_{indirect}$ the indirect hand-to-mouth transfer factor.

Analogous to direct exposure, the intake of lead from indirect hand-to-mouth activity can vary for each time an individual contacts his/her mouth, based on variation in the surface area of the hand in contact with the material reaching the mouth, the lead loading on the hand, and the fraction of lead on the hand in contact with the material reaching the mouth that is transferred with each contact. Characteristics of the intermediate object(s) may also result in variations in intake of lead during different indirect hand to mouth activities. For example, differing amounts of lead may be transferred from the hand to an object, depending on the object's pH, moisture content, oil content and size. Specifically, the amount of lead reaching the mouth through indirect hand to mouth activities may vary between eating an orange, which has a pH ≈ 4 (lower pH will favor the transfer of lead from the hands), eating a sandwich with a large and moist surface (moisture may favor the transfer of lead from the hand(s), and the large surface may favor a larger hand to object contact surface area), and eating oily foods such as chips (the oily surface may affect the transfer of lead from the hand(s) and favor a reduction in the hand to object contact surface area, e.g., eating with fingertips only). The intake of lead during fishing from indirect hand-to-mouth contact will be the sum of intake from each indirect contact *i* during fishing, as given by:

$$Intake_{HM\ indirect} = \sum_{i=1}^{n} L_{hand\text{-}I\ i} \times SA_{I\ i} \times f_{indirect\ i}.$$

Individuals may be exposed through their own handling of an object, as well as others handling the object that is mouthed (e.g., transfer of lead from one person's hands to an orange that is then shared and eaten by another).

Again this interpretive guideline provides representative parameter values so that intake of lead from indirect hand-to-mouth exposure can be calculated by:

$$Intake_{HM\ indirect} = L_{hand\text{-}I} \times SA_I \times f_{indirect} \times \lambda_I \times t.$$

The indirect transfer involves the transfer of lead from the hand to an intermediate object, and then the introduction of lead from the intermediate object(s) through eating or some other contact (e.g., smoking a cigarette). Along the way, some lead may be lost from the object that ultimately may come into contact with the mouth. For simplicity the $f_{indirect}$ is expressed here in terms of two factors, $f_{direct,}$ and f_{loss}, the fraction of lead mass loading lost during the intermediate steps:

$$f_{indirect} = f_{direct} \times (1 - f_{loss}).$$

Thus,

$$Intake_{HM\ indirect} = L_{hand\text{-}I} \times SA_I \times [f_{direct} \times (1 - f_{loss})] \times \lambda_I \times t. \qquad \text{(Eq. 1b)}$$

In applying equations 1a and 1b, repetitive handling of fishing tackle is assumed, and it is further assumed that after each hand-to-mouth contact, the fishing tackle is handled and lead "reloading" onto the hand occurs. That is, lead loading on the hand removed by each direct or indirect hand-to-mouth contact is replenished by subsequent handling of the fishing tackle. Lead loadings on the hands for direct and indirect hand-to-mouth contacts – i.e., $L_{hand\text{-}I}$ and $L_{hand\text{-}D}$, – are not necessarily the same. No loss of lead loaded on the hand ($L_{hand\text{-}D}$) is assumed for direct hand-to-mouth contact. As stated above, the loss factor, f_{loss}, in equation 1b is intended to capture the overall mass loss between the hand and the mouth for indirect hand-to-mouth activities.

Total intake of lead from hand-to-mouth activity would be the sum of total intake from direct and indirect exposure:

$$Intake_{HM} = Intake_{HM\ direct} + Intake_{HM\ indirect}.$$

Selection of Default Parameters

f_{direct}, the Direct Hand-to-Mouth Factor

Controlled Laboratory Studies Providing Information on f_{direct}

No data were identified by OEHHA in the scientific literature on the amount of lead transferred from the hand to the mouth as a result of handling fishing tackle products during non-occupational use. What follows is a discussion of the available scientific data relevant to this interpretive guideline. Limitations on the applicability of these studies to the question at hand are also discussed. For example, findings from soil and pesticide studies may have varying applicability to the hand-to-mouth transfer of inorganic lead in fishing tackle products due to the differences in chemical and physical properties of the substances, the activity patterns and circumstances involved, and the ways in which transfer of a substance from the hand to the mouth is defined.

Two controlled laboratory studies provide data with some relevance to the development of a hand-to-mouth transfer factor for lead associated with the use of fishing tackle products. The first study, by Camann *et al.* (2000, also described in a 1995 report by the same authors) provides data on the removal of three pesticides from the hands of three adults. In the second study by Kissel *et al.* (1998) total soil loading on the hand, and its transfer to the mouth from particular parts of the hand (i.e., thumb; two fingers; palm) was measured in four adults. This latter study provides the soil mass transferred to the mouth divided by the soil mass on the entire hand, rather than the part of the hand that is in contact with the mouth. Thus it can be used to estimate an extreme lower bound on the direct hand-to-mouth transfer factor, f_{direct}. A third study by Cohen Hubal *et al.* (2005) that explored a new technique for measuring transfer of substances to and from the hand is also briefly described here, although it did not provide data used in developing the hand-to-mouth transfer factor presented in this interpretive guideline.

Camann *et al.* (2000) measured the fraction of three pesticides removed from the hands of three adult volunteers by gauze wipes moistened with human saliva, artificial saliva, or a mild surfactant, 1.3% dioctyl sulfosuccinate (DSS). Application of pesticide to the hand was accomplished by pressing and rotating the hand onto a piece of foil containing a known mass of either chloryrifos, pyrethrin I, or piperonyl butoxide (technical mixtures). The amount transferred from the foil to the hand was determined, based upon the amount remaining on the foil. The fraction removed from the hand by the different wipe solutions was calculated for each pesticide, based upon the pesticide mass transferred from the hand to the gauze wipe as a result of wiping the whole hand within twenty seconds of the exposure time, the extraction efficiency of the wipe samples, and data on the pesticide mass initially loaded on the hand.

Wipes moistened with DSS removed pyrethrin I and piperonyl butoxide from the hands with greater efficiency than wipes moistened with human or artificial saliva (Table 1). The mean removal efficiency for all three pesticides was 48.3% for human saliva, 42.1% for artificial saliva, and 55.0% for DSS. Based on these data, the removal, or transfer efficiency from the hand to the mouth, f_{direct}, is approximately 50% for each of the three pesticides.

Table 1. Percent Removal Efficiency by Gauze Wipes Moistened with Different Media

Pesticide	Human saliva			Artificial saliva			1.3% DSS*		
	No. of samples	Mean	Std. Dev.	No. of samples	Mean	Std. Dev.	No. of samples	Mean	Std. Dev.
Chlorpyrifos	9	52.0	13.4	9	47.1	11.4	9	51.7	9.7
Pyrethrin I	9	52.3	9.3	9	41.6	7.0	5	61.8	12.9
Piperonyl butoxide	9	40.7	13.6	9	37.7	13.4	5	51.4	9.3

Adapted from Camann *et al.* (2000), Table 18
* DSS: Dioctyl sulfosuccinate, a mild surfactant

In the study of Kissel *et al.* (1998), the average percent of the total soil on the whole hand transferred to the mouth by thumb-sucking, finger mouthing, and palm licking was 10.1% (95% CI: 8.7 – 11.8%), 15.9% (95% CI: 13.8 – 18.4%) and 21.9% (95% CI: 20.5 – 23.4%), respectively. As discussed above, because these fractions are based on removal from the entire hand rather than the portion of the hand in contact with the mouth these data represent a lower bound estimate of f_{direct}.

OEHHA reviewed a third study investigating the utility of a fluorescent imaging technique in measuring riboflavin surface-to-hand transfer (Cohen Hubal *et al.*, 2005), but determined that it did not provide data useful for development of the hand-to-mouth transfer factor for lead. This controlled laboratory study of three adult volunteers included a limited set of measurements of riboflavin removal from the hand as a result of thumb-sucking or three other kinds of removal actions (i.e., hand washing, hand smudge to clean surface, hand press to clean surface). Negative removal (i.e., addition of riboflavin to the hand) was observed in several of the trials following thumb-sucking (average percent removal ranged from -14 to 34%), and occasionally following the hand smudge or hand press removal actions. The authors noted that further development and verification of the fluorescent imaging methods used to characterize removal by mouthing was needed.

Assumptions or Estimates on Hand-to-Mouth Transfer Made in Other Studies

Other studies that have derived estimates for a hand load transfer factor or transfer efficiency include the analyses of Dubé *et al.* (2004, a published paper from an earlier 2001 Gradient report), Beyer *et al.* (2003), and the Consumer Product Safety Commission (CPSC, 2003). However, these studies discussed hand-to-mouth transfer in terms of average hand load ingested per day, and did not include hand-to-mouth contact frequency or the fraction of the hand in contact with the mouth to enable determination of hand-to-mouth transfer as defined above.

Dubé *et al.* (2004) estimated the fraction of dislodgeable residue on the hands that is incidentally ingested on a daily basis from data on average soil adherence to the hand from Roels *et al.* (1980), together with an estimate for average soil ingestion for children between 2 to 6 years of age (extrapolated from an analysis of soil ingestion data for children between 1 to 4 years by Stanek and Calabrese (1995)). This estimate was 25% (range: 7 – 100%), in units of hand load per day, for 2 to 6 year olds. Dubé *et al.* assumed that individuals 7 years old and up would ingest half the amount of soil as 2 to 6 year olds, yielding an estimate of 13% (range: 3.5 – 50%) per day for 7 to 31 year olds. Dubé *et al.* (2004) do not provide the information needed to develop a direct hand-to-mouth transfer factor for soil, as it does not estimate the fraction of material on the hand in contact with the mouth that is transferred, the number of hand to mouth contacts nor losses through intermediate contacts.

Beyer *et al.* (2003), in their assessment of incidental ingestion of metals from laundered shop towels in the workplace, used a value of 13% as the fraction of dislodgeable residue on the hands incidentally ingested on a daily basis by adults. This value was based on the same analysis as that described for Dubé *et al.* (2004).

The Consumer Product Safety Commission (CPSC) developed an estimate of the percent of dislodgeable residue on the hands that is ingested on a daily basis by children based on data on soil ingestion, soil – skin adherence, and contact surface area of the hand with soil from multiple studies (CPSC, 2003). CPSC noted the large uncertainties in the available data, and combined reasonable upper and lower bound values reported for soil ingestion and skin adherence to estimate the percent of residue on the hands that is ingested. Their daily intake estimates for children ranged from 3% to 700% of the mass loaded on the hand (i.e., "handload"), with an average of 43% for both direct and indirect hand-to-mouth activities combined.

Finally, a doctoral thesis that developed an estimate of skin-to-mouth transfer efficiency based primarily on assumptions and professional judgment, rather than empirical data, is included here for the sake of completeness. For adults in the occupational setting, Paull (1997) derived an estimate of the fraction of material on the total contact surface of the skin that is transferred to the mouth of 5%, with range 1.8 – 7.4%. The lower estimate of 1.8% was derived by combining an assumption that the mass of contaminant on 30 cm^2 of skin surface -- equivalent to the surface area of all 10 fingertips -- is ingested twice each day with the assumption that the total daily skin contact surface area is 3360 cm^2. Thus material on 60 cm^2, or 1.8% of the total daily skin contact surface area of 3360 cm^2, was assumed to be entirely consumed (1.8% = 60 cm^2 / 3360 cm^2). In making this estimate Paull (1997) implicitly assumed that f_{direct} was 100%. The upper estimate of 7.4% was derived using data on adult soil ingestion from Calabrese *et al.* (1989) together with an estimate of the average adherence of soil to skin of 0.2 mg/cm^2 and the same total daily skin contact surface area as used in deriving the lower estimate.

The U.S. Environmental Protection Agency (U.S. EPA, 2005) derived a statistical distribution for hand-to-mouth transfer efficiency for arsenic from chromated copper arsenate (CCA)-treated wood. U.S. EPA defined hand-to-mouth transfer efficiency as the fraction of chemical mass that enters the mouth and remains in the mouth as a result of one hand-to-mouth contact. The value of 50% from Camann *et al.* (2000) was used as the lower bound on the transfer efficiency, with 100% assigned as the upper bound and the mode of distribution set to 75%. The resulting fitted beta distribution of the hand-to-mouth transfer efficiency for arsenic had a mean value of 78% and a 75th percentile value of 84.9% per hand-to-mouth contact.

Zartarian *et al.* (2000) developed the U.S. EPA's Residential Stochastic Human Exposure and Dose Simulation Model for Pesticides (Residential-SHEDS) to estimate children's exposure to chlorpyrifos, and assumed the hand-to-mouth transfer efficiency of chlorpyrifos ranged from 10 to 50%. The 50% transfer efficiency value was based upon the data of Camann *et al.* (2000), and the 10% value was based upon the data of Kissel *et al.* (1998). As discussed above, the 10% value of Kissel *et al.* (1998) represents the average percent of the total soil on the whole hand transferred to the mouth by thumb-sucking, and is not equivalent to the hand-to-mouth transfer factor addressed in this interpretive guideline.

The hand-to-mouth transfer efficiency value of 50%, from an earlier report of the pesticide studies of Camann *et al.* (2000), has been used by the CPSC (1997) in estimating hand-to-mouth exposure to lead from children's polyvinyl chloride products and by the U.S. EPA Office of Pesticide Programs as a default value for use in estimating hand-to-mouth exposure to pesticides (U.S. EPA, 2001). In an exposure assessment of wood preservatives that predated the studies of Camann *et al.* (2000), hand-to-mouth transfer efficiency values of 50% were assumed for arsenic, chromium and copper, and 100% for pentachlorophenol by the California Department of Health Services (CDHS, 1987).

Hemond *et al.* (2004) questioned the application of the 50% value from the pesticide studies of Camann *et al.* (2000) to the estimation of the hand-to-mouth transfer of arsenic from CCA-treated wood, considering 50% too low to represent dislodgeable arsenic because "the skin has higher permeability to oil-soluble materials like pesticides than to more polar inorganic chemicals; saliva, being water-based, is expected to be an indifferent solvent for the hydrophobic chemicals." In assessing children's exposure to arsenic from CCA-treated wood, Hemond *et al.* (2004) assumed a hand-to-mouth transfer efficiency of 100% for arsenic.

Selection of f_{direct}

As reviewed above, direct information is not available on the amount of lead transferred from the hand to the mouth as a result of handling fishing tackle products. Due to the lack of lead-specific data, it is necessary to rely on the only study available that provides the data necessary to directly estimate a hand-to-mouth transfer factor, f_{direct}, for any substance, which is the controlled laboratory study by Camann *et al.* (2000). In this study, the removal efficiencies (i.e., f_{direct}) of chlorpyrifos, pyrethrin I, and piperonyl butoxide were found to be approximately 50%. The controlled laboratory study of Kissel *et al.* (1998), while not providing the information needed to estimate a hand-to-mouth transfer factor, can be used to establish a lower bound on f_{direct}. That study found that 21.9% of the soil adhering to the whole hand was removed by mouthing only a portion of the hand (i.e., palm licking). Thus, based on the available data (i.e., Camann *et al.*, 2000), a value of 50% is selected as the direct hand-to-mouth transfer factor, f_{direct}, for lead in fishing tackle products.

There are multiple uncertainties associated with the 50% value from the study of Camann *et al.* (2000). These include the uncertainty with which the controlled laboratory conditions of the study reflect the hand-to-mouth transfers under real world situations, the uncertainty with which the small number of study participants (n = 3) represent the variability within the human population, and the uncertainty associated with how well the three organic pesticides studied represent transfers of inorganic lead from fishing tackle products. Compared to lead, these pesticides likely have higher skin permeability and less availability for hand-to-mouth transfer, resulting in lower hand–to-mouth transfer efficiency.

This hand-to-mouth transfer efficiency value of 50% from Camann *et al.* (2000) has also been used in an assessment of lead exposure from children's polyvinyl chloride products (CPSC, 1997), and it is the default value used by the U.S. EPA in assessing incidental ingestion of pesticides (U.S. EPA, 2001).

Selection of f_{loss} and hence $f_{indirect}$

In the absence of data and given the complexity of the nature of indirect hand-to-mouth activities, f_{loss} is assumed to be equal to 50%. This factor takes into account the possible mass loss during the potentially multiple intermediate steps between loading on the hands and transfer to the mouth, such as the mass loss that would occur as a result of wiping the hands on an item of clothing (e.g., pants), then wiping an apple on the same area of clothing, and eating the apple. Since $f_{indirect}$ is given by $f_{direct} \times (1 - f_{loss})$, $f_{indirect}$ is therefore 25%, or 0.25 (= 0.5 × [1 – 0.5]).

λ_D and λ_I, Direct and Indirect Hand-to-Mouth Contact Rate

The selection of values for the direct and indirect contact rate parameters λ_D and λ_I is difficult because no studies of hand-to-mouth activity in adults were identified in the published literature. Cherrie *et al.* (2006) has assumed 5 and 10 hand-to-mouth contacts per hour as the frequency for workers in two different occupational settings. The only studies of hand-to-mouth activity patterns are in children, and most are limited to studies of children under the age of six. The frequency of hand-to-mouth activity reported in these studies is summarized in Table 2.

As shown in Table 2, within a given study there are large differences in the hand-to-mouth contact frequency among study subjects, as indicated by the standard deviations reported. Average and median values can be considerably less than the values in the upper end of the ranges, such as the 98th percentile.

Table 2. Hourly Hand to Mouth Contact Frequency in Children

Study	**Age**	**N***	**Average Number of Contacts** (standard deviation)**
Reed *et al.*, 1999	3 – 6 years	20	9.5 (7)
Zartarian *et al.*, 1998	2.5 - 4.2 years	4	11 (NA[#])
Freeman *et al.*, 2001[+]	3 - 12 years	19	6 (9)
Tulve *et al.*, 2002	11 months – 5 years	72	16 (NA)
AuYeung *et al.*, 2004	14 months - 6.8 years	38	11.7 (NA)
Black *et al.*, 2005	3 – 4.4 years	9	22.1 (22.1)
Freeman *et al.*, 2005	2 – 4.6 years	10	10.2 (6)
Ko *et al.*, 2007	1 – 5 years	37	Median = 26 (range: 6-129)

* N: Number of study subjects
** Calculated by averaging the number of contacts per child, with the exception of the Tulve *et al.* study. In this case the average reflects the average over the observations (i.e., one child may have several observations of hand–to-mouth activities).
[+] Weighted averages from four age subgroups
NA: not available

In 2002, U.S. EPA concluded from the data of Reed *et al.* (1999) and Zartarian *et al.* (1998), that a value of 9 hand-to-mouth contacts per hour was a reasonable estimate for children 2-6 years old (U.S. EPA, 2002). Since that time additional studies have reported higher mean values for children, thus 9 contacts per hour could be an underestimate for the frequency of children's hand-to-mouth activity. The studies on children's behavior that report over 20 contacts per hour (e.g., Black *et al.*, 2005 and Ko *et al.*, 2007) are assumed by OEHHA to provide an upper bound estimate of λ_D for adults during fishing.

The hand-to-mouth activity patterns for adults engaged in fishing may be quite different from those of adults performing daily tasks. Fishing commonly involves use of the hands to perform repetitive tasks involving the handling fishing tackle, and as a recreational activity, fishing is likely to be associated with a greater frequency of hand-to-mouth contact associated with the consumption of food and beverages during the event. For fishers that are smokers, fishing is also likely to be associated with a greater frequency of hand-to-mouth contact (on average 10 puffs for a cigarette smoked, 20 cigarettes per day for heavy smokers) than other daily activities (e.g., smoking-restricted environment like working, shopping, or dining at a restaurant). Other activities, such as nail-biting, may also occur at a greater frequency during fishing, as compared with other settings.

Cherrie *et al.* (2006) evaluated the importance of inadvertent ingestion of toxic substances in occupational settings. They evaluated two scenarios, that of a pesticide worker and inorganic lead worker. For the first case they assumed a value of 10 inadvertent hand-to-mouth contacts per hour, and for the second case a value of 5. In assigning these values they noted some qualitative studies of hand to face behaviors. Given the recognized differences between occupational settings and a recreational setting such as fishing, the values of 5 and 10 for number of hand-to-mouth contacts per hour from Cherrie *et al.* (2006) may be underestimates of λ_D for adults during fishing.

In the absence of empirical adult activity data, the value of 9 hand-to-mouth contacts per hour is selected as λ_D, the rate of direct hand-to-mouth contact per hour during fishing for an adult. This value is selected after considering the available hand-to-mouth contact frequency data, which is presently limited to studies conducted in children, along with the assumptions used by Cherrie *et al.* (2006) for two occupational settings, and considerations regarding the more relaxed atmosphere associated with recreational fishing and the types of activities (e.g., eating, drinking) likely to occur during recreational fishing. Seven of the eight studies in Table 2 have average hand-to-mouth contacts per hour higher than the value assumed here for adults; thus, the value for λ_D should not be construed as the adoption of a child specific value for adult use. Other factors were also considered, as outlined above.

Indirect hand-to-mouth activities are more complex than the direct hand-to-mouth contacts and thus more challenging to characterize. Equation 1b above is used to estimate indirect intake of lead by snacking (e.g., eating chips) and other indirect exposure (e.g., smoking). No data are available to inform the selection of representative rates of indirect hand-to-mouth contact activity during fishing. Thus contact rates were selected based upon two scenarios. Scenario 1 was modeled on the consumption of bite sized snack foods such as chips, and Scenario 2 on the handling and eating of a relatively large object such as a sandwich or an apple. In any given hour people were assumed to be exposed indirectly to lead from either Scenario 1 or Scenario 2.

Eating one serving of chips could result in 20 indirect contact events. A higher contact frequency is likely when people eat smaller objects like nuts, bite-sized crackers or other snacks. In the absence of data on λ_I, the rate of indirect hand-to-mouth contact per hour during fishing, a value of 10 per hour is selected for indirect exposure via fingertips is selected for Scenario 1. Eating one serving of chips over a two-hour period could result in this rate. For Scenario 2, it was assumed the large objects like a sandwich or an apple would be consumed once over a one-hour period, and that their consumption would involve handling by most of the palmer surface (i.e., surface area pertaining to the palm of the hand) of one hand. For purposes of this interpretive guideline, for each hour during a given fishing event, the indirect hand-to-mouth contact rate for either Scenario 1 or Scenario 2 is applied. Thus, multiple scenarios are not assumed to occur in the same hour, although under real-world conditions, this may indeed occur.

SA_D and SA_I, Hand Surface Area in Contact with Mouth and Material that Reaches Mouth

Direct Hand-to-Mouth Activities

The safe harbor for the reproductive and developmental toxicity of lead is lower than that for the carcinogenicity of lead. The fetal developmental period is especially sensitive to the effects of lead, and will be used here as the basis for the exposure calculation. Exposure to the developing fetus are mediated through the mother. Thus, a typical adult female hand was used as the basis for estimating SA_D and SA_I. Values for SA_D and SA_I based on a typical adult male hand are also presented.

From the EPA Exposure Handbook (U.S. EPA, 1997), the representative value of the surface area of the hands is 750 cm^2 and 840 cm^2 for women and men, respectively. Gurunathan *et al.* (1998) divided the palmar surface area of the hand by 2, with each half representing the palm and the palmar surface area of the fingers. In this interpretive guideline the palmar surface area (defined as the surface area of the grasping side of the hand) is also assumed to be 50% of the surface of both the front and back sides of the hand, and each finger counts for 10% of the palmar surface area. It is further assumed that the surface area of direct hand-to-mouth contact is 3 fingertips (i.e., the thumbtip and two fingertips), and that each fingertip is 30% of the finger. Thus the surface area for direct hand contact is equal to 19 cm^2 for men and 17 cm^2 for women.

$$19\ cm^2 = 420\ cm^2/\text{hand} \times 0.5\ \text{palmar surface/hand} \times 0.1\ \text{finger/palmar surface} \times 3\ \text{fingers} \times 0.30\ \text{fingertip/finger (for men).}$$

$$17\ cm^2 = 375\ cm^2/\text{hand} \times 0.5\ \text{palmar surface/hand} \times 0.1\ \text{finger/palmar surface} \times 3\ \text{fingers} \times 0.30\ \text{fingertip/finger (for women).}$$

OEHHA therefore selects 19 and 17 cm^2 as the value for SA_D for adult men and women, respectively.

Cherrie *et al.* (2006) assumed that 10 cm^2 of the hand was contacted (5% of palmar surface) via the ingestion route for workers. EPA (2001) uses a default of 20 cm^2 as the surface area of the hands contacted by the hand-to-mouth route for estimating children's pesticide exposure. These two values, one for occupational settings and the other for children, bracket the values for SA_D assumed here for direct hand-to-mouth contact for women and men during fishing.

Indirect Hand-to-Mouth Activities

For indirect hand-to-mouth activities, the hand surface area contacting the material that eventually is introduced to the mouth can be larger than that directly contacting the mouth. For this interpretive guideline two indirect hand-to-mouth exposure scenarios are described, and the selected values for SA_I and λ_I are given for each. In Scenario 1 indirect exposure (such as would occur as a result of snacking on savory chips) is assumed to involve, on average, the surface area of three fingertips (i.e., thumbtip and two fingertips), or 17 cm^2 and 19 cm^2 for women and men, respectively (the same surface area as is assumed for a single direct hand-to-mouth contact). It is assumed that this fingertip type of indirect exposure contact occurs at a rate of 10 times per hour, thus $SA_{I\ \text{Scenario 1}}$ is 17 cm^2 and 19 cm^2 for women and men, respectively and $\lambda_{I\ \text{Scenario 1}}$ is 10/hour. In Scenario 2 indirect exposure is assumed to involve, on average, 90% of the palmer area of one hand, or 189 (= 210 × 0.9) and 169 cm^2 (= 187.5 × 0.9) for men and women, respectively. This palmar type of indirect exposure contact occurs at a rate of once per hour. OEHHA therefore selects values of 170 cm^2 and 190 cm^2 for $SA_{I\ \text{Scenario 2}}$ for women and men, respectively, and 1/hour for $\lambda_{I\ \text{Scenario 2}}$. In any given hour it is assumed that the fisher is indirectly exposed according to either Scenario 1 or Scenario 2.

Summary of Default Parameters

The following values are selected for this interpretive guideline based on the best available information and professional judgment:

f_{direct} (direct hand-to-mouth transfer factor):	50%
$f_{indirect}$ (indirect hand-to-mouth transfer factor):	25%
SA_D (surface area contacted for direct transfers for men):	19 cm^2
SA_D (surface area contacted for direct transfers for women):	17 cm^2
λ_D (direct hand-to-mouth contact frequency):	9/hour
$SA_{I\ \text{Scenario 1}}$ (surface area contacted for indirect transfers for men):	19 cm^2
$SA_{I\ \text{Scenario 1}}$ (surface area contacted for indirect transfers for women):	17 cm^2
$\lambda_{I\ \text{Scenario 1}}$ (indirect hand-to-mouth contact frequency):	10/hour
$SA_{I\ \text{Scenario 2}}$ (surface area contacted for indirect transfers for men):	190 cm^2
$SA_{I\ \text{Scenario 2}}$ (surface area contacted for indirect transfers for women):	170 cm^2

$\lambda_{I\ Scenario\ 2}$ (indirect hand-to-mouth contact frequency): 1/hour

During any given fishing event it is assumed that both direct and indirect hand-to-mouth activity occurs, and that for indirect activity, either Scenario 1 or Scenario 2 is assumed to apply to each hour of fishing.

This interpretive guideline covers lead transfer from the hands to the mouth in the context of fishing tackle use and does not apply to the handling of other products containing lead (e.g., power cords, crystal glassware). The basic concepts and formula for exposure assessment presented in this interpretive guideline may be applied to other hand-to-mouth exposures to lead, with appropriate adjustments and modifications, to account for the exposure scenario. The values given above are intended for use only in the context of calculating lead exposure from fishing tackle for purposes of Proposition 65 compliance and should not be generalized to other hand-to-mouth exposures. These values may be modified as new relevant data become available.

This interpretive guideline does not provide values for L_{hand}, the loading of lead from fishing tackle onto the hand (i.e., object to hand transfer), or lead transfer from the tackle directly to the mouth through mouthing the tackle. Moreover, this guideline does not address lead exposure from fishing tackle by the inhalation route, such as might occur as a cigarette to which lead has been transferred is smoked, or by the dermal route. Further, this guideline does not provide guidance on estimating the efficiency of lead uptake by the gastrointestinal tract, which can depend on several factors, such as an individual's age, nutritional status, and time since last meal.

Calculation Example

A hypothetical example calculation of lead intake is given below for a woman fisher. Similar calculations can be conducted for men using the male values for contact surface areas presented in the summary above.

In this example, the length of the woman's fishing trip is hypothetically set to be four hours. The duration of four hours is not a default value selected by OEHHA, but used here for illustrative purposes. Here the hand loadings of lead for direct and indirect contacts are assumed to be the same hypothetical value, i.e., $L_{hand\text{-}D} = L_{hand\text{-}I} = 0.001$ μg/cm^2. This hypothetical value is not based on actual measurements, and is selected for illustration purposes only, and not as a default value. In reality the loadings, $L_{hand\text{-}D}$ and $L_{hand\text{-}I}$, could differ from each other and from this value.

To calculate lead intake from direct hand-to-mouth route:

$$Intake_{HM\ direct} = L_{hand\text{-}D} \times SA_D \times f_{direct} \times \lambda_D \times t$$

Since SA_D, f_{direct}, and λ_D are set at 17 cm^2, 0.5, and 9/hr, respectively, and these factors multiplied together are 76.5 cm^2/hr (= 17 cm^2 × 0.5 × 9/hr) the expression simplifies to:

$$Intake_{HM\ direct} = 76.5\ \text{cm}^2/\text{hr} \times L_{hand\text{-}D} \times t,$$

which for this case becomes

$$Intake_{HM\ direct} = 76.5\ \text{cm}^2/\text{hr} \times 0.001\ \mu\text{g/cm}^2 \times 4\ \text{hours}$$
$$= 0.31\ \mu\text{g}$$

To calculate lead intake from indirect hand-to-mouth route:

$$Intake_{HM\ indirect} = L_{hand\text{-}I} \times SA_I \times [f_{direct} \times (1 - f_{loss})] \times \lambda_I \times t$$

Following Scenario 1, SA_I, $[f_{direct} \times (1 - f_{loss})]$, and λ_I multiplied together are 42.5 cm^2/hr, (= 17 cm^2 × [0.5 × (1 − 0.5)] × 10/hr). Thus the above expression simplifies to

$$Intake_{HM\ indirect} = 42.5\ \text{cm}^2/\text{hr} \times L_{hand\text{-}I} \times t$$
$$= 42.5\ \text{cm}^2/\text{hr} \times 0.001\ \mu\text{g/cm}^2 \times 4\ \text{hours}$$
$$= 0.17\ \mu\text{g}$$

Under Scenario 2, SA_I is 10 times as large and λ_I is 10 times smaller, so the same indirect intake results. For any given hour it is assumed either Scenario 1 or Scenario 2 occurs, but because they result in the same intake it is not important to assume one over the other. In this example, the hand loadings ($L_{hand\text{-}I}$) for Scenarios 1 and 2 are assumed to be the same. In reality they could be different.

Here total lead intake from hand-to-mouth route from fishing tackle products is 0.48 µg, the sum of direct and indirect hand-to-mouth intakes.

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