Overview of Issues Related to the *Standard Operating Procedures For Residential Exposure Assessment*

Presented to:
FIFRA Scientific Advisory Panel
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Executive Summary

This document, "Overview of Issues Related to the *Standard Operating Procedures (SOPs) for Residential Exposure Assessment*," presents seven key issues concerning the calculation of residential and other non-occupational pesticide exposures, especially for children, for review and comment by the FIFRA Scientific Advisory Panel (SAP). The Office of Pesticide Programs (OPP), EPA, plans to make significant improvements and changes in its Residential SOPs to assure that its exposure assessment methods are based on the most recent and best science available. As explained in the Background section below, OPP previously presented these SOPs to the SAP in September, 1997, as well as other related materials in subsequent SAP meetings. Today's document does not present a revised version of the 1997 *Standard Operating Procedures for Residential Exposure Assessment*. Rather, OPP is presenting the most critical issues for discussion prior to developing a revised SOP document. Accordingly, OPP is requesting the SAP's input on these issues and, in particular, responses to the specific questions which immediately follow this executive summary.

OPP's approach to non-occupational exposure assessment presumes that human exposure in residential settings depends primarily on two factors: how much pesticide residue is available for human uptake and what human activities occur that would result in contact with and uptake of residues. Many of OPP's Residential SOPs involve algorithms for estimating dermal exposure resulting from contact with pesticide-treated surfaces (e.g., turf, carpets, etc.). In general, these algorithms are some form of the following equation and employ either data or default assumptions for each variable.

[Transferable residues (ug/cm2)] x [Human activity transfer coefficient (cm2/hr)]

x [Duration of activity (hr)] divided by body weight =

Amount of exposure (ug/kg body weight)

Following is a list of seven key issues which OPP would like the Panel to address, including the changes that OPP plans to make to its Residential SOPs. Complete discussions of the issues, the relevant data, and the supporting reasons for OPP's proposals are found in each chapter of this document.

Issue 1: Calculating percent dislodgeability of available pesticide residues from lawns, indoor surfaces, and pets

Turf--When chemical-specific "percent transferable residue" data on turfgrass are not available, OPP proposes to assume that 5% of the amount applied is dislodgeable or transferable (rather than 20%) for calculation of post application dermal exposure estimates. There is sufficient evidence in the published literature and in guideline studies submitted to the Agency that suggest the current standard value of 20 percent dislodgeability is an overestimate, regardless of method used.

Indoor surfaces--When chemical-specific "percent transferable residue" data are absent for indoor surfaces, OPP proposes to use 5% transferability (rather than 50%). The 50% transferable rate was obtained by washing carpet "coupons" in a dislodging solution (to show the potential maximum dislodgeable residues), whereas the 5% figure was based on hand press, drag sled and cloth roller data for carpeting and desktops. It should be noted, however, that one study which evaluated hard surfaces showed transferability from sheet vinyl ranging from about 10% to 20% for drag sled and cloth rollers, and from 3% to 4% for hand press. OPP would like the SAP to consider whether/how to incorporate such results when developing a dislodgeablity percentage assumption designed to be inclusive of all indoor surfaces.

Pet fur--Continue to assume 20% "percent transferable residues" from fur based on (1) 20% over predicts residues when measured using cotton gloves combined with stroking an animal's flank and (2) 20% approaches the mean of values measured using cotton gloves combined with vigorous rubbing. This assumption appears to overestimate potential exposure, but more research is needed in this area.

Issue 2: Use of choreographed activities as surrogates for estimating children’s dermal exposure

Exposure Duration--For estimating postapplication exposure following indoor and outdoor broadcast applications of a pesticide, OPP plans to use transfer coefficients derived from Jazzercise™ (a choreographed exercise program for adults lasting twenty minutes) to represent four hours of typical human activities and to represent one hour of extreme activity. Studies using Jazzercise™ compare well to available postapplication studies in which biological monitoring of adults performing choreographed activities was conducted. However, OPP recognizes that more research is needed to identify activity patterns that lead to post application exposure.

Transfer coefficients--OPP proposes to retain the current transfer coefficient for turf (43,000 cm^2/hr) and to increase the current transfer factor for indoor surfaces to 200,000 cm^2/hr.

Children's exposures--Until more is known about the differences between adult's and children’s exposure, OPP will continue to estimate children’s exposure using activity transfer coefficients based on activities choreographed to simulate children's behavior performed by adults that are modified by appropriate scaling factors to compensate for corresponding body weights and surface areas.

Issue 3: Characterizing hand (or object)-to-mouth activities

Frequency of hand-to-mouth events for children--Based on the SAP's previous recommendations, OPP will increase the frequency of hand-to-mouth events from 1.56 events per hour to 20 events per hour. Also based on SAP's recommendations, OPP plans to assume that two or three fingers will be placed in the mouth rather than both hands, reducing the surface area from 350 cm^2 to 20 cm^2. Thus, the total assumed transfer rate would be 400 cm^2/hr (20 events/hr X 20 cm^2). OPP is asking the Panel to confirm if this assumption is reasonably protective of teething toddlers (8-18 months old), particularly concerning the assumption of two to three fingers being placed in the mouth per hand-to-mouth event. OPP is also asking if there are sufficient data to address age-specific mouthing behaviors.

Pesticide available on a child's hands--OPP currently assumes that 100% of residues on the hands are available for dermal absorption and that 100% are also available for non-dietary ingestion. However, available studies indicate that the extraction efficiency and dermal absorption are influenced by residence time on the skin and by the amount on the skin. One study suggests that 50% represents the maximum mouthing removal rate for dried pesticide residues. Therefore, on a case-by-case basis, OPP plans to evaluate a pesticide's chemical properties such as solubility when considering the amount of pesticide on a child's hands that may be available for non-dietary ingestion.

Dermal absorption--In response to concerns that the skin of infants and children may be more permeable than adult skin, EPA examined the scientific literature, which generally indicated no significant, age-related differences in permeability.

Model for non-dietary ingestion--OPP is considering using a model for non-dietary ingestion through hand contact with plastic and plush toys (Gurunathan et al., 1998), coupled with more realistic residue removal efficiencies as suggested by Lu and Fenske (1999).

Issue 4: Calculating exposure to pesticides that may result from track-in, spray drift, bathing or showering

House dust--In most cases, OPP will attempt to estimate exposure to house dust. However, in most cases, OPP believes the magnitude of concentration and subsequent exposure estimates from house dust contaminated with pesticides will be considerably lower than estimates made using transferable residues following conventional uses of pesticides.

Bathing or Showering--A model addressing exposure while showering is under development and not available for review at this time. The model is based on an approach used by the Agency in other programs, such as Superfund, and relies on physical/chemical properties of the pesticide and other parameters currently used in the SOP for addressing swimmer exposure.

Issue 5: Estimating exposure of children of farmers or farm workers to pesticides

Consideration of new model--Available data indicate that children living near farms may experience higher pesticide exposures than children who live at a distance from such sites. OPP proposes to address such potentially higher exposure by estimating deposition on lawns resulting from drift when pesticides are used on nearby farms or other sites and including that exposure when assessing the residential pathway. The Environmental Fate and Effects Division (EFED) of OPP is developing models to estimate deposition, based on Spray Drift Task Force data for aerial, orchard airblast and groundboom applications. The results are expected to be similar to the AgDRIFT model, but EFED has not defined a deposition level at the edge of the orchards because there are little or no data for edge-of-orchard and in-orchard deposition levels. EFED's proposed method, which was presented to the SAP on July 23, 1999, estimates the 95th percentile deposition value at 25 feet downwind of sites with high drift potential to be 15% of the amount applied. The Health Effects Division (HED) of OPP intends to employ EFED's deposition models after they have improved in light of the SAP review. Exposure to residues cause by drift migrating to residential areas can be assessed using existing SOPs addressing postapplication exposure to turf residues and soil ingestion. Track-in can be addressed based on the work of Nishioka et al. (1996 and 1999).

Issue 6: Exposure to drift

Bystander exposure--The encroachment of suburbia on rural farming environments raises an additional possible exposure scenario. The Agency proposes to develop upper bound estimates of direct exposure of people to drift of pesticides by assuming that an individual is 25 feet from the edge of the treated site and the person experiences exposure equal to a pesticide flagger, as reflected in Pesticide Handlers Exposure Database.

Issue 7: Calculating exposure from use of pesticides in schools, day-care centers, and other public places

Exposures in schools and related locations--To be sure exposure at schools and similar locations is addressed, OPP will determine if:

❏ pesticides which are labeled for application to schools, are also registered for use in residences. If a pesticide is registered for schools and not residences, a separate exposure assessment must be conducted.

- ❑ a potential drift scenario from agricultural applications was conducted for the residential scenarios. If a drift exposure assessment was conducted for a residence, one is not needed for schools. Agricultural drift scenarios are needed if the application of a pesticide to residential lawns results in a higher residue level than that estimated for schools.

- ❑ the use pattern for schools differs significantly from the residential use pattern. If it differs significantly, a separate assessment for schools is needed.

Questions for the Scientific Advisory Panel

OPP requests that the SAP consider the seven key issues described in this document concerning proposed revisions to its “Standard Operating Procedures for Residential Exposure Assessments.” In particular, OPP would like the Panel to answer the following questions:

Issue1: OPP is proposing to change the default assumptions in its SOPs for "percent transferable residues" of pesticides on lawns, indoor surfaces and pets. Does the Panel find these changes reasonable and scientifically defensible, based upon the available data? In particular, does the Panel agree with OPP's proposed assumption of 5% transferability for indoor surfaces, recognizing that data for carpet and desktops support this level, but data for vinyl surfaces show 10% to 20% transferability? Similarly, should OPP consider using a higher "percent transferable residue" factor for wet surfaces and/or sticky hands or not?

Issue 2: OPP has indicated the intention to continue to use choreographed activities by adults as surrogates for estimating dermal exposure to children. Specifically, OPP has proposed the use of 20 minutes of Jazzercise as a surrogate for up to 4 hours of mixed activities. This position is based on comparisons to biological monitoring studies with adults performing choreographed activities. The Panel is asked to comment upon this approach and its utility when addressing short-term exposures (1 - 7 days) or exposures of longer durations. In addition, the SOPs currently do not account for potential differences in permeability of children's skin compared to adult skin and the Agency has found no scientific data to document such differences. How does the Panel think that the SOPs should address the concern that infants' and children's skin may absorb pesticides at a greater rate than adult skin?

Issue 3: OPP has adopted the SAP's previous recommendations concerning the frequency of hand-to-mouth events (20/hr) and available hand surface area (20 cm^2). Are these assumptions protective of teething toddlers (8-

18 months old), particularly concerning the amount of the hand placed in the mouth (two to three fingers; 20 cm^2)? The frequency of 20 events per hour is the 90th percentile from a study involving observations of children at home and in day care centers. The mean in that study is ~10 events per hour. Panel is also asked to comment on the use of these values when addressing short-term exposures (1 - 7 days) or exposures of longer durations.

Issue 4: Given the relatively low magnitude of exposures from track-in, bathing or showering relative to other scenarios, should OPP estimate exposure to pesticides that may result from these sources? If so, have we identified the most critical scenarios and approaches to be used to do the estimation?

Issue 5: OPP proposes to address exposure of children living on or near farms where pesticides are used by estimating deposition on lawns resulting from pesticide drift; OPP is developing a drift model for this purpose. Does the Panel consider this approach reasonable and are there other important non-residential pathways of potential pesticide exposure that should be evaluated for farm children?

Issue 6: OPP is proposing to initiate the use of a spray drift model to estimate the likely magnitude of unintentional exposure to pesticide residues as a result of direct exposure to sprays. What is the Panel's opinion concerning the introduction of this new source of exposure into the risk assessment process?

Issue 7: OPP currently assumes 24 hour residential exposure as a basis for its assessment of risk. OPP believes that this assumption is sufficiently conservative to protect from exposures that are likely to be encountered in other non-residential settings such as schools, day care centers, or other public places where the use patterns are comparable. Does the Panel agree or disagree and why?

Background

The passage of the Food Quality Protection Act in 1996 mandated the U.S. EPA (the Agency) to immediately begin considering aggregate exposure to pesticides. Aggregate exposure includes pesticides in food and drinking water, as well as non-dietary, non-occupational pesticide exposures for the general population. The latter type of exposure can occur, for example, in a residential setting (or other areas frequented by the general population). These exposures may include breathing vapors while inside a treated home, exposures to children playing on a treated lawn, or exposures attributable to the mouthing behaviors of infants and children. Prior to the passage of FQPA, OPP addressed these kinds of exposures on a case-by-case basis, typically in the Special Review process.

In response to FQPA, OPP developed *Standard Operating Procedures (SOPs) For Residential Exposure Assessment,* which it first brought before the FIFRA Scientific Advisory Panel (SAP) for review on September 9, 1997. The intent of the SOPs was to provide a means for consistently calculating single pathway, screening level exposures and not to provide guidance on other related topics such as aggregate exposure assessment. These SOPs are the backbone of the Agency's current approach for completing residential exposure assessments. However, the state-of-the-art has changed since the release of the original document in 1997 and the public's attention has clearly focused on the scientific and policy issues raised by the implementation of FQPA.

Residential exposure and risk assessment issues have also been raised before SAP meetings convened to review the following: Series 875, Post-Application Exposure Monitoring Guidelines (1998); dichlorvos-specific exposure assessment approaches (1998); and application of the FQPA Uncertainty Factor (1998, 1999). [Note: All of these referenced reports and accompanying documents are available from the Internet at http://www.epa.gov/pesticides/SAP.] OPP has also received numerous comments, petitions, and responses to chemical-specific risk assessments that focused on general risk assessment procedures and many of the same issues raised by these previous SAP panels, as well as raise additional ones.

The following sections discuss the seven key issues which OPP would like the Panel to address concerning OPP's plans to revise its SOPs to reflect the most recent and best science available.

Introduction

The passage of the Food Quality Protection Act in 1996 mandated the U.S. EPA (the Agency) to immediately begin routinely addressing nondietary and non-occupational pesticide exposures for the general population. These are exposures that can occur in a residential setting (or other areas frequented by the general population) and that do not occur as part of the diet or as a result of participation in occupational practices. These exposures may include breathing vapors while inside a treated home, exposures to children playing on a treated lawn, or exposures attributable to the mouthing behaviors of infants and children. Prior to the passage of FQPA, the Agency addressed these kinds of exposures on a case-by-case basis, typically in the special review process. In response to FQPA, the Agency developed *Standard Operating Procedures (SOPs) For Residential Exposure Assessment,* which it brought before the FIFRA Scientific Advisory Panel (SAP) for review on September 9, 1997. The intent of the SOPs was to provide a means for consistently calculating single pathway, screening level exposures and not to provide guidance on other related topics such as aggregate exposure assessment. These SOPs are the backbone of the Agency's current approach for completing residential exposure assessments. However, the state-of-the-art has changed since the release of the original document in 1997 and the emphasis of industry, as well as academia and others, has clearly focused on the scientific and policy issues raised by the implementation of FQPA and the use of the first generation SOPs.

The report of the 1997 FIFRA SAP that reviewed the original SOP document raised several issues in the field of residential exposure assessment that the Agency has been attempting to address since that report was issued. The concerns of that panel can be summarized as follows: longitudinal exposures across media were not considered; the scope of the document needed clarification; adequate risk characterization data were not provided; and a common mechanism of toxicity was not considered. In addition to that meeting of the FIFRA SAP, residential exposure and risk assessment issues have also been raised before several other SAP panels convened to review the following: Series 875, Post-Application Exposure Monitoring Guidelines (1998); dichlorvos-specific exposure assessment approaches (1998); and application of the FQPA Uncertainty Factor (1998). [Note: All of these referenced reports and accompanying documents are available from the Internet at http://www.epa.gov/pesticides/SAP.] The Agency has also received numerous comments, petitions, and responses to chemical-specific risk assessments and focused on general risk assessment procedures that note many of the same issues raised by these previous SAP panels, as well as raise additional ones.

This document does not present a completely revised version of the 1997 *SOPs For Residential Exposure Assessment*. Instead, the Agency thought it would be a wiser use of resources to present some of the critical issues first to the Panel for discussion and resolution prior to developing a final product in the form of a revised SOP document. The purpose of this document is to provide the background information necessary for the July meeting of the FIFRA SAP and suggest the Agency's proposed direction on modifying the SOP’s.

Overview of Residential Exposure Assessment

This section provides an overview of the approach that has been used by the Agency to complete residential exposure and risk assessments. Key elements of the process as well as some of the underlying factors are discussed.

0.1 Scope

The first step in assessing residential exposure and risk assessment is determining the scope of these types of assessments. The term "residential" refers to the generic umbrella of general population, nonoccupational exposures, regardless of where they occur. The term "general population exposure" could be easily substituted. If exposures occur as a result of activity directly related to an application, they are referred to as "handler" exposures (e.g., one who mixes or applies a pesticide product). On the other hand, if exposures occur as a result of activities in a previously treated area, they are referred to as "post-application" exposures. The other distinction that is made by the Agency is the one between the terms "residential" and "homeowner." The term homeowner is used to refer to that segment of the population who purchase pesticides and make their own applications. Conversely, it is possible to have a routine residential post-application exposure scenario that results from the occupational use of a chemical. For example, if a lawncare company or a structural pest control company treats a lawn or a house, the residents can be exposed through their normal activities inside and/or on the treated turf.

Given the above definitions, the Agency currently categorizes exposures in the following manner when completing a residential risk assessment:

- ❏ **Homeowner, Handler Exposures** result from an individual, not as a condition of his/her employment, applying a pesticide.

- ❏ **Residential, Post-Application Exposures** result from entry and activity in an environment previously treated with a pesticide. These exposures may result from both occupational or homeowner applications and may occur in a variety of settings including homes, schools, day care facilities, and other public places (e.g., parklands).

[Note: All events considered in this document are nonoccupational in nature. Exposures that can occur to bystanders of occupational applications or from bring-home events to children (e.g., drift and residue track-in) are also considered as they may cause exposures to those individuals not involved in the occupational activity (e.g., children of a farmworker or pest control operator).]

The toxicity of pesticides also determines how the Agency completes its risk assessments. For example, the effects associated with a pesticide can differ based on how it enters the body (e.g., different effects can occur based on whether it is absorbed through the skin or is inhaled). The Agency structures assessments based on the toxicological effects associated with each pesticide and the potential for exposures related to each route of exposure.

0.2 Exposure/Risk Assessment Approach

In order to illustrate the critical issues pertaining to the *SOPs For Residential Exposure Assessment* and the future approaches the Agency envisions for residential exposure assessments, it is necessary to summarize the current practices and how the current efforts to refine the assessment approaches are consistent with sound exposure assessment practices.

The risk assessment approach used by the Agency is rooted in the mandate of the Food Quality Protection Act (FQPA) amendments to the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and the Federal Food, Drug, and Cosmetic Act (FFDCA). The current approach is also consistent with the Agency-wide guidance for exposure assessment detailed in the document *EPA Exposure Assessment Guidelines* (U.S. EPA, 1992). FQPA requires the Agency to address aggregate exposures as follows:

1. Section 408(b)(2)(A)(ii) defines “safe” to mean that “there is a reasonable certainty that no harm will result from aggregate exposures to the pesticide’s chemical residue from all anticipated dietary sources as well as all exposures from other sources for which there are reliable information.”

2. Section 408(b)(2)(C) requires EPA to give special consideration to infants and children by requiring “that there is reasonable certainty that no harm will result to infants and children from aggregate exposure to the pesticide’s chemical residues....”

When FQPA was passed, the Agency had to interpret these mandates and determine how to implement them. The Agency believed that the “reasonable certainty of no harm” could only be established for food use pesticides by conducting appropriate risk assessments. Moreover, the Agency decided that such risk assessments had to routinely include non-occupational (residential) exposures as well as the usual dietary exposures. Finally, the Agency concluded that the procedures developed for these assessments must be adequately protective. These decisions provided the genesis of the *SOPs For Residential Exposure Assessment* (U.S. EPA, 1997).

In order to ensure that the standard of “there is a reasonable certainty of no harm” was established in the risk assessments completed by the Agency, the original *SOPs For Residential Exposure Assessment* document were developed using a deterministic, assumptive approach to exposure assessment that intentionally produced bounding estimates. This approach is based on conservative estimates, the Agency believes, and results in exposure estimates for a single exposure pathway that are protective or do result in a “reasonable certainty of no harm.” The Agency, in taking this approach, was consistent with its own peer reviewed *Exposure Assessment Guidelines* in that the values calculated resemble the TUBE (or Theoretical Upper Bounding Estimate) of exposure described in the guidelines. TUBE values were to be calculated in lieu of more refined chemical- and scenario-specific data (U.S. EPA, 1992). The following, excerpted from the guidelines, describes the use of TUBE estimates of exposure:

> **From Section 5.3.4.1 of the U.S. EPA Exposure Assessment Guidelines - - Preliminary Evaluation and Bounding Estimates:** “The first step that experienced assessors usually take in evaluating the scenario involves making bounding estimates for individual exposure pathways. The purpose of this is to eliminate further work on refining estimates for pathways that are clearly not important. The method used for bounding estimates is to postulate a set of values for the parameters in the exposure or dose equation that will result in an exposure or dose higher than any exposure or dose expected to occur in the actual population. The estimate of exposure or dose calculated by this method is clearly outside of (and higher than) the distribution of actual exposures or doses. If the value of this bounding estimate is not significant, the pathway can be eliminated from further refinement. The theoretical upper bounding estimate (TUBE) is a type of bounding estimate that can be easily calculated and is designed to estimate exposure, dose, and risk levels that are expected to exceed the levels experienced by all individuals in the actual distribution. The TUBE is calculated by assuming limits for all variables used to calculate exposure and dose, that, when combined, will result in the mathematically highest exposure or dose. It is not necessary to go to the formality of the TUBE to assure that the exposure or dose calculated is above the actual distribution, however, since any combination that results in a value clearly higher than the actual distributions can serve as a suitable upper bound.”

It should also be pointed out that the procedures outlined in the original document were also not meant to be aggregated without a definitive characterization by the assessor because it violates the basic tenets of exposure assessment by adding highly conservative estimates of exposures that result in "bounding, unrealistic estimates of exposure" (U.S. EPA, 1992).

The focus of the Agency is now to develop more sophisticated exposure and risk assessment methodologies that are required to complete more refined, aggregate exposure analyses. This initiative also concurs with the guidance provided in the *EPA Guidelines for Exposure Assessment* (U.S. EPA, 1992). On this matter, the *EPA Guidelines for Exposure Assessment* provide the following guidance:

> **Section 5.3.4.2 - - Refining the Estimates of Exposure and Dose:** "For those pathways not eliminated by bounding estimates or judged trivial, the assessor will then evaluate the resulting exposure or dose. At this point, the assessor will make estimates of exposure or dose that are designed to fall on the actual distribution. The important point here is that unlike a bounding estimate, these estimates should focus on points in the actual distribution. Both estimates of central tendency and estimates of the upper end of the distribution curve are useful in crafting risk descriptors."

> **Section 5.3.5.1 - - Individual Exposure, Dose, and Risk:** "If almost no data are available, it would be difficult, if not impossible, to estimate doses in the high end. One method that has been used, especially in screening-level assessments, is to start with a bounding estimate and back off the limits used until a combination of parameter values is, in the judgement of the assessor, clearly in the distribution of exposure or dose."

0.3 Use and Usage Information

Often overlooked but equally important in addressing residential exposure assessments is use and usage (use related) information. Information addressing specific locations of pesticide use (behind cabinets in kitchens) as well as usage information such as the frequency of those applications are needed for matching exposure scenarios with appropriate toxicity studies in aggregate risk assessments. It is anticipated that well designed use and usage surveys will play an important role in risk assessments in the future.

The amounts of chemical pesticides that are used annually in the home and garden market as well as in other areas that can potentially contribute to residential exposures are presented below in order to establish the import of addressing these kinds of exposures. According to a report entitled *Pesticide Industry Sales and Usage 1994 and 1995 Market Estimates* (U.S. EPA Report 733-R-97-002, 1997), 133 and 135 million pounds, respectively, of pesticide active ingredients were applied in domestic home and garden settings in 1994 and 1995. This market accounted for approximately 11 percent of all domestic, conventional pesticide use in each of those years. This economic sector was defined in the report as homeowner applications to homes and gardens, including lawns.

Applications by owner/operators and custom/commercial applicators to industrial, commercial, and government facilities, buildings, sites, and land as well as custom/commercial applications to homes and gardens, including lawns, also accounted for the annual use of another 159 and 150 million pounds, respectively, of pesticide active ingredient in 1994 and 1995 (U.S. EPA Report 733-R-97-002, 1997). Some of these applications may contribute to residential exposures because they include applications in residential environments and include uses in facilities frequented by children such as schools and day care centers. These types of applications accounted for approximately an additional 12 to 13 percent of all domestic pesticide use each year.

The categories of conventional chemicals that were considered by in the 1997 EPA report included: herbicides (including plant growth regulators); insecticides and miticides; fungicides; fungicides and nematicides; other (e.g., rodenticides, molluscicide, and insect regulators). Insecticides and herbicides were the most commonly used individual chemicals. Total annual sales of conventional pesticide active ingredients were about 1.2 billion pounds per year in both 1994 and 1995. This does not include the sales of industrial wood preservatives, specialty biocides, and chlorine/hypochlorites which accounted for 73 percent of the total pesticide market in 1995 (about another 3.5 billion pounds of active ingredient). These chemicals also can contribute to residential exposures.

Using the data currently available to put the residential exposure issue into perspective, EPA Report 733-R-97-002 (1997) indicates that the annual use of conventional pesticides in the home and garden marketplace was around 135 million pounds of active ingredient in 1994 and in 1995 and that this trend remains relatively steady. Additionally, this report, indicates that in 1994 pesticides were used in approximately 70 million of the 95 million households in the United States and that an average of 1.9 pounds of active ingredient were applied in each user household (i.e., most homeowner products are dilute so this means that tens or even hundreds of pounds of consumer (end-use) products are potentially used in or around the average household each year). It follows that is likely that at least two application events (or more) occur every year in each household because of the quantities of end use products used. Therefore, it can be theorized that there are at least 140 million annual pesticide application events by homeowners alone that could result in exposures to the users themselves as well as to anyone living in those households.

A significant amount of use and usage data that are collected each year that pertains to the amount of chemicals annually applied. The data required for exposure analysis, however, are sometimes lacking; currently, many efforts are being made through the Agency and various stakeholders to obtain those kinds of data. For example, the Agency is working with several groups to obtain information about pesticide use in the residential environment through efforts with groups such as the National Pest Control Association and the American Mosquito Control Association. As these and other kinds of critical use and usage information become available, they will be used to refine exposure assessments.

1 Issue 1: Calculation of percent dislodgeability of available pesticide residues from lawns, indoor surfaces and pets

OPP's approach to non-occupational exposure assessment presumes that human exposure in residential settings depends primarily on two factors: how much pesticide residue is available for human uptake and what human activities occur that would result in contact with and uptake of residues. Many of OPP's Residential SOPs involve algorithms for estimating dermal exposure resulting from contact with pesticide-treated surfaces, e.g. turf grass, carpets, etc. In general, these algorithms are some form of the following equation and employ either data or default assumptions for each variable.

[transferable residues (ug/cm2)] x [human activity transfer coefficient (cm2/hr)] x [duration of activity (hrs.)] divided by body weight.

This section focuses on the determination of values for the transferable residues variable. Data show that human contact with treated surfaces does not result in the immediate transfer of all of the pesticide initially deposited on the surface to the human. Many factors affect how much residue is "transferable." Foremost is the amount of pesticide applied. Other important factors are 1) the type of formulation; 2) the type of surface; and 3) the amount of dissipation. Because these and other factors may significantly decrease the amount of pesticide actually available for human uptake, EPA believes it is inappropriate to assume that 100% of the applied pesticide is available for uptake. Transferable residues may either be measured directly or, in the absence of data, calculated by assuming that a specific percentage of the amount of pesticide initial deposited is transferable.

There is considerable controversy over the appropriate assumption to be used in the SOPs for "percent transferable residues." At present, in the absence of appropriate data, the SOPs assume that 50% is the "percent transferable residues," both for pesticides applied to turf grass and to indoor surfaces. As explained more fully below, the 50% assumption is derived from a study in which pesticide residues on a carpet were extracted using detergent. Other methods of sampling pesticide residues on carpet and smooth surfaces produce much lower measurements of percent transferable residues. Values range from 0.1% to 24%, depending on the sampling method and the type of surface being sampled. As discussed below, EPA is considering changing the assumption it uses in the absence of data about the amount of applied residue that is transferable.

OPP believes that its current assumption of 50% transferable residues, together with other values used in the Residential SOPs algorithms, probably overstates, to a significant degree, the amount of residue available to humans through transfer by skin contact with pesticide-treated surfaces. There are several reasons supporting this conclusion. First, numerous studies have been conducted using a variety of sampling techniques to measure transferable residues. None of the techniques comes close to collecting the percentage of initially deposited residues measured by the solvent extraction method. Moreover, several of the sampling techniques employ methods which closely resemble the actual phenomenon being modeled: transfer of pesticide residues from a treated surface as a result of contact of human skin or clothing with the surface. Data using these sampling techniques show a relatively lower percent transferable residue than does the solvent extraction method.

In addition, OPP believes is appropriate to modify the assumption about the "percent transferable residues" in order to used a value derived by the same sampling technique as was used in the studies on which OPP's "transfer coefficients" are based. It is important to recognize the interdependence of the "transferable residue" value and the human activity "transfer coefficient." It is almost impossible to measure, directly at the moment of transfer, the residues that are actually available and being transferred from a surface to a human by a specific activity, e.g. touching a surface. Therefore, scientists typically rely on other techniques to measure "transferable residues." "Transfer coefficients" are typically derived by measuring pesticide residues present on an individual who has performed a particular activity for a fixed period of time. Then the residues on the person are compared to the residues present on the treated surfaces to determine how much of the residue was transferred. Since different sampling methods collect different amounts of residue, the calculation of the transfer coefficient for a specific activity depends on the method being used to measure residues present on a surface. The higher the measured residues are, the lower the transfer coefficient will appear, and vice versa.

The importance of using the same methodology for measuring transferable residues for purposes of calculating the "transfer coefficient" and for the SOP algorithm can be illustrated by an example. Assume that a pesticide is applied (i.e. deposited on surfaces contacted by humans) at a rate calculated or measured as 100 ug/cm2; also assume that patch testing or biomonitoring shows that in one hour a particular pattern of human activity resulted human dermal exposure of 2000 ug. If the transferable residue is measured at 1 ug/cm2 (i.e. 1% of the deposited rate), the transfer coefficient would be 2000 cm2/hr. On the other hand, if the transferable residue is measured at 20 ug/cm2 (i.e. 20% of the deposited rate), the transfer coefficient would be calculated as 100 cm2/hr. It is important, therefore, that a transfer coefficient be developed not only for a particular human activity, but also for a particular method of measuring transferable surface residues, and that the same sampling method be used for the values employed in the Residential SOP algorithms.

The transfer coefficient for dermal exposure to pesticide-treated turf and indoor surfaces was based on calculations using data on transferable residues measured by the Cloth Roller sampling technique. Data from studies of transferable residues measured by the Cloth Roller technique show that the percentage transferable residues on carpets ranges from 1.1% to 4.9%. Concurrent measurements using other techniques produced similar values. See Table 4. Therefore, OPP has decided it would be appropriate to assume in the absence of data that 5% of initially deposited residues are transferred to human skin through contact with pesticide-treated surfaces.

While OPP believes that using an assumption of 5% transferable residues is appropriate for algorithms that involve estimating dermal exposure to pesticides on turf grass and indoor surfaces, there are also reasons to question whether such an assumption is adequately conservative. First, data show that the percent transferable residues is considerably higher on smooth, hard surfaces such as counters, linoleum or wood floors, than for turf or textured surfaces such as carpet or upholstery. At least some of the surfaces people will contact will be smooth, hard surfaces with the higher percent transferable residues. Second, most measurements of transferable residues have been made on surfaces where pesticide residues have dried. Data show that a higher percentage of residue is transferred when human contact occurs during the period of time after initial deposition that the surface remains wet with the pesticide spray. Third, in light of the data showing greater percentages of transfer of wet residues, some have speculated that residues may be transferred to humans more readily if an individual's skin is wet or sticky (for example with food or drink residues).

OPP requests comment from the Panel on the appropriateness of using an assumption of 5% transferable residue in the dermal exposure algorithms in the Residential SOPs.

Finally, OPP has included information on several studies related to the transfer of residues from pets to humans. These studies used a variety of techniques to collect data on this potential source of exposure. OPP believes that there remain a number of serious methodological issues with respect to evaluating this pathway of exposure, and requests comment from the Panel on research directions for improving the models for estimating this potential source of exposure.

It is well recognized in the published literature that only a certain portion of an applied pesticide will normally be available for potential human exposure through dermal contact. This fairly straightforward concept of the dislodgeability of pesticide residues is complicated by a wide variety of terms and approaches used by various investigators. For the purposes of this document, EPA makes the following distinctions:

❑ The term *dislodgeable foliar residues* (DFR) has its origins in agricultural postapplication exposure studies in which plant material (leaf punches) of a known surface area is placed in a jar containing an aqueous-surfactant dislodging solution and shaken. The resulting suspension/solution is then taken to the laboratory for analysis. This residue value is expressed as micrograms per square centimeter ($\mu g/cm^2$). This method is described in Iwata et al., (1977). Agricultural DFRs based on this method typically represent 20 percent of the application rate and are the basis for the percent dislodgeable value currently in use for assessing postapplication exposure to pesticides applied to turfgrass.

- *Transferable residue* (TR) methods rely on pressure and friction rather than a dislodging solution, to "transfer" residues from the treated surface to a sample collection media. *Transferable residue* (also known as transfer efficiency) methods involve the dragging, pressing or rolling a material such as cotton cloth over a known surface area treated with a pesticide. Transferable residues are taken in situations where 1) leaf punches are not practical due to small leaf size, as is the case with turfgrass, or 2) measuring residues after pesticide applications have been made to carpets or other indoor surfaces. The pesticide residues transferred to the material are extracted and expressed in the same manner as the DFR's ($\mu g/cm^2$).

There are two basic approaches to determining how much available residue transfers to a person (a) transfer coefficients and (b) transfer efficiency. For (a), in post application studies required by the Agency, dislodgeable/transferable residues are collected concurrently with a specified reentry activity. While performing the reentry activity, study volunteers wear dosimeters (cloth patches or cotton clothing). Residues are extracted from the dosimeters which represent certain surface areas of the body. In agricultural situations, which make up the majority of postapplication studies submitted to the Agency, the dermal exposure is normalized as micrograms per hour ($\mu g/hr$). The relationship between the dermal exposure and the dislodgeable residues is expressed as a *transfer coefficient*. The transfer coefficient is simply calculated by dividing the hourly exposure by the residues measured at the time of the activity.

The transfer coefficient is calculated by the use of this simple equation:

$$\text{Transfer Coefficient } (cm^2/hr) =$$

$$\text{Hourly exposure } (\mu g/hr) \div \text{Transferable residue } (\mu g/cm^2)$$

Transfer coefficients can be used to calculate potential dermal exposure (mg/kg/day) to varying levels of pesticide residues by use of the following equation:

Transferable Residue ($\mu g/cm^2$) X Transfer Coefficient (cm^2/hr) X duration (hrs) ÷ body weight (kg)

Some researchers consider transferable residues as surrogates for human exposure and refer to those residues as *transfer efficiencies*. Rather than conduct a concurrent dermal, post application study, these transfer efficiencies are assumed to be directly transferred to the skin. The Agency's Office of Research and Development (ORD) is using these "transfer efficiencies" to develop non-dietary exposure models through the use of the emerging video tape technology. However, both ORD and the regulated community utilize some of the same residue sampling methods, and results from those studies can be used to revise the percent dislodgeable values currently in the SOP. The use of dislodgeable/transferable residues in the Residential SOPs is based on the *transfer coefficient* concept.

1.1 Dislodgeable and Transferable Residues - Turf

There are many variables influencing transferable residues on lawns, including application rate, formulation type (e.g., spray or granular), and label directions such as recommending that the pesticide be watered-in. Another factor that may influence a pesticide's transferability is pesticide penetration of the waxy cuticle of the grass leaf or uptake by the plant's roots in the case of systemic pesticides. Dissipation of the residues, which is chemical and formulation specific, is also addressed by dislodgeable or transferable residue studies. Dissipation of turf residues is influenced by factors such as sunlight, moisture, rainfall/irrigation, new growth and mowing. The length of time the pesticide residues are available in the environment will influence whether short term exposure (1-7 days) and/or intermediate-term exposure (7-90 days) are estimated.

There are several techniques developed and used to measure dislodgeable and transferable residues. A brief description of the methods use by investigators to measure transferable/dislodgeable residues is as follows:

❑ **<u>The Foliar Wash</u>** utilizes a detergent solution to "dislodge" the residues from turf leaves equaling a known surface area. This method most closely resembles the dislodgeable foliar residue measurement method used for agricultural reentry studies which typically use 40, one-inch leaf punches. Since leaf punches are not possible with turf, weighted amounts of fresh grass are taken. In the dislodgeable residue technique, all grass is obtained from randomly selected, defined areas of the treated plot. Prior to the study, multiple grass clipping samples must be obtained from the test plot to establish a correlation between leaf surface area and weight. This correlation is established by weighting fresh grass clippings that have been placed on a template of known surface area or the use of a leaf area meter. When the correlation is established, weighed samples can be dislodged in the same way as the leaf punches. Other methods, as shown below, use a matrix such as cotton cloth or polyurethane foam (PUF) to collect the residues through the use of pressure and friction. Residues collected using the following techniques are referred to as transferable residues.

❑ **<u>The Shoe Method</u>** or cheese cloth wipe technique. This technique involves a person scuffing forward and backward over a designated area of treated turf (Thompson et al., 1984) (Sears et al., 1987). An investigator's shoes are wrapped with plastic. Then the shoes are wrapped with the cheese cloth. In some cases, a platform such as cooking pan is attached to the bottom of each shoe and the cheese cloth is attached to the underside of the platform. The cheese cloth is removed from the platforms or shoes and taken to the laboratory for extraction and total analysis.

- ❑ **<u>The Cloth Roller</u>** was developed by the California Department of Pesticide Regulation. The method consists of a cotton (e.g., percale) sheet situated over a known surface area that had been treated with a pesticide. The sheet is secured with a template. A weighted roller (25 pounds) is then rolled over the fabric. Care is taken not to press too hard with one sample consisting of ten rolls. Each roll consists of moving the roller once forward and once back. (Ross et al., 1991). Total residues are extracted from the cotton fabric.

- ❑ **<u>The Polyurethane Foam (PUF) Roller</u>** was developed by EPA's ORD in cooperation with Southwest Research Institute. The PUF roller is similar to a common paint roller which forms the front wheel of the sampler. Two rear wheels situated further apart than the roller provide stability. The PUF roller also has a platform to accommodate various weights. The PUF roller is rolled over a known surface area. The PUF sleeve is removed and extracted for total pesticide residue analysis.

- ❑ **<u>The Drag Sled</u>** developed by the Dow Chemical Company, uses denim fabrics attached to a weighted block which is dragged over a known surface. The denim is extracted for pesticide residues. Various weights can be used as with the PUF roller, most cases utilize weights simulating the pressure exerted by a crawling or standing child (Vacarro et al., 1996).

Although there are limited data bridging the percent transferable residues (Lewis et al, 1995) that are collected by some of the available dislodgeable/transferable methods, there is sufficient evidence, in the published literature and in guideline studies submitted to the Agency, that suggest the current standard value of 20 percent dislodgeability is an overestimate, regardless of method used. For example, Nishioka et al., (1996) reported transferable residues representing 0.1 to 0.2 percent of the turfgrass application rates for 2,4-D and Dicamba respectively, using the PUF Roller. Nishioka et al., (1997) also reported percent transfer of turf application rates using the PUF Roller as follows: Dicamba (0.18%), 2,4-D (0.27%), Dicamba Isomer (0.1%), Chlorpyrifos Granular (0.005%), Chlorpyrifos Spray (0.008%) and Chlorthalonil (0.21%). Other published literature data considered in this document include studies conducted by Cowell et al. (1993) and Hurto and Prinster (1993). In addition, transferable data collected by the California Department of Pesticide Regulation (Cal-DPR), Goh et al. (1986) were also considered.

Proprietary data submitted to the Agency were also evaluated. The combined data suggest that less than 0.1 to 4 % of the application rate is transferable for sprayable formulations such as flowable concentrates and emulsifiable concentrates. For granular formulations, available data suggest 0.2 to 0.6% of the application rates are transferable. One notable exception is a transferable value of 9% identified in the literature (Solomon et al., 1993). In that study the shoe wipe method was used with concurrent biological monitoring rather than passive dosimetry for the herbicide 2,4-D. This study is discussed in Chapter 2, Issue 2. It has been observed that this method which is believed to be vigorous wiping, may not be representative of actual human contact with treated turf (Nishioka et al., 1996). The transfer coefficient in that study based on a one hour exposure duration after sprays have dried was ~4600 cm^2/hour. This illustrates the importance of matching transfer factors with the appropriate percent transferable assumptions.

Table 1 presents the difference between the percent dislodgeable/transferable residues as currently estimated in the Residential SOP's and the percent dislodgeable/transferable residues from empirical measurements as discussed above. For example, total deposition of one pound of active ingredient applied on an acre basis is equal to 11.209 micrograms per square centimeter ($\mu g/cm^2$). In the current Residential SOP, EPA assumes 2.24 $\mu g/cm^2$ (20%) is dislodgeable/transferable portion of each pound of the active ingredient applied on an acre basis.

Table 1. A Comparison of Transferable Residues Estimated by the Residential SOP's and Transferable Residues Collected from Empirical Studies After Sprays Have Dried and Dusts Have Settled on Turf:

Chemical ai = active ingredient ae = acid equivalent	Transferable Residue (μg/cm^2) as Estimated by Residential SOP (20% transferable)	Transferable Residue (μg/cm^2) from Empirical Measurements (% transferable in parentheses)	Method	Comments
Chlorpyrifos - spray (1 lb ai/acre)	2.24	0.03 (0.27%)	Foliar wash	Hurto and Prinster, 1993
Chlorpyrifos - granular (2 lb ai/acre)	4.48	0.139 (0.6%)	Drag sled	MRID 441671-01
Chlorpyrifos - spray (2 lb ai/acre)	9	0.03 (0.06%)	Drag sled	MRID 430135-01
Diazinon - granular (4 lb ai/acre)	9	0.13 dry (0.3%) 0.27 Watered-in (0.63%)	Foliar wash	MRID 420633-01
DDVP - spray (2 lb ai/acre)	4.48	0.1 (0.45%)	Foliar Wash	Goh et al., 1986
Fonofos - granular (4 lb ai/acre)	9	0.006 - 0.11 dry (0.013 - 0.24%) 0.018 - 0.074 Watered-in (0.039 - 0.16%)	Foliar Wash	MRID 420633-01
Malathion - spray (5 lb ai/acre)	12.2	0.57 (1%)	Cloth roller	MRID 439450-01
Isofenfos - spray (flowable) (2 lb ai/acre)	4.48	0.91 (4%)	Foliar wash	Hurto and Prinster, 1993
Dithiopyr - Micro-encapsulated. (1 lb ai/acre)	2.24	0.36 (3.19%)	Foliar wash (20% acetonitrile)	Micro-encapsulated formulations appear to be more dislodgeable than granular formulations, Cowell et al., 1993.
Amidochlor - spray (Plant Growth Regulator (PGR) (4 lb ai/acre)	9	0.22 (0.4%)	Shoe	Cowell et al., 1993
2,4-D 2-EHE - spray (1.7 lb ae/acre)	3.81	0.025 (1.46%)	Cloth roller	446557-01
2.4-D DMA - spray (1.725 lb ae/acre)	3.87	0.033 (0.845%)	Cloth roller	446557-01
MCPA 2-EHE (1.544 lb ae/acre)	3.46	0.015 (0.845%)	Cloth roller	446557-01
MCPA DMA (1.547 lb ae/acre)	3.46	0.07 (0.4%)	Cloth roller	44657-01
2,4-DP-p DMA (0.596 lb ae/acre)	1.34	0.016 (1.2%)	Cloth roller	44657-01
MCPP-p DMA (0.599 lb ae/acre)	1.34	0.13 (1.91%)	Cloth roller	44657-01
2,4-DP-p 2-EHE (0.612 lb ae/acre)	1.37	0.013 (0.186%)	Cloth roller	44657-01
2,4-D DMA (1.585 lb ae/acre)	3.55	0.13 (0.73%)	Cloth roller	44657-01
Amidochlor - spray (4 lb ai/acre)	9	0.17 (0.37%)	PUF roller	Cowell et al., 1993

As previously mentioned, one of the concerns of field investigators and residential exposure assessors has been how to compare the various methods used to collect the transferable residues. Rather than conduct bridging studies, investigators have examined differences between some methods with respect to reproducibility, sensitivity, and consistency. Some methods have been evaluated in studies conducted by EPA's Office of Research and Development (ORD) and by the Outdoor Residential Exposure Task Force (ORETF). The ORETF has selected the Cloth Roller for its membership and according to a draft ORD report, ORD has also suggested that the Cloth Roller is the preferred method for collecting transferable residues from turf. Both entities have modified the original California Roller by modifying the template and including a handle for ease of use.

The assertion that 20% dislodgeable/transferable residues on turf is an overestimate was first suggested at the September 1997 SAP in which the Residential SOPs were presented. The Cal-DPR, in formal comments to the SAP, contended that transferable residues represented less than 5% of the deposition rate when the cloth roller is used. Particularly since the cloth roller was used to derive the transfer coefficient used in the SOPs to estimate post application dermal exposure. Linking percent dislodgeable residue methods and corresponding dermal exposure measurements is discussed in more detail in Chapter 2, Issue 2. The Department's comments also apply to the Residential SOPs use of 50% dislodgeable/transferable for indoor surfaces.

In the absence of chemical specific transferable residue data on turfgrass, the Agency recommends dislodgeable values of 5 percent for use in post application dermal exposure estimates in the Residential SOPs.

1.2 Transferable Residues - Indoor Surfaces

Characterizing transferable residues as a result of indoor applications of pesticides or from pesticides tracked indoors from outdoor applications is complicated by the complexity and the variety of indoor surfaces and materials. Based on the application method, care must be taken to sample the right locations. Broadcast applications to carpets, in most cases, are fairly straightforward. However, for products such as total release aerosol foggers, investigators should consider residue measurement locations such as furniture surfaces as well as carpets and other flooring materials. Ross et al. (1991) calculated the percentage of fogger contents landing on the floor for both chlorpyrifos and allethrin to be approximately 69% and 55%, respectively. It was noted that those figures were substantially lower than some hypothetical estimates derived from Maddy et al. (1987), for estimating postapplication exposure to propoxur containing foggers (100%). Transferability of pesticides is also influenced by type of fabric and textures.

Although it is hypothesized that residues do not dissipate indoors as quickly as they do outdoors there appear to be several other factors influencing dissipation:

1) Loss of solvent inerts (via evaporation/absorption/adsorption) which maintain the pesticide in a transferable thin film solution;

2) Absorption of the pesticide into carpet fiber;

3) Chemical or electrostatic binding of the pesticide onto the carpet fiber surface;

4) Degradation of the pesticide into non-detectable products;

5) Volatilization of the pesticide into the atmosphere;

6) Migration of the pesticide, either independently or attached to dust or other particles, into areas not available for contact such as the carpet backing or foam pad (Ross et al., 1991).

Other factors may influence the transferability of pesticides applied indoors. These include the suspension of the pesticide in a thin liquid film soon after the application, the dried residues, and when residues become dust bound.

There are methods available for investigators to collect indoor residues other than those presented in the previous section:

❑ **Surface Wipe:** One of the methods first used to assess residues available for post application exposure for the indoor environment was the surface wipe. The surface wipe method, as recognized by Health Canada and OSHA, consists of the use of a moistened cloth in which the investigator wipes across a surface in one direction, followed by resampling the same location at a 90 degree direction to the first wipe. The California Department of Pesticide Regulation enforcement personnel also use this method.

Other methods used to collect indoor surface residue measurements include:

❑ **Hand Press and Hand Drag:** These methods rely on the hands of human volunteers as the collection media rather than cotton or other materials. Individuals wash their hands with soap and water prior to the study. The hand pressure to apply to the treated surface is determined by pressing the palm (excluding fingers) on a pressure plate or scale to approximate a

12 pound force (5.4 kg). This value is estimated to be that of a crawling infant or walking toddler. The volunteer is instructed to press the palm against a treated area or dragged across a treated area. Hand rinses are taken to a laboratory for analysis. The surface area of the subjects hands is determined so the results of analysis can be expressed as $\mu g/cm^2$.

- ❑ **HVS3 - Vacuum Surface Sampler:** This method has been referred to as a dislodgeable technique as it relies on the use of a vacuum cleaner to dislodge quantities of dust from carpets. This modified vacuum directs the dust particles through a cyclone into a catch bottle. The collected dust is sieved to eliminate particles greater than 150 μm. A total of forty passes are made over a known area. The dust is analyzed for pesticide residues and expressed either as concentration ($\mu g/g$, ppm) or as surface loading ($\mu g/m^3$).

- ❑ **Lioy-Weisel-Wainman Sampler:** This device uses the movement of a block across a template covering a known surface area (100 cm^2). Filter media are attached to the silicone rubber pad attached to the block which moves across the template at a constant pressure. The filters are wetted with methanol and hexane with excess solvent shaken off prior to attachment. The filter is analyzed and residues are expressed as $\mu g/cm^2$.

As with the turfgrass transferable residues, there are several methods to collect transferable residue measurements on indoor surfaces. To our knowledge, all of the methods described under turfgrass transferable residues (except the shoe wipe), have been used by various investigators to collect residues on treated indoor surfaces such as carpets and floors. The dislodgeable rinse typically used in agricultural reentry studies was used in one EPA study,"Assessment of Time-Motion Video Analysis for the Acquisition of Biomechanics Data in the Calculation of Exposure to Children" (EPA, 1998). In that study, presented in Table 2, carpet coupons were collected after an application of chlorpyrifos was made to a carpet of the same material. Carpet coupons were washed in a dislodging solution. This method resulted in approximately 50% of the depostion rate to be transferable. This is the source of the 50% transferable value in the current SOP's. The dermal activity measured was an adult crawling on the treated carpet. Note the lower transfer factor ~6000 cm2/hr was derived from having a large transferable residue denominator of 6.24 $\mu g/cm^2$. If the investigators selected a transferable residue measurement that yieled 5% of the deposition rate, the transfer coefficient, the transfer factor would be ~47,000 cm^2/hr.

Table 2. Dermal Transfer Coefficient from Crawling on a Chlorpyrifos-Treated Nylon Carpet

Replicate	Exposure Duration[a] (seconds)	Exposure Level		Average Deposition (μg/cm^2)	Average Transfer-able Residue (μg/cm^2)	Transfer Coefficient[c] (cm^2/hr)
		μg/rep	μg/hr[b]			
1	139.2	1,326	34,293	14.69	5.70	6,016
2	149.1	1,665	40,201	17.02	7.54	5,331
3	149.5	1,412	34,001	14.57	5.47	6,216
Average	145.9	1,467	36,165	15.42	6.24[d]	5,854

a - Exposure duration represents the total time the test subject was within the treated area.
b - Exposure (μg/hr) calculated based on the following equation:

$$E (\mu g/hr) = (E (\mu g/rep)/duration (s/rep)) \quad (60s/min) \quad (60 min/hr)$$

c - Transfer Coefficient (cm^2/hr) = Exposure (μg/hr) ÷ Transferable Residue (μg/cm^2)

d - Average transferable residue value of 6.24 μg/cm^2 represents 48.3 percent of the total residue level anticipated based on the theoretical application rate (e.g., average transferable residue level represents approximately 50 percent of the theoretical application rate of 12.91 μg/cm^2.

As previously mentioned the Cal-DPR, in formal comments to the September 1997 SAP, contended that transferable residues represented less than 5% of the deposition rate, when the cloth roller is used. Particularly since the cloth roller was used to derive the transfer coefficient used in the SOPs to estimate post application dermal exposure. Linking percent dislodgeable residue methods and corresponding dermal exposure measurements is discussed in more detail in Chapter 2, Issue 2.

Table 3 illustrates the difference between the dislodgeable measurements from carpets with a cloth roller and the spray deposition measurements (total) collected with gauze pads. The deposition measurements are expressed as MGD = mean gauze deposition (Ross et al., 1991). The units in the table are expressed as μg/cm^2 (Percent transferable = mean transferable residue ÷ MGD 100):

Table 3. Comparison between deposition measurements on gauze (MGD) and transferable residue measurements from treated carpet expressed as $\mu g/cm^2$ (percent transferable in parentheses):

	Chlorpyrifos	d-trans allethrin
zero hours post application		
mean transferable	0.055 $\pm$0.035 (2.1%)	0.0064 $\pm$0.0042 (2.9%)
MGD	2.36	0.2175
six hours post application		
mean transferable	0.030 $\pm$0.019 (1.4%)	0.0060 $\pm$0.0032 (2.5%)
MGD	2.11	0.2350
twelve and a half hours post application		
mean transferable	0.023 $\pm$ 0.017 (1.1%)	0.0044 $\pm$0.0029 (1.8%)
MGD	2.019	0.2450 (includes MDL)

Currently the SOP's for indoor surfaces assume, in absence of data measuring transferable residues, that 50% of the application rate to carpets and floors is transferable. This value came from the study presented in Table 2. A review of published transferable residue measurements reported by authors such as Fenske et al., (1990), Vacarro (1990), Ross et al., (1990) suggest transferable/dislodgeable residues for carpets represent 0.13 to 5 % of the deposition rate. These values are similar to the levels of percent transferable/dislodgeable residues measured by the cloth roller used to develop the transfer coefficient derived from Jazzercise™.

Many indoor pesticide applications are made to directly to carpets. The majority of transferable residue data are based on transferable residue measurements taken as soon as the sprays have dried. Higher transferable residue measurements were noted in Fenske (1990), showing 5 - 11% transferability one half hour after a broadcast application. However, it was noted by Vacarro (1992) that the surfaces may not have dried completly prior to taking the samples. Applications to surfaces such as vinyl tile also show higher percentages of transferability than carpets when using similar methods. This is most notable in Camann et al., (1995) showing transferable residue rates from vinyl of ~10 to 25%. This is important when addressing total release foggers that will treat all indoor surfaces rather than when addressing target specific (carpet) sprays.

The influence of wet or sticky hands may also influence exposure to children when crawling on a treated surface. Camann et al., 1995 and Lu and Fenske (1999) partially address this issue by using moistening materials such as PUF prior to sampling. Camann et al., (1995) observed that transferability residue measurements using moistened materials such as denim and PUF were highly variable although all transferable values using moistened media were below 5% (0.6 to 2.1%). Pre moistened PUF and surface wipes were also made by Lu and Fenske (1999) also showing less than 5% transferability (1 - 3.1%). Lu and Fenske suggest that the hand is a much poorer collector of residues than when using the methods PUF or surface wipes. Hand press values were less than 0.3% transferable from carpets and 0.7% transferable from desk tops. In Camann et al., (1995), single hand presses were lower (4-5%) than PUF or Drag Sled (~10 - 25% respectively) when measuring transferable residues from vinyl surfaces.

Table 4. Percent Transferable Residues for Indoor Surfaces

Chemical	Deposition (μg/cm^2)	Transferable (μg/cm^2)	Percent Transferable	Method	Comments
Chlorpyrifos	14	0.69 - 1.6	**4.9 - 11.4%**	Wipe	Fenske et al., 1990
	5-15	0.02 - 0.05	0.13 - 1%	Drag sled	Vacarro, 1990
	2.3	0.02 - 0.06	1.1 - 2.9%	Cloth roller	Ross et al., 1990
Chlorpyrifos - plush carpet	13.5	0.67	4.9%	Cloth roller	Camann et al, 1995
		0.18	1.35%	Drag sled	
		0.12	0.9%	PUF roller	
Chlorpyrifos - level-loop carpet	10.6	0.3	2.7%	Cloth roller	
		0.18	1.7%	Drag sled	
		0.16	1.5%	PUF roller	
Chlorpyrifos - plush carpet	19.8	0.08	0.4% -dry	Drag sled	
		0.05	0.26% - dry	PUF roller	
		0.13	0.66% - **moistened**	Drag sled	
	19.8	0.42	2.1% - **moistened**	PUF roller	
Chlorpyrifos - plush carpet	5.8	0.006	0.1%	Drag sled	
		0.002	0.03%	PUF roller	
Piperonal Butoxide - plush carpet	5.8	0.007	0.12%	Drag sled	
		0.002	0.04%	PUF roller	
Pyrethrin I - plush carpet	0.56	0.001	0.19%	Drag sled	
		0.0002	0.4%	PUF roller	
Methoprene - plush carpet	0.08	0.0025	3%	Drag sled	
		0.0008	1%	PUF roller	
		0.0003	0.4%	Hand press	
Piperonal Butoxide - plush carpet	4	0.13	3.2%	Drag sled	
		0.056	1.4%	PUF roller	
		0.017	0.43%	Hand press	
Chlorpyrifos - sheet vinyl	8	1.9	**23.5%**	Drag sled	
		0.78	**9.7%**	PUF roller	
		0.26	**3.1%**	Hand press	

Chemical	Deposition ($\mu g/cm^2$)	Transferable ($\mu g/cm^2$)	Percent Transferable	Method	Comments
Piperonal Butoxide - sheet vinyl	7.6	1.67	**21.9%**	Drag sled	
		0.63	**8.3%**	PUF roller	
		0.3	**4%**	Hand press	
Pyrethrin I - sheet vinyl	1.2	0.19	**15.9%**	Drag sled	
		0.12	**9.6%**	PUF roller	
		0.04	**3.2%**	Hand press	
Chlorpyrifos - carpet, spray	12.3	0.34 (30 min after application)	2.8%	Wipe	Lu and Fenske, 1999
		0.12 (3.5 hrs after application)	1%	Wipe	
		0.18 (average for 30 min and 3.5 hrs after application)	1.5%	PUF roller	
		0.006	0.05%	Hand press	
		0.005	0.04%	Hand drag	
Chlorpyrifos - carpet, aerosol	2.64	0.07	2.65%	Wipe	
		0.06	2.15%	Wipe	
		0.08	3%	PUF roller	
		0.003	0.13%	Hand press	
	2.64	0.001	0.05%	Hand drag	
Chlorpyrifos - carpet	1.97	0.005	0.26%	Hand press	
Chlorpyrifos - furniture (desk tops)	1.79	0.056	3.1%	Wipe	
		0.012	0.7%	Hand press	

The transferable residue measurements shown in Table 4 demonstrate the complexity of estimating exposure to pesticides applied indoors. There are differences in transferable residue measurements among residue measurement methods, when using dry and moistened sampling media, when the surface is smooth or textured and whether the surface sampled was still wet from the application. Lu and Fenske (1999) assert " the central finding of these data is that the current methods of measuring transferable residues on carpets and furniture surfaces after commercial pesticide applications substantially overestimated the amount of residue removed by skin contact." Similar differences between percent transferable residues of hand presses and those of the PUF and drag sled methods is apparent in the data collected by Camann et al. (1995).

Given the potential differences in transferability based on surface type (carpet 0.1- 4.9%, compared to smooth surfaces 3.3 - 23.5%), the use of a 5% transferability value is recommended by the Agency to be used in the absence of chemical specific data.

This conclusion is based on:

- ❏ **removal of residues by the hands from surfaces such as vinyl range from 0.04 to 4%;**
- ❏ **the decision to use transfer coefficients from transferable residue data generated by the same sampling methods (see Section 3, Issue 2).**

However, OPP would like the SAP to consider whether/how to incorporate such results when developing a transferable percentage assumption designed to be inclusive of all surfaces.

1.3 Residues from Applications to Pets

Postapplication exposure to pesticide residues that may be transferred from the fur of pets is difficult to model due to the limited data addressing this exposure pathway. In addition, continued contact with the treated pet is less likely than continued contact with a treated surface such as when playing on indoor carpeting. For dermal exposure, the SOPs direct the assessor to assume that 20% of the application rate is retained on the pet as dislodgeable residue and that 10% of the residues are transferred to an individual. For non-dietary ingestion, there is an assumed one-to-one relationship between the transferable residue on the surface of the pet and on the surface area of the skin (both hands) after contact with the pet. For example, a 30 pound dog has approximately 6000 cm^2. If 30 mg of a pesticide was applied to this 30 pound dog, the SOP directs the assessor to calculate the transferable residue as follows:

Transferable Reside ($\mu g/cm^2$) = 30mg   20% ÷ 6000 cm^2

Transferable Residue = 0.001 mg/cm^2

Or   1 $\mu g/cm^2$

The transferable value is then used in the hand-to-mouth scenario as follows:

0.001 mg/cm^2 350 cm^2 (surface area of child's hands)   1.56 events***** per/hr

***** This value is being revised.

For the proposed SOP revisions, the Agency has considered two very different studies measuring transferable residues from the fur of dogs. In each study, dogs were treated with dipping solutions of pesticides. In both studies, the investigators would pet the treated animal in a specified area with cotton gloves. In one study submitted to Health Canada, the animals flanks were stroked. The area was defined by multiplying the length of the animal's flank by the length of the investigators hand. Ten animals were used (beagles and hounds). In a study conducted by Boone et al. (1999) the upper back, behind the neck was the defined area (4" x 10" - approximately 258 cm^2). In the study submitted to Health Canada, the animals were stroked firmly with cotton gloves. In the study conducted by Boone, over 40 dogs of varying sizes and coat lengths were vigorously rubbed in the marked area for a period of 5 minutes by individuals wearing cotton gloves. The Boone data shown in Table 5 were presented at the March 31 and April 1, 1998 "Proceedings for the Science to Achieve Results" (STAR) program workshop on Children's Exposure to Pesticides and as a poster at the 1999 Society of Toxicology meeting in New Orleans, LA on March 14-18, Boone et al. (1999).

The average and range concentrations were calculated by dividing the known surface area stroked, by the amount of pesticide extracted from the gloves. The animals were treated four times with two to three weeks between treatments. The glove values represent measurements following the fourth dip.

Table 5. Transferable Residues from Dog Fur

Time after fourth dip	μg on Glove/5 minutes	Range (μg)	Average - ($\mu g/cm^2$)	Range - ($\mu g/cm^2$)
Chlorpyrifos, no shampooing between treatments				
4 hours	1,229 ±158	157 - 6,999	4.8	0.6 - 27.1
7 days	332 ± 68	4 - 2,584	1.3	0.015 - 10
14 days	215 ± 61	1 - 2,472	0.8	0.004 - 10
21 days	139 ± 43	1 - 1,469	0.5	0.004 - 5.7
Chlorpyrifos, shampooing between treatments				
4 hours	662 ± 81	17 - 2,674	2.6	0.07 - 10.4
7 days	83 ± 16	9 - 479	0.3	0.04 - 1.9
14 days	30 ± 6	1 - 190	0.12	0.004 - 0.7
21 days	19 ± 4	1 - 139	0.07	0.004 - 0.5
Phosmet, no shampooing between treatments				
4 hours	2,841 ± 339	79 - 11,620	11	0.3 - 45
1 day	1,103 ± 157	57 - 6,066	4.3	0.2 - 23.5
3 days	602 ± 110	1 - 3,405	2.3	0.004 - 13.2
7 days	164 ± 29	1 - 895	0.6	0.004 - 3.5
14 days	48 ± 13	0.3 - 386	0.2	0.001 - 1.5

In the poster session, the authors suggest a postapplication exposure model consisting of a child playing with a dog for 5 minutes touching an area of 80 in^2 area (twice the surface area sampled in the study). For an example of this exposure estimate a chlorpyrifos residue of 4.8 μg/cm^2 was selected from Table 5.

A transferable residue value of 4.8 μg/cm^2 chlorpyrifos results in a potential dermal exposure of approximately 2.5 mg/day

where 80 in^2 or 516 cm^2 4.8 μg/cm^2 = 2,477 μg/day or 2.5 mg/day.

The authors cautioned that the act of a child petting a dog may not be similar to the vigorous rubbing method that investigators were trained to do. They also speculated the child may not play with the dog for the first day. They suggest that the five minute data is an appropriate surrogate for a much longer duration. This is due to the sample technique of continuous petting with firm pressure.

In the study that was submitted to Health Canada to support a registration of a pet dip product, transferable fur residue measurements were taken from dogs treated with a microencapsulated formulation of chlorpyrifos. In the study, dogs were shampooed, then dipped. Residue measurements were taken 2, 4, 12 and 14 hours after dipping. The submission was subsequently withdrawn.

A mass balance approach was used to determine the amount of active ingredient applied to each dog. The amount of chlorpyrifos on each dog was first calculated by measuring the concentration of the dip [2 fl.oz product (2.5%)/gallon or 59 mL/3785 mL] which was 385 μg/mL. Then, the amount retained on the dog was calculated by measuring the remaining dip emulsion collected in the tub where dipping was performed.   Finally, the dip was applied to the measured areas of the dog and thus, a deposition was estimated. The proprietary data suggest transferable residues in the 0.8 to 5% range with an average of 2.8%.

Boone et al, 1999, did not estimate deposition. For comparison purposes OPP made estimates based on the percent active ingredients used in the proprietary study and those used by Boone. In Table 5 presented above, the animals were treated with a similar chlorpyrifos application rate (2 fluid ounces 3.8% chlorpyrifos per gallon) as the proprietary study. Phosmet was applied at one fluid ounce of 11.6% active ingredient per gallon. Estimates of the chlorpyrifos and phosmet concentrations in the study presented in Table 5 are approximately 600 μg/mL and 900 μg/mL respectively.

The SOPs rely on an algorithm available in the Wildlife Exposure Factors Handbook (12.3   body wt$^{0.65}$ (grams)) to estimate an animals surface area. Accordingly, a German shepherd from Boone et al., (1999) weighing 35 kg would have a surface area of 11,055 cm^2. In the proprietary study, 72.3 mL was used to treat a surface area of 1426 cm^2. Therefore, 560 mL will treat a surface area of 11,055 cm^2. At an estimated concentration rate of 600 μg/mL, the application rate is 3.36 x 10^5 μg. This amount divided by the surface area of 11,055 cm^2 yields a deposition rate of 30 μg/cm^2. Based on this estimated deposition, an average transferable residue value of 4.8 μg/cm^2 (presented in Table 5), is 16% transferable. This is considerably higher than the study that was submitted to Health Canada. This suggests the Agency should continue assuming 20% of the residues applied to the dog are transferable.

There are several limitations to comparing the transferable residue results from the two studies discussed above.

1) The difference between the vigorous rubbing technique used by Boone et al. (1999) and the stroking method used in the proprietary study submitted to Health Canada.

2) In the Boone study the area wiped was the withers (topline behind the neck between the shoulder blades). This was the area receiving most of the dip applied to the dog.

3) There was also a greater variety of dogs (size and fur length) in Boone et al. (1999) than the study submitted to Health Canada (hounds and beagles).

4) Different formulations were used. In Boone et al., liquids were used. In the proprietary study a microencapsulated formulation was used.

5) The number of applications. The dogs in the Boone study, were treated four times and were the pets of volunteers participating in the study. The animals in the study submitted to Health Canada were treated once.

Modeling exposure to residues on pets is difficult given the potential variability of the types of animals treated (coat length). In addition several issues need to be considered:

- ❏ The use of gloves as surrogates for skin. Cotton gloves tend to overestimate exposure (Fenske et al., 1998,; Smith et al., 1991; Brouwer et al., 1998);

❑ The intermittent relationship of the petting event. The potential loss of residues when a person touches other surfaces such as clothing, soil or other fabrics after petting the animal. (Reed et al., 1999, Zartarian et al., 1997, 1998; Freeman et al. NHEXAS un published).

Since understanding the amount of residues on a child's hands has a direct influence on the amount of residues available for non-dietary ingestion, the following issues need to be considered:

❑ The amount of residue on the skin that can be removed by saliva. This may be influenced by the number of touches and residence time on the skin.

❑ The portion of the hand that is inserted into the mouth (Kissel et al., 1998, SAP Aggregate Report, April, 1999);

❑ The portion of the hand that contacts the animal [although this may not be as critical with softer surfaces such as pet fur (Brouwer et al., 1998; Kissel et al., 1998; SAP Aggregate Report, April 1998].

Finally, it is not clear how these data compare to new generation products applied as spot treatments to the dog's skin which distribute the pesticide throughout the body via the oils secreted by the sebaceous glands.

The current SOP attempts to address exposure to pet fur residues in two ways. One is to estimate the amount of pesticide applied to the dog (based on weight of the animal). Then we assume 20% of the pesticide applied to the fur is available on the pet, and that 10 percent of those residues are transferred to the human. An exposure assessment for contact with German shepherd discussed above when using the SOPs is:

336 mg applied to the animal   20%   10% = 6.72 mg/day

The SOP addressing non-dietary ingestion from hand-to-mouth exposure relies on a similar algorithm. The hand-to-mouth algorithm replaces the 10% transfer with the division of an animals surface area. This provides a value expressed as $\mu g/cm^2$. The dislodgeable residues from our German shepherd example are estimated as follows:

336 mg applied to the animal   20% ÷ 11,055 = 0.006 mg/cm^2 or 6 $\mu g/cm^2$.

This value is similar to the average chlorpyrifos value measured four hours after dipping as presented in Table 5. The SOPs use this transferable residue value and assumes a one to one transfer to the skin of surface area representing both hands. This assumption suggests equilibrium is established between the transferable residues on the pet and the residues on the hand after contact. The concept of equilibrium is discussed in Issue 2, and may have utility in constructing scenarios such as a child hugging a dog or a child sleeping with a dog. This is possible by assuming, direct transfer of transferable residue estimates to human surface area values. Incorporation of clothing penetration rates may also be possible.

For example:

The Exposure Factors Handbook suggests that a clothing scenario of short pants, short-sleeved shirt and shoes leaves 25% of the skin exposed and that a two to 3 year old child has a surface area of ~6,000 cm^2. The area exposed is ~1,500 cm^2 and the area clothed is ~4,500 cm^2.

These areas can be reduced by half, based on the assumption that 50% of the surface is in contact (front half) with the fur during the hug. For this example, a clothing penetration of 50% is assumed.

$750\ cm^2\quad 6\ \mu g/cm^2 = 4{,}500\ \mu g$

$2250\ cm^2\quad 6\ \mu g/cm^2\quad 50\% = 7{,}500\ \mu g$

The sum of those exposures is 12 mg/day.

The Agency believes more research is needed in this area. However, the Agency believes that contined use of 20% transferability of deposited residues is protective. This is based on: 1) 20% transferablity over predicts residues when measured using cotton gloves combined with the sampling method of stroking an animal's flank and 2) 20% transferability approaches the mean values measured using cotton gloves combined with vigorous rubbing. In addition, the Agency wishes to explore potential scenarios such as the hug and looks forward to suggestions regarding this approach from the Panel.

2 Issue 2: Use of Choreographed Activities as Surrogates for Estimating Children's Dermal Exposure

As noted earlier, the two primary factors in determining human exposure to pesticides in residential and similar settings are: 1) the amount of pesticide residue available for human uptake, and 2) the types and durations of human activities that result in contact with and uptake of such pesticide residues. Chapter 1 discussed a variety of aspects of the issues relating to the estimation of the level of residue available for uptake. This chapter addresses OPP's approach to the characterization and measurement of human activities that would result in dermal exposure to residues on pesticide-treated surfaces, both outdoors (e.g., turf) and indoors (e.g., carpet). It particularly focuses on whether OPP's current models and assumptions are appropriately conservative for estimating the dermal exposure of children.

All of the current algorithms for estimating dermal exposure in residential and similar settings use a "transfer coefficient" to characterize quantitatively the impact that human activities have on exposure. Obviously, there are many different types of activity that potentially involve contact with pesticide-treated surfaces and subsequent uptake of residues by humans. Moreover, these activities differ in ways which could significantly affect exposure, e.g., in the frequency of specific behaviors that involve contact with pesticide treated surfaces. For example, contrast cutting the lawn with sitting in the yard while reading a book. Mowing the grass would involve far more movement than sitting, and it would probably lead to contact with a greater percentage of the lawn area than sitting still. Accordingly, lawn mowing would have a higher transfer coefficient than sitting.

Because there are so many different types of activities involving potential dermal exposure to pesticides in residential and similar settings and because its Residential SOPs are designed as screening devices, OPP has chosen to focus on and derive transfer coefficients for those activities which are likely to result in relatively higher levels of exposure. OPP recognizes that young children are the population subgroup having activity patterns – e.g. crawling, rolling on the floor or grass – that are most likely to produce the highest frequency and extent of contact with pesticide treated surfaces.

With the above considerations in mind, OPP has decided to employ in the SOPs a "transfer coefficient" based on a study using a defined activity pattern that, it believes, reflects children's potential exposures. The activity is a scripted program of low-impact aerobics (Jazzercise) performed by adults in a room with pesticide-treated carpeting. (For both ethical and practical reasons, researchers and regulators are reluctant to use children in studies to establish transfer coefficients.) The physical movements are intended to simulate the behavior of young children and involve extensive contact of all parts of the body (feet, legs, front torso, back, hands, arms, and shoulders) with the carpeted surface. Section 2.1.3. describes the methodology and the results of the studies on which OPP bases the “Jazzercise transfer coefficient” for dermal exposure in its current Residential SOPs.

Although OPP believes that its “Jazzercise transfer coefficient” is appropriately conservative for children, many commenters (including the SAP) have questioned that conclusion. The comments point out that children are not little adults and adults cannot mimic the activities of children. In addition, commenters have suggested that dermal absorption rates for children may be higher than for adults, and as a consequence the same external deposition rate (mg/kg b-wt) would produce a higher internal dose for children than for adults. They note that OPP does not have data to evaluate the potential for differential skin permeability.

OPP has attempted to evaluate these concerns about the “Jazzercise transfer coefficient” using a variety of data. First, OPP has compared the estimates of exposure generated by its current Residential SOPs to measurements of exposure in adults derived from biomonitoring. These comparisons show that the Residential SOPs consistently produce a higher estimate of exposure than the exposure calculated through biomonitoring. OPP has also examined data collected in studies of adults and children from the general population, from farming areas, and from families living in homes that were illegally treated with the organophosphate insecticide, methyl parathion. While these data are limited, they also indicate that actual exposures are lower than the values estimated by OPP’s residential SOPs. Importantly, the data also provide insight on the relative magnitude of exposure of adults and children. These values will prove to be useful when estimating intermediate-term (7 days to several months) and chronic aggregate exposures.

Second, OPP has examined available scientific literature on the relative absorption of pesticides through skin of adults and the young. The literature do not appear to support the conclusion that there is a significant age-related difference in dermal permeability. See sec. 2.1.5. OPP also notes that in some cases when data are not available, OPP assumes that 100% of the amount of the pesticide that actually reaches the skin is absorbed. Thus, even if there were a difference in skin permeability, it would not be relevant when the SOPs’ default assumption about dermal absorption is used.

In conclusion, based on this analysis (presented more fully below), OPP concludes that its current Residential SOPs using the “Jazzercise transfer coefficient” are not likely to underestimate dermal exposure to either adults or children who come in contact with pesticide-treated surfaces in residential and similar settings.

Due to ethical and logistical concerns, there is a reluctance in the regulated community and by other researchers to use children in post application exposure monitoring studies. As a result, most post application exposure estimates are derived from models using a combination of environmental measurements and assumptions (Gurunathan et al., 1998, Berteau, 1989) or are based on studies utilizing adults performing choreographed activities (Ross et al., 1990). These choreographed activities include adults performing child-like activities such as crawling (Vacarro 1996), or the use of a low-impact aerobic routine (Jazzercise™). Dermal exposure, measured while adults are Jazzercising, is the basis for the transfer coefficient used in the residential SOPs to estimate post application exposure following treatments to lawns and indoor surfaces.

To date, children have not been used in studies where there is purposeful exposure to recently applied pesticides, as is done for adults. Children are being monitored in real world situations where pesticides may have been used (NHEXAS and Esteban et al., 1995). These studies, while not necessarily addressing acute exposure, can provide information regarding the magnitude of our estimates and clues regarding intermediate and chronic aggregate exposures.

2.1 Estimating Dermal Exposures

2.1.1 Transfer Coefficients

Transfer factors/coefficients were first used to estimate post application dermal exposure of farm workers. It is well recognized that post application exposures vary according to the type of task an individual performs and based on the physical parameters of the crop, such as crop height and canopy density, as well as ergonomic factors (stooping to pick strawberries or reaching into fully grown canopies in vineyards to harvest grapes).

Table 6. Example Harvest Activities and Corresponding Transfer Coefficients (measured on the hands and dosimeters worn on the outside of clothing): Krieger et al.: Assessing Human Exposures to Pesticides, Reviews of Environmental contamination and Toxicology, Vol. 128, 1992.

Work Task	Potential Dermal Transfer Coefficient Range (cm^2/hr)	Primary Dermal Contact	Example Macro Activity
sort/select	50 to 800	hand	Mechanical harvest (garlic, tomatoes)
reach/pick	500 to 8,000	arm/hand	Strawberry harvest
search/reach/pick	4,000 to 30,000	upper body/hand	Tree fruit harvest
expose/search/reach/pick	20,000 to 150,000	whole body/hand	Raisin and wine grape harvest

The term transfer coefficient is used when the element of time is considered. Transfer coefficients are calculated as follows:

Transfer coefficient (cm^2/hr) = hourly exposure (μg/hr) ÷ residues ($\mu g/cm^2$)

Transfer coefficients can be used to calculate potential dermal exposure (mg/kg/day) to varying levels of pesticide residues by use of the following:

Residue ($\mu g/cm^2$)   Trans. Co. (cm^2/hr)   duration (hours) ÷ body weight (kg)

Due to the variability of individual activites in the non-occupational, “residential” environment, researchers have struggled with identifying activities that are representative of potential exposure to pesticides applied in and around the home. In particular, children’s exposure to pesticides. Unfortunately, to date, ORD and other researchers have not concurred on a common activity that can be captured in guideline studies submitted by registrants to defend pesticide products.

2.1.2 Human Activity Patterns

Human activity patterns are broadly classified as macro activity patterns and micro activity patterns. Macro human activity patterns are broad categories of activities where individuals spend their time (at work or school, commuting, an afternoon of gardening). Micro human activity patterns are the numbers and durations of contacts with treated surfaces leading to dermal exposure for a given micro activity (the frequency and duration of contacts with each hand and knee while a child crawls). Understanding the frequency and duration of hand contact with contaminated surfaces is essential to understanding the potential for non-dietary ingestion from hand-to-mouth behavior. Estimating potential concentrations of pesticides on a child’s hands from crawling activity is the subject of current modeling activities at the Agency’s Office of Research and Development (ORD). ORD is currently working on the Stochastic Human Exposure and Dose Simulation (SHEDS) model for pesticides. A presentation of this model will be made during this session of the SAP.

Since there are two broad groups of activity patterns, it follows that there are two approaches to address human activity exposure: the macro activity approach and the micro activity approach.

In the **macro activity approach**, dermal and non-dietary exposures are modeled using empirically-derived transfer coefficients to lump the mass transfer associated with a series of contacts. This macro activity approach has been used extensively to assess occupational exposure of agricultural workers, and has also been applied in a residential setting for adults performing choreographed reproducible activities. In this approach, the dermal and non-dietary exposure associated with a given <u>macro activity</u> (e.g., playing in the yard) is measured and used to develop an activity-specific transfer coefficient (Cohen et al., 1998).

In the **micro activity approach**, dermal and non-dietary exposures are explicitly modeled as a series of discrete transfers resulting from each contact with a contaminated surface. In this approach, the dermal or non-dietary exposure associated with a given <u>micro activity</u> or event (e.g., each time a child touches a given object) is quantified, as is the number of times during a day that each micro activity is performed (Cohen et al., 1998).

Surveys, such as the National Human Activity Pattern Survey (NHAPS) are useful for identifying macro activity patterns. NHAPS and data from the California Air Board (CARB) are available in EPA's Exposure Factors Handbook (EPA 600/P-95/002). These macro activity data are useful for conducting inhalation exposure assessments by matching air concentrations of pollutants with well established respiratory levels based on an individual's level of exertion, and the activity duration. Respiratory levels will differ from activity to activity such as watching television or active play on lawns.

Specific activities (frequency and duration of dermal exposure events) related to dermal exposure are impossible to recall through standard survey tools such as interviews or diaries. Trying to estimate the number of times you touched a specific surface during the day demonstrates the complexity trying to capture the level of detail needed to define the dermal micro activity for an exposure assessment. Trying to quantify the number of times children touch a treated surface and then their mouth is difficult using traditional diaries or other survey tools such as interviews and questionnaires.

To measure discrete micro activity events, researchers have relied on direct observation, either live or with video tape. Live observation relies on the expertise of the individual at the time of the event, with care being taken not to influence the behavior of the child. A disadvantage of live observation is that an observer may be distracted and therefore, an activity can be missed. Video taping techniques being developed by researchers at EPA's ORD and universities such as Stanford (Zartarian et al., 199, 1997) and Rutgers (Reed et al., 1998) are being used by industry (Outdoor Residential Exposure Task Force-ORETF) and ORD to identify activity patterns to monitor and for use in future model development. A distinct advantage with the video tape technology is that the video tapes can be viewed repeatedly and in some cases, programs have been developed to capture the time and frequency of micro activity events which can then be presented graphically. It should be noted, that the video tape methods are not standardized and it is recognized that exposure estimated from these data will have to be validated with exposure studies. Until these micro activities can be quantified in a meaningful manner, and studies are developed to monitor those types of exposures, Agency assessors will continue to rely on dermal exposure estimates using the macro activity approach. Both ORD and the ORETF are currently comparing the number and frequencies of contacts from video tapes of children to the frequency and duration of a choreographed macro activity, Jazzercise™.

2.1.3 Dermal Exposure, Macro Activity Pattern - Jazzercise™

Jazzercise™, as an exposure monitoring tool, was purposefully designed to achieve maximum contact of the entire body with a surface (grass or floor), using low impact aerobic movements. All body surfaces (dorsal, ventral and lateral) contact the treated surface. Standardized movements are timed to the beat of music for a period of 20 minutes (the time period includes entering and exiting the treatment area). The use of this technique, to standardize adult and child exposure, was developed by Ross et al., (1990). It was the first method used to measure indoor residential post application exposure after efforts by Berteau et al. (1989) to model a child's exposure caused alarm. The method was later adopted by investigators interested in estimating exposure of active children playing on treated lawns and indoor surfaces.

The cohorts in the first Jazzercise studies conducted by Ross et al., 1990. wore the following dosimeters:

- ❑ Footless tights (54% cotton, 36% polyester, and 10% Spandex);
- ❑ Long sleeved tee shirt (100% cotton);
- ❑ Thin gloves (100% cotton);
- ❑ White "athletic" socks (100% cotton) (Ross et al., 1990).

The distribution of pesticide on various body parts represented by the above dosimeters are presented in table 6:

Table 7. Mean Percent Total Chlorpyrifos and d-trans Allethrin Residue Accumulated on Dosimeter Clothing (Chlorpyrifos in bold type)

Time post venting	Tights	Shirt	Socks	Gloves
0 hours	**33.6 ± 16.1**	**27.6 ± 17.6**	**24.5 ± 10.1**	**14.3 ± 8.4**
	30.0 ± 13.1	26.0 ± 15.7	25.9 ± 12.1	18.2 ± 10.2
6 hours	**35.0 ± 24.7**	**25.0 ± 15.2**	**25.9 ± 16.9**	**14.2 ± 10.1**
	30.4 ± 19.0	25.1 ± 12.4	26.2 ± 17.2	18.5 ± 13.2
12.5 hours	**33.9 ± 10.5**	**26.0 ± 6.2**	**28.0 ± 7.9**	**12.2 ± 4.4**
	31.9 ± 8.3	28.6 ± 5.5	23.7 ± 10.6	15.9 ± 6.9
Grand Mean	**34.2 ± 17.1**	**26.2 ± 13.0**	**26.1 ± 11.6**	**13.6 ± 7.6**
	30.8 ± 13.5	26.6 ± 11.2	25.3 ± 13.3	17.5 ± 0.1

The amount of pesticide on each dosimeter clothing was divided by the body surface area that piece of clothing represented; i.e., shirt's values were divided by 7440 cm^2, tights by 7220 cm^2, gloves by 1310 cm^2 and socks by 1220 cm^2 (These body surface areas are based on EPA Subdivision U, 1987 [current designation 875-Group A]) to arrive at a level of $\mu g/cm^2$ in each body part.

Ross et al., suggest that the relative distribution of the total dose, on the body surface, can be used to suggest more realistic estimates of individuals wearing a shirt, pants and socks which may reduce potential exposure by more than 70%. This method can also be used to establish a quantitative estimate of exposure to the hands and estimates of their contribution to potential non-dietary exposure. The current SOP does not consider any reduction in potential exposure due to the type of clothing being worn (including shoes).

Non-dietary ingestion estimates from hand-to-mouth exposure is currently considered separately. Thus, EPA has been criticized for double counting the route of exposure from pesticide residues on the hands by 1) assuming 100% of the residues on the hands are available for dermal absorption and 2) assuming 100% of the residues on the hands are available for non-dietary ingestion. Furthermore, the SOPs do not consider removal of the pesticide on the skin by washing (e.g. showering, bathing and hand washing). Neglecting this mechanism may lead to overestimates of exposure. OPP estimates non-dietary ingestion of pesticides on hands by using a micro-activity approach. This issue is discussed under Issue 3 in Chapter 3.

From Ross et al. (1990), identified the distribution of chlorpyrifos on various parts of the body after volunteers performed the Jazzercise™ routine following the use of an indoor fogger. The distirbutions are presented below:

- ❑ Upper torso - represents 43 percent of the body and received 26±13 percent of total exposure;
- ❑ Lower torso - represents 42 percent of the body and received 34±17 percent of total exposure;
- ❑ Hands - represents 8 percent of the body and received 14±8 of total exposure;
- ❑ Feet - represents 7 percent of the body and received 26±12 of total exposure.

Cloth dosimeters such as those used in Ross et al., have the potential to overestimate dermal exposure (Brouwer et al., 1998, Fenske et al., 1998, Smith et al., 1991) because they have more theoretical loading capacity than relatively non-porous skin, especially for high contact areas (i.e., hands, knees and feet). The SOPs use transfer coefficients derived from these measurements as estimates of directs contact to skin. Clothing penetration values are not used.

Transfer coefficients derived from dermal exposure monitoring studies are, strongly influenced by the amount of residues available for transfer. In the residential SOPs, the transfer factor used for the lawn and indoor surface post application exposures was from a study using Jazzercise™ (on carpeted surface). In that study concurrent transferable residue measurements were made with the cloth roller representing a rate of transfer less than 5% of deposited residues.

Tables 8 and 9 present the data which form the basis for both the current indoor and outdoor (lawn) post application dermal exposure scenarios. The study measured transferable residues with the cloth roller concurrently with a dermal exposure study (Jazzercise™) in which dermal exposure was measured using the same types of dosimeters that were used in Ross et al. (1990). The transferable residue measurements are presented in Table 7. The dermal exposure measurements using Jazzercise™ are presented in Table 8.

Table 8. Total and Transferable Residues of Propetamphos on the Carpet and Air Residues Following Carpet Treatment. California Environmental Protection Agency, HS-1731, August 9, 1996 (Formoli, 1996).

Post application reentry (hours)	Total carpet residue on deposition cloths (μg/cm^2)	Transferable residue (cloth roller) (μg/cm^2)	Transfer to cloth roller (%)	Air residue at 6 inches (μg/m^3)	Air residue at 36 inches (μg/m^3)
3	16.3	0.079	0.49	6.05	8.41
6	21.1	0.074	0.35	6.36	6.88
9	17.2	0.112	0.65	9.83	12.90
Average	18.2	**0.088**	0.50	7.41	9.73

Table 9. Dermal Exposure of Adult Volunteers Performing Jazzercise on Carpets Treated with Propetamphos wearing cotton dosimeters including gloves and socks (Formoli, 1996).

Reentry - hours after treatment	Duration of Exposure (hour)	Head exposure (μg/person)	Body exposure (μg/person)	Hand exposure (μg/person)	Dermal exposure (μg/person/ 0.33 hr)	Dermal exposure (μg/person/ 1 hr)
3	0.308	1.3	979	162	1,143	3,711
6	0.275	1.2	768	140	909	3,305
9	0.308	1.0	1,188	183	1,371	4,451
Average	0.297	1.2	978	162	1,141	**3,822**
% of total		0.10	85.7	14.2	100	

The transfer coefficient was calculated using the average transferable residue measurement presented in Table 8 and the average dermal exposure measurement presented in Table 9 (**in bold**) as follows:

$$\text{Transfer coefficient (cm}^2\text{/hr)} = \frac{\text{Dermal exposure (per hr) } \mathbf{3{,}822\ \mu g/hr}}{\text{Transferable residue } \mathbf{0.088\ \mu g/cm^2}}$$

$$= 43{,}431 \text{ cm}^2\text{/hr}$$

The average transferable residue measurement 0.088 μg/cm^2 represents

0.5% of the deposition rate.

It is important to note the critical relationship between the measurement of transferable residue and the transfer coefficient. If, the investigators selected a method that resulted in transferable residues of 50 percent (as currently used in the Residential SOP's), the residues would be (18.2 μg/cm^2 50%) = 9.1 μg/cm^2.

And the resulting transfer coefficient would be:

Transfer coefficient (cm^2/hr) = <u>Dermal exposure (per hr) **3,822 μg/hr**</u>
Transferable residue **9.1 μg/cm^2**

= 420 cm^2/hr

Care must be taken when selecting transfer coefficients and when making assumptions regarding transferable residues. The following example shows how the SOPs currently overestimate exposure by assuming high transferable residues and using a transfer coefficient derived from a method having lower sensitivity.

0.088 μg/cm^2 43431 cm^2/hr = 3,822 μg/hour using transferable residue obtained from the cloth roller;

9.1 μg/cm^2 43431 cm^2/hr = 395,222 μg/hour using transferable residue values from the SOP (50%).

2.1.4 Macro Activity Pattern - Adults Performing Choreographed "children's activities"

Data from a variety of other studies indicates that the combination of data and assumptions employed in the current and proposed SOPs are very conservative and likely to not underestimated exposure. Estimates of dermal exposure, using dermal transfer coefficients derived from Jazzercise™ are comparable to measurements of internal doses of volunteers exposed to pesticide treated areas for longer durations.

Biological monitoring of adults performing various activities on turf was evaluated 4 hours after a broadcast application of chlorpyrifos (4 lb/active ingredient per acre) was made. Five different activities were conducted by the adult volunteers that include picnicking on a blanket (60 minutes), playing frisbee (60 minutes), sunbathing on a blanket (30 minutes), weeding to simulate crawling (30 minutes), playing touch football (60 minutes) in which intimate contact with the treated surface was reportedly apparent. All volunteers were barefooted and dressed in t-shirts and running shorts. The volunteers wore shoes during the touch football segment. Urine analysis of 3,5,6-trichloropyridinol (TCPY) indicated a mean chlorpyrifos dosage of **7.07μg/kg** and a standard deviation of 2.65. These internal dose values would account for the contribution of both the dermal and inhalation pathways. These data were also submitted to the Agency to support chlorpyrifos as part of the reregistration process (MRID 430135-01) and were reported in the published literature (Vacarro et al. 1996).

Transfer coefficients derived from Jazzercise™ can be used to compare an approach to estimate post application exposure to turfgrass pesticides and the results of the Vacarro study. Consider the following exposure estimate using the following assumptions:

❑ Assume the 4 lb ai/acre rate used in the Vacarro study (4 lb ai/acre = 44.8 μg/cm^2);

❑ Assume a percent transferable residue rate of 2.5% from Ross et al., 1990, Table 2);

❑ the Jazzercise transfer coefficient in the current version of the SOP, for a duration of 20 minutes (the actual time of a Jazzercise study); and

❑ the use of the dermal absorption value for chlorpyrifos of 3% (EPA and Nolan et al., 1994).

$$44.8\ \mu g/cm^2 \times 2.5\% = 1.12\ \mu g/cm^2$$

$$1.12\ \mu g/cm^2 \times 43{,}431\ cm^2/hr \times 0.33\ hr \div 70\ kg\ \text{(adult body wt.)} \times 3\%\ \text{d.a.} = 6.9\ \mu g/kg$$

The proposed SOP, use of 5% transferable residues, would result in an exposure estimate of 13.8 μg/kg.

The above calculation does not include inhalation exposure which was assumed to contribute to the dose measured in Vacarro. Assuming 20% transferable residue rate, currently in the SOP this dermal exposure estimate would be ~ 55 μg/kg. If we assume someone is Jazzercising for two hours on a lawn as current SOP requires, the dermal estimate would be ~ 330 μg/kg.

2.1.5 Macro Activity Pattern - Choreographed “adult activities”

A similar comparison may be performed with data from Harris and Solomon, 1992. Urinary metabolites of volunteers were measured after they performed activites on treated turf (0.87 lb ai/acre 2,4-D). In that study, 10 adult volunteers were exposed to treated turf one hour after application for a duration of one hour while alternating every 5 minutes the activities-walking, sitting or lying. An arithmetic mean of 8.45 mg/m^2 (0.845 $\mu g/cm^2$) was measured using the shoe method of Thompson et al., (1984) to sample transferable residues. This value represents approximately 9 percent (8.7) of the deposited residues. Five adult volunteers wore long pants, short-sleeved shirts, socks and enclosed footwear and five volunteers wore short pants, short-sleeved shirts, and were barefoot. Urinary 2,4-D was found in only 3 volunteers (all of whom wore short pants, short-sleeved shirts and were barefoot: one individual reportedly took his shirt off). A transferred dermal uptake of 227.6 micrograms/hour/8.45 milligrams per square meter of transferable residues was calculated.

A transfer coefficient can be calculated by dividing the internal dose by the dermal absorption rate of 5.8% as suggested by Feldman and Maibach (1974) and the transferable residues expressed as $\mu g/cm^2$.

$$227.6\ \mu g \text{ per hour} \div 5.8\% \div 0.845\ \mu g/cm2 = 4600\ cm^2/hr$$

For comparison purposes, if we assume chlorpyrifos transferable residues were 8.7% of the applied rate (4 lb ai/a = 44.8 μg/cm2) as measured using the method of Thompson et al. (1984), a transferable residue rate approximately 4 $\mu g/cm^2$ (40 mg/M^2) can be assumed. If the same 3% dermal absorption rate for chlorpyrifos is used, the following dose can be estimated using the transfer coefficient discussed above

$$4\ \mu g/cm^2 \times 4600\ cm^2/hr \times 3\% \div 70\ kg = 7.9\ \mu g/kg/day$$

The Agency recognizes that more research needed to identify activity patterns that lead to post application exposure. It is also likely that exposures to residues on carpets will differ from exposures to residues on turf. What is notable however, is how well studies using Jazzercise™ compare to the available postapplication studies in which biological monitoring of adults performing choreographed activities was conducted.

In another study submitted to the Agency and reported by Vacarro et al. (1996), urinary metabolites were collected from adult volunteers performing choreographed activities following a broadcast application of chlorpyrifos to carpeted areas of two houses. Although this use is no longer supported the registrant, the study results are useful to compare proposed SOP refinements using the Jazzercise transfer factor from Ross et al., 1990. In this study, total deposition measurements of approximately 14 μg/cm^2 were measured. Adult males wearing bathing suits were exposed to the carpet for durations of four hours while playing with blocks (60 minutes), crawling on hands and knees (60 minutes) walking barefoot (60 minutes) lying on back (30 minutes) and abdomen (30 minutes). The mean chlorpyrifos dose estimated by urine analysis was 12.4 μg/kg.

In Ross et al. 1990, an average of 3609 μg/person for a 20 minute period (10817 μg/hr) was measured following a fogger use of chlorpyrifos (Transfer coefficient of 200,000 cm^2/hr). The total deposition in the study was 2.4 μg/cm^2. Transferable residues measured using the cloth roller were 0.055 μg/cm^2 (~2.3% transferable). The total deposition measurement in Ross et al. (1990) is approximately 5.8 times lower than the indoor study using biological monitoring of adults performing choreographed activities of children (14 μg/cm^2). Therefore:

---

14 μg/cm^2 2.3% transferable residue 200,000 cm^2/hr 0.33 hr ÷ 70 kg 3% dermal absorption = 9.1 μg/kg

---

The term Jazzercise™ conjures any number of images of those unfamiliar with the purpose and results of dermal exposure studies relying on this routine. The this routine was chosen, in the absence of any agreed upon activity pattern, to estimate the potential for exposure of young children playing on a treated surface such as a carpet. Despite the short duration, the routine coupled with absorptive clothing serving as a substitute for skin compares very well to activites conducted under similar circumstances in which internal dose was measured via analysis of urinary metabolites. It is true that adults cannot physically accomplish certain activities of young children. Because adults have greater weights the added pressure that may be applied against treated surfaces may in some measure limit those potential differences.

For the SOPs addressing postapplication to indoor and outdoor broadcast applications the Agency recommends, the continued use of transfer coefficients derived from Jazzercise™

Current transfer coefficients from Jazzercise™ studies are extrapolated from studies lasting a duration of twenty minutes.

Exposure estimates using these 20 minute durations are comparable to exposure studies of longer duration in which internal dose was estimated using biological monitoring.

The studies in which internal doses were measured using biological monitoring were conducted for durations of 4 hours (Vacarro) and 1 hour (Harris and Solomon).

Due to the limited durations of the studies, the Agency proposes the use of the transfer coefficient currently in the SOPs to represent longer exposure durations when making exposure estimates. For example, 4 hours of typical activities and one hour of extreme activity.

The transfer coefficient of 43,000 cm^2/hr is proposed to be used when addressing postapplication exposure to pesticides applied to lawns and other turf areas.

The use of the transfer coefficient of 43,000 cm^2/hr when used in the SOPs for durations of 20 minutes did not compare favorably with internal doses measured using biological monitoring representing 4 hours of activity indoors. Using the transfer coefficient from Ross et al., 1990, of 200,000 cm^2/hr when adjusted for deposition did.

Therefore, for indoor surfaces OPP recommends increasing the transfer coefficient for indoor surfaces to 200,000 cm^2/hr

2.1.6 Differences in Skin Permeability of Children and Adults

The differences in permeability between children's skin and adult skin was not considered in the comparisons presented above. The influence of the age of skin with respect to dermal absorption is discussed in "Dermal Exposure Assessment: Principles and Applications" (EPA/600/8-9/011F, January 1992). Under the section 2.3.1.2 *Age of the*

Skin: "Infants and children represent a population at high risk for the toxic effects of environmental pollutants because of, among other reasons, their immature detoxification pathways and rapidly developing nervous systems. Infants and children are also at increased risk for dermal exposure to toxic compounds because of their greater surface-to-volume ratio. Reports of toxic effects occurring in infants after the topical application of various drugs or pharmaceutical agents are not uncommon in the literature. These toxic effects, however are most likely the result of the increased surface-to-volume ratio in infants resulting in greater total absorption of the compound, rather than to the increased permeability of the skin of infants relative to adults. Full term infants have been shown to have a completely functional stratum corneum with excellent barrier properties." In addition the document asserts that "dermal permeability remains relatively invariant in humans as a function of age."

Shah et al. (1987) compared the penetration of 14 pesticides through the skin of young and adult rats. "*In vivo* percutaneous absorption of 14 pesticides was studied in young (33-d-old) and adult (82-d-old) female Fischer 344 rats, at three different dose levels. Carbon-14-labeled pesticides in acetone were applied to previously clipped middorsal skin. The treatment area was 2-3% of the body surface area. Penetration of the pesticides during a 72-h period ranged from approximately 1-90%, depending on compound, dose, and age of animal. No clear age-related pattern of dermal absorption among compounds was found. Only chlordecone, folpet, and permethrin did not show significant age-dependent differences in skin penetration. Atrazine, carbaryl, chlorpyrifos, and hexachloro-biphenyl had greater absorption in the young, while carbofuran, captan, dinoseb, DSMA, MSMA, nicotine, and parathion displayed greater absorption in the adult."

In Shah et al. (1987), the medium rate and high rate of chlorpyrifos were 23% and 53% greater in the young than adult. Absorption in these animals was approximately 90 percent. Based on a personal conversation with the author, the high rate of penetration may have been influenced by the acetone carrier.

2.1.7 Estimates of Environmental Exposure to General Populations

OPP considers available health surveillance data and available biological monitoring of other populations to provide a reality check on our modeled exposure estimates. Measurements of dose in the general population are useful with respect to noting the magnitude of exposure of the individuals being monitored. Unfortunately, the nature and source of pesticide residues in those individual situations cannot be known. Therefore, there utility for estimates of acute exposure are limited. These data can provide insight to future estimates of chronic and intermediate-term aggregate exposures.

Urine analysis of approximately 1,000 adults was conducted by the National Center for Health Statistics from human subjects participating in the Third National Health and Nutrition Examination Survey (NHANES III), Hill et al. (1995). As stated in the introduction of Hill et al. (1995), " assessments of exposure from multiple sources and routes are better made by measuring pesticides and their metabolites in human specimens because these measurements more nearly reflect total exposure from all routes of Exposure (Needham, 1994)." The metabolite TCP, a biomarker for a the widely used pesticide chlorpyrifos, was identified in 82 percent of the 1,000 adults monitored.

At the 1998, ISEE/ISEA Meetings in Boston, MA, preliminary results from the National Human Exposure Assessment Survey (NHEXAS) were presented. The presentation included a subset of NHEXAS, referred to as the Minnesota study. This study was designed to:

1) Document complex exposure patterns involving multiple acute exposure and exposures to chemical mixtures for school children in two poor, racially diverse neighborhoods in Minneapolis.

2) Examine temporal variability by monitoring complex exposures for a two year period.

3) Evaluate the relationship between measured exposures and delivered dose using biological markers of exposure in blood and urine. Methods include:

   - ❏ Conducting video analysis of 19 children ages 3 to 12
   - ❏ Evaluating environmental residue concentrations
   - ❏ Evaluating hand rinses
   - ❏ Conducting biological monitoring of 100 children

Selected values (3,5,6-trichloro-2-pyridinol (TCP) μg/g creatinine) from both studies are presented in the following table. The analyte TCP is a marker for Chlorpyrifos, a widely used chemical evaluated in both studies.

Table 10. μg/g Creatinine Concentrations from Selected Human Health Surveillance Data. Estimated doses of chlorpyrifos (μg/kg/day) are identified in bold

Metabolite	%> Detection Limit	MEAN (s.d.)	50th percentile	75th percentile	90th percentile
3,5,6-trichloro-2-pyridinol (TCP) **NHEXAS-Children**	92	9.1 (5.9)	7.7 **0.45#**	11.4 **0.66#**	17.3 **1#**
TCP **NHANES III** **Adults**	82	3.1 (NR)	2.2 **0.3#**	3.5 **0.49#**	6.3 **0.89#**

#μg TCP/g creatinine amt creatinine excreted/day (350.6 MW CHLOR/183.5 MW tcp÷ 70% (percent excreted)÷BW. Creatinine excretion rates of 0.32 grams and 3.647 grams creatinine per day were used for children and adults, respectively. The 100th percentile for NHANES III for chlorpyrifos is ~ 7 μg/kg/day.

To provide clues regarding the magnitude of exposure of adults and children, biological monitoring data addressing doses of individuals exposured to methyl parathion following illegal indoor applications. The Agency acknowledges that, as with any regulated commodity, misuse may be occurring, but absent information showing a widespread and commonly recognized practice of misuse, EPA will continue to regulate on label uses since the label is the premise for all legal application events. In a SAP meeting (March, 1998) addressing probabilistic exposure assessment, Assistant Administrator Lynn Goldman reiterated the Agency's policy to base risk assessments on allowable uses and to not base regulatory assessments on misuse. However, incident data are evaluated for risk assessments and will continue to play a role in Agency risk management decisions. As a follow-up to the recent, widely reported misuse of methyl parathion in homes, the following study was conducted:

Association Between Indoor Residential Contamination with Methyl Parathion and Urinary Para-Nitrophenol: Esteban E., Rubin C., Hill R., Olson D. and Pearce K.; Journal of Exposure Analysis and Environmental Epidemiology, Volume 6, No. 3, 1996, pp. 375-387.

Methyl parathion, an active ingredient registered for outdoor uses in agricultural situations was illegally applied to more than 200 homes in Lorain County, Ohio. Analysis measuring urinary para-nitrophenol as well as air and surface wipe measurements were taken in 64 of those homes.

Table 11. Air concentrations of MP in 39 houses (69.9%), Lorain County, Ohio

Day After Treatment	Median Measurement ($\mu g/m^3$)	($\mu g/m^3$) - range	Number of houses
<31	9	1 - 30	25
>31	ND	ND - 18	14

Table 12. Surface Wipe of MP (or p-np) in 59 houses (92.2%) (kitchen, splash board and wall under kitchen sink)

Day After Treatment	Median Measurement ($\mu g/cm^2$)	($\mu g/cm^2$) - range	Number of houses
<31	1.7	0.5 - 9.8	50
>31	0.43	ND - 12	9

Children younger than three years of age (n=6) had a greater median cp-np (creatinine corrected) concentration (147 μg/g) and lived in homes with a greater median maximum p-np surface wipe concentration (127 μg/ 100 cm^2) than did older residents (urinary cp-np concentration 25 μg/g and surface p-np concentration 51 μg/ 100 cm^2). There was no significant difference between the air concentrations in those homes.

Estimated Median Dose in Adults and Children Where:

μg Analyte/g creatinine   creatinine exc./ day   1.89 (ratio:MP/p-np) ÷ BW (kg)

Adults were assumed to excrete 3.647 grams creatinine per day and a 70 kg body weight. A 2.5 year old child was assumed to excrete 0.32 grams creatinine and weigh 15 kg. These body weight assumptions used in this example were assumed since we did not have access to the raw data.

The respective molecular weights of MP and p-np are 263 and 139. According to Cal-DPR and as presented in the Biological Exposure Index (TWA/PEL table), there is a 1:1 ratio between excreted p-np and MP.

Table 13. Estimated Doses of Adults and Children to Methyl Parathion

Adult or Children	Median cp-np (μg/g) creatinine	Median surface wipe (μg/cm)	Dose (μg/kg)
Adult	25	0.51	2.5
Children	147	1.27	5.9

Although exposure appears to be associated with surface concentrations, it is difficult to interpret these data. Reports subsequent to this paper, have asserted that the exposure values presented above were due to exposure to para-nitrophenol rather than methyl parathion (Grissom et al., 1998).

Until more is known about the differences between adult and children's exposure, we will continue to estimate children's exposure based on choreographed activities using adults with appropriate scaling factors to compensate for corresponding body weights and surface areas.

3 Issue 3: Characterization of Hand (Object)-to-Mouth Activities

The contribution of non-dietary ingestion to children's exposure to pesticides is unknown. The majority of research in this area is built upon prior work addressing exposure to contaminants such as lead. Since lead is no longer a gasoline additive and lead based pigments are no longer formulated into house paints, the suggestion that the dominant children's exposure route is through ingestion of contaminated soil and house dust is well founded. Newly emerging techniques to substantiate the role of non-dietary ingestion for exposure assessments include the use of video tapes and computers to enumerate child hand-to-mouth and object-to-mouth behavior in children. These methods are being evaluated by the Agency's ORD. This technology presents a challenge to traditional pesticide exposure assessment assumptions and a discussion of the issues related to this pathway will be presented in this document.

3.1 Non-Dietary Ingestion

In the past, the Residential SOPs addressed the potential for hand-to-mouth exposure by using the following algorithm, which is a crude attempt to address this pathway via the micro activity approach:

$$TR\mu g/cm^2 \times 350\ cm^2 \times \mathbf{1.56\ hand\text{-}to\text{-}mouth}\ \text{events per hour} \times 2\ \text{hours} \div 15\ kg$$

The **transferable residues (TR)** have already been discussed in the previous sections of this document (See Issue 1). The **350 cm^2** value represents the surface area of both hands of a child. This value is the mean of the median of the total surface area for males and females in the 2<3 and the 3<4 yr age groups multiplied by the average percentage of the total body represented by the hands (SOP). Some have suggested that the use of central tendency exposure values underestimates exposure and is thus, not conservative. It should be pointed out that OPP's use of central tendency values for surface area and body weight are consistent with policy in other Agency programs. Consider the following from the Risk Assessment Guidance for Superfund, Volume 1, "To calculate the reasonable maximum exposure for this pathway, the 50th percentile values, instead of 95th percentile values, are used for the area of exposed skin. This is because surface area and body weight are strongly correlated and 50th percentile values are most representative of the surface area of individuals of average weight (e.g., 70 kg)."

There are several issues that must be considered when attempting to model hand-to-mouth (object) behavior. These issues include:

- ❑ Characterization of the hand-to-mouth (object) event;
- ❑ The relationship between dermal absorption and saliva extraction at the time of the hand-to-mouth (object) event;
- ❑ Skin (hand) loading versus time and the concept of equilibrium.

3.2 Characterization of the Hand-to-Mouth (Object) Event

The **1.56** hand-to-mouth events is the geometric mean of 2,305 observations taken from 33 studies reported in the open literature for frequency and duration of hand-to-mouth activity (<3 months to >87 months). The data used for this number were presented in "The Role of Child Behavior and Activities in Determining Exposure to Xenobiotics." The data presented in this paper was extracted from behavioral science and child psychology papers where researchers focused on selected age groups of children such as those with learning disabilities. Thus, there were data gaps in the literature which made ORD's analysis of those studies difficult. That is to say, not all age groups were well represented. Furthermore, some studies in the body of literature reviewed involved adults holding children on their laps and introducing objects to them rather than observing their unstaged activities.

Since the presentation of the Residential SOPs to the SAP Panel in September 1997, additional data regarding hand-to-mouth frequencies of young children have been made available. These data have been generated by using video tape as an observational tool. (Reed K.J., Jimenez M., Freeman N.C.G, Lioy P.J., Quantification of Children's Hand and Mouthing Activities; supported by a co-operative agreement #CR821902 as subcontract from Research Triangle Institute, N.C. for the National Human Exposure Assessment Study (NHEXAS).) Some of these data were used in the study “Accumulation of Chlorpyrifos on Residential Surfaces and Toys Accessible to Children”, Gurunathan et al. (1998).

Videotaping methodology is a newly emerging technique to quantify the types and frequencies of children’s hand and mouthing events. Data acquired via this method are expected to be used in exposure models based on the micro activity approach. These micro-activity based models are still in development at EPA’s Office of Research and Development (ORD).

In the Reed study, twenty children in day care centers, aged 3 to 6 years, were videotaped during their waking hours for one day (except when in the bathroom). Parents of each child completed questionnaires for the purpose of evaluating the accuracy of parental reports of hand-to-mouth rates. Another 10 children, ages 2 to 5 years, were also taped in their homes concentrating on hand and mouthing behaviors. Taping ceased when the child was in the bathroom, sleeping, or changing clothing. The day care children were taped from 3 to 7 hours yielding 112 hours of taping. The children taped in their homes ranged from 5 to 6 hours for a total of 56 hours. From these data a mouthing rate of 9.5 contacts per hour was determined. The study authors noted this value corresponded well to the 9.0 value determined by Zartarian et al., (1997) in which video tapes were made of 4 children of farm workers in Salinas California. The Reed report asserts that “these values are considerably higher than the current default value of 1.56 contacts/hour under consideration by the EPA (1997).

Preliminary results of micro-activity observations using video taping were collected by Dr. Freeman, EOSHI, as part of the NHEXAS study. These preliminary results are as reported by representatives of ORD. Video tapes of 19 children were conducted in households reporting pesticide usage. Children were grouped into those less than 7 years and those greater than 7 years. For those under 7 years, the mean hand-to-mouth frequency was 6.6 times per hour with a standard dev. of 5.1. The median was 5.4 times per hour. Other contact frequencies for the children less than 7 were: dirt (21.3 contacts/hour), objects (138.1 contacts/hour), smooth surfaces (129.7 contacts/hour), and textured surfaces (38.1 contacts/hour).

What is missing in the Reed and Zartarian reports as well as the information available to OPP from the NEXAS report, is a characterization of a hand-to-mouth event. The current SOP assumes 100 percent ingestion of the all residues theoretically transferred to the entire surface area of both hands. It also assumes continuous exposure and complete replenishment of the entire surface area of both hands after each hand-to-mouth event.

The OPP value addressing the frequency of hand-to-mouth events per hour has received considerable attention. Following a recent SAP meeting in February 1999 (Aggregate Exposure), the Panel provided the following comments regarding the median surface area of both hands (350 cm^2) and characterization of the hand-to-mouth event:

> "Regarding the use of the median hand surface area is possibly true if the total surface area of the skin of the palm, back of hands, and sides of fingers is taken into account. The area cited in the SOP is appropriate for contact with air, and immersion contact with fluids such as water and perhaps sand.
>
> The area is not appropriate for hand contact with dust or surface soil particles. Concentrations of contaminants on children's hands are primarily on the finger tips and pads of the fingers and palm, not the back or sides. Children do not typically have their knuckles or the backs of the hand in contact with surfaces.
>
> A better estimate of hand surface area can be obtained from the Children's Dietary Lead Study. In this study toddlers (mean age 30 months old) had their hands area traced on graph paper. The average combined surface area of the palms and fingers of both hands was 114 cm^2, approximately 1/3 the value provided in the SOP.
>
> For hand-to-mouth activities of toddlers, even this value of 114 cm^2 is a gross overestimate of the amount of the hand that enters the mouth, typically 1 to 3 fingers. When fingers other than the thumb are placed in the mouth, the finger pads are placed on the tongue in contact with the tongue and saliva, while the top of the finger pads are facing the roof of the mouth exposed to moist air of the buccal cavity. In contrast, when the thumb is placed in the mouth, the back of the thumb and nail are against the tongue and the tongue presses upwards so that the thumb pad is pressed against the roof of the mouth. In this case the entire finger inside the buccal cavity is bathed in saliva."

The comments from the SAP addressed the 1.56 events/hour value:

> "Based on the independently conducted studies by Zartarian et al., (1997, 1997) and Reed et al (1999), this value seriously underestimates the mouthing behavior of children 3 - 5 years old. As noted in the March SAP

meeting (Post Application Guidelines), a value between 9 and 10 times per hour would be more accurate. The observed value is 6 times higher than the value provided in the SOP. The use of average value point estimates for mouthing behavior, whether the EPA value of 1.56 or the Zartarian/Reed values of 9.5, place limitations on the exposure estimate calculated with the point estimate. Since EPA appears to need to understand high end exposure, the 90th percentile from Reed's data (approximately 20 times per hour) should be used until larger databases are available."

Table 14 presents the hourly frequency of hand-to and object-to-mouth activities of the children studied by Reed et al. (1998).

Table 14: Hourly Frequency Counts of Hand and Mouthing Behaviors for Intra-Child Variability in Day Care Children and in Residential Children. The day care children were ages 3 to 6 and the residential children were ages 2 to 5 (Reed et al., 1998).

ID	Hand to Mouth Range	Hand to Mouth Mean	Hand to Mouth Median	Object to Mouth Range	Object to Mouth Mean	Object to Mouth Median
Day care						
101	1-9	5	6	0-3	1	0
102	0-4	2	2	0-16	4	3
103	0-10	6	7	0-5	1	0
104	0-5	2	2	0	0	0
105	2-12	6	6	0-36	6	1
106	1-13	7	6	0-15	3	1
107	0-6	3	4	0-9	4	4
108	0-15	7	6	0	0	0
109	0-12	4	3	0-26	6	3
110	0-9	3	3	0-4	1	1
111	1-24	15	17	0-1	1	1
112	0-70	25	11	0	0	0
113	3-12	9	11	0-3	1	0
114	1-30	15	14	0	0	0
115	2-35	16	13	0-1	0	0
116	17-41	26	25	0-7	3	2
117	0-18	7	6	0-1	0	0
118	0-22	10	10	0-3	1	0
119	0-14	8	9	0-32	6	1
120	1-30	13	8	0	0	0
Residential Children						
201	0-1	0	0	0-1	0	0
202	5-25	11	10	2-29	11	7
203	7-62	21	12	1-15	5	4
204	4-17	8	6	0-5	2	0
205	1-21	10	8	0-39	7	0
206	2-6	5	5	0-10	5	5
207	1-25	10	7	0-9	2	1
208	2-26	11	7	0-4	2	1
209	0-22	9	7	0-14	5	2
210	0-23	11	13	0-17	4	1

Table 15. Range of frequency Contacts per Hour from Video Cassettes (Reed et al., 1998)

Variable Hand to -	Mean	Median	Minimum	90^{th} Percentile	Maximum
Clothing	66.6	65.0	22.8	103.3	129.2
Dirt	11.4	0.3	0.0	56.4	146.3
Hand	21.1	14.2	6.3	43.5	116.4
Mouth	9.5	8.5	0.4	20.1	25.7
Object	122.9	118.7	56.2	175.8	312.0
Object-to-mouth	16.3	3.6	0.0	77.1	86.2
Other	82.9	64.3	8.3	199.6	243.6
Smooth surface	83.7	80.2	13.6	136.9	190.4
Textured surface	22.1	16.3	0.2	52.2	68.7

Differences in age specific mouthing behavior among videotaped children are not delineated in the avaliable literature. The Agency believes the 12 to 24 month age range is critical due to the unique behavior of crawling and hand/object-to-mouth activity. The following study may provide information to determine if the Agency can make age distinctions based on mouthing behavior, in the SOPs. In a study conducted by the Wageningen Agricultural University in the Netherlands, (Groot et al., 1998) 42 children were observed by their parents for mouthing behaviors. Parents were trained by professional observers and kept diaries. The study design relied on parental observation since parents are keen observers of their children. There were also concerns regarding the influence on children's behavior when strangers and or video taping equipment are present. Children were also observed at home as children were believed to behave differently in day care facilities. Parents were instructed to observe their children ten times 15 minutes per day on two days and could be divided between 1) waking and 11 am (3x); 2) between 11 am and 3 pm (3x); and between 3 pm and going to bed (4x). Distinctions were made between licking and sucking/biting. Licking is defined when the object touches the lips or tongue is outside the mouth but is not put inside the mouth. Sucking /biting is when the object is put in the mouth. Distinctions were made between kinds of objects: pacifier (dummy), fingers, non toys, toys meant for mouthing and toys not meant for mouthing. Children were grouped based on the following behavioral characteristics:

3-6 months	begin to look around and notice their environment;
6-12 months	able to sit and have control over the muscles of their hands so they can grip objects by themselves;
12-18 months	able to crawl, some can walk and can move about freely;
18-36 months	able to play alone.

The following tables provide descriptive statistics of the total mouthing time per product category during the time awake.

Table 16: 3-6 Months, Total Mouthing Time (minutes) Per Category

	Std Deviation	Minimum	Mean	Maximum
non toys	2.8	0.0	2.8	6.9
Toys for mouthing	5.1	0.0	3.4	12.2
Other toys	10.0	0.6	11.3	26.8
Fingers	18.8	1.6	20.5	50.7
Total	19.1	14.5	36.9	67.0

Table 17: 6-12 Months, Total Mouthing Time (minutes) Per Category

	Std Deviation	Minimum	Mean	Maximum
non toys	8.4	0.2	9.4	25.7
Toys for mouthing	11.4	0.0	5.8	39.7
Other toys	28.5	0.4	22.1	101.5
Fingers	11.6	0.0	7.5	41.6
Total	44.7	2.4	44.0	171.5

Table 18: 12-18 Months, Total Mouthing Time (minutes) Per Category

	Std Deviation	Minimum	Mean	Maximum
non toys	14.2	0.0	7.2	50.3
Toys for mouthing	0.1	0.0	0.0	0.4
Other toys	3.5	0.0	3.6	10.4
Fingers	14.9	0.0	5.8	52.7
Total	18.2	0.0	16.4	53.2

Almost 70% of the time, children in the age group 18-36 months mouth on their fingers. In this group no child mouthed on toys meant for mouthing.

Table 19: 18-36 Months, Total Mouthing Time (minutes) Per Category

	Std Deviation	Minimum	Mean	Maximum
non toys	3.4	0.0	2.0	11.6
Toys for mouthing	0.0	0.0	0.0	0.0
Other toys	1.2	0.0	1.1	3.8
Fingers	9.1	0.0	6.3	25.7
Total	9.8	0.0	9.3	30.9

It appears that the 18 to 36 month group had a higher mean time mouthing the fingers than the than the 12 to 18 month group. Therefore our current model of a 15 kg child (2-3 years from the Exposure Factors Handbook) is a reasonable worst case. The 3 to 6 and 6 to 12 month group had a higher mouthing rates than the othe groups however, they are less mobile.

The current SOP for estimating hand-to-mouth behavior needs to be revised to reflect the more realistic estimates observed by Reed and Zartarian. The SAP asserted that the palms are expected to be in contact with treated surfaces such as carpets. Additional characterization provided by the SAP regarding the hand-to-mouth event suggests the event includes 1 to 3 fingers. The following comparison suggests that the original SOP, although flawed in concept, was a reasonable estimate of this important non-dietary ingestion route.

- ❑ Current SOP:

  350 cm^2 (surface area of two hands) x 1.56 events per hour = 564 cm^2

- ❑ As characterized by the SAP:

  approximately 20 cm^2 (estimated contact surface area of 2-3 fingers) x 20 events per hour = 400 cm^2. Information regarding surface areas of fingers is needed to refine this algorithm as the 20 cm^2 is an estimate, made for discussion purposes and is based on one half of the hand representing the palm and the other half representing the fingers as was done in Gurunathan et al., 1998.

The Agency will revise the hand-to-mouth estimate based on the recomendations of the Scientific Advisory Panel. However, the Agency asks the Panel for advice regarding surface areas that may be used to represent the palmar surface area of the fingers, and if there are sufficient data to address age specific mouthing behaviors.

If these data are not sufficient, what can be done to adequately address this pathway?

3.3 The Relationship Between Dermal Absorption and Saliva Extraction at the Time of the Hand-to-Mouth Event

Another factor influencing the amount of pesticide ingested from mouthing fingers is how much of that residue can be extracted from the hand by saliva. The Agency is considering data from studies evaluating removal efficiency of residues on hands, by solvents and detergents, to make estimates of residue removal by each mouthing event.

In addition to the assumption that 100% of the residues on the hands are available for dermal absorption, the current SOP suggests that 100 percent of those residues transferred to the hands are available for non-dietary ingestion. Keeping track of the hand loading values and subsequent removal of residues by hand-to-mouth exposure is a challenge for those developing micro activity based models. It is also difficult for exposure assessors using a simple micro-activity algorithms for hand-to-mouth exposure and dermal exposure estimates using the macro activity approach.

Dermal absorption and removal by washes appears to be influenced by how much is on the skin. Extraction efficiency also appears to be influenced by residence time on the skin. The following papers address removal of pesticide residues from the hands or soil from the hands:

❏ J.C. Kissel, J.H. Shirai, K.Y. Richter, R.A. Fenske. 1998. Empirical Investigation of Hand-to-Mouth Transfer of Soil. Bulletin Environ. Contam. Toxicol. 60:379-386.

Four adult volunteers participated in a study to establish an empirical basis for evaluating soil and contaminants that might be transferred from the hand to the mouth. The protocol was as follows:

1) wash and dry subject's hands
2) loading one hand by pressing the hand into a shallow pan of soil

3) mouthing three fingers above the first knuckle
4) rinsing the mouth three times
5) sucking the thumb
6) rinsing the mouth three times
7) licking the palm (three swipes with the tongue)
8) rinsing the mouth three times
9) washing the remainder of the soil from the hand

Table 20. Mass and Fraction of Total Soil Load on the Hand Recovered from Mouths Following Each Activity Based on Aggregate Data from All Replicates (n=36)

Activity	Soil in mouth (mg)		Percent, soil in mouth vs on hand	
	Geo. mean	95% CI	Geo mean	95% CI
Thumb sucking	7.4	6.2-8.7	10.1	8.7-11.8
Finger mouthing	11.6	9.8-13.8	15.9	13.8-18.4
Palm licking	16.0	13.7-18.6	21.9	20.5-23.4

The authors suggest, "It appears that transfer of 10 or more mg of soil from a hand to the oral cavity in one event is possible, but requires moderate soil loading and more than incidental hand-to-mouth contact. The actual frequency of contact events that could be expected to produce transfers of this magnitude is unknown. Hand-to-mouth contact exhibited by a small group (n=4) of California farmworker children aged 2 to 4 years have been tallied following videotaping (Zartarian et al., 1997). Those children exhibited individual median hand-to-mouth contact rates of 2 to 8 per hand per hour."

"However, many of the observed contacts were less extensive than those tested here, involving only touching of the lips by some part of a hand without actual penetration of the oral cavity. Contacts resulting in insertion of part of either hand into the mouth were less frequent. The tests reported here were conducted with adult volunteers. Since children have smaller hands, the same activities should result in the transfer of less soil mass given similar loading levels. Also, the fraction of soil transferred from hand-to-mouth that is subsequently swallowed is unknown but may be less than 100 percent."

It should be noted that the hand-to-mouth transfer shown in this study occurred shortly after hand contact with soil. Other studies such as the one that follows have demonstrated that extraction efficiency of residues from the hand decreases with increasing time that residues remain on the hand.

- Webster, R.C. and Maibach, H.I. 1989. Dermal Decontamination and Percutaneous Absorption. In: Percutaneous Absorption. 2nd ed. R. Bronaugh and H.I. Maibach, eds. New York: Marcel Dekker, pp 335-342.

  Decontamination of a chemical from the skin is commonly done by washing with soap and water. It has always been assumed that washing will remove the chemical. However, recent evidence suggests that many times the skin and the body are unknowingly subjected to enhanced penetration and systemic absorption/toxicity because the decontamination procedure does not work or may actually enhance absorption. In this article the authors review some literature involving decontamination techniques. The first table illustrates extraction efficiency and residence time with a potential for increased extraction efficiency as percent concentration increases.

Table 21. Dermal Wash Efficiency for PCBs in Guinea Pig

PCB%	Wash Time	Dose Removed (%± SD)
42	immediate	58.9±7.5
42	post 24-hr	0.9 ± 0.2
54	post 24-hr	19.7 ± 5.5

The wash procedure consisted of rinsing twice with water, twice with acetone, twice with water (Webster et al., 1984).

Table 22 gives the *in vivo* skin decontamination of 42% PCBs applied in mineral oil to rhesus monkey skin. After an initial 15 minute application interval, the skin was washed immediately at 10 minutes, and at 1, 3, 6, and 24 hours later with soap and water or mineral oil. With immediate wash, the mineral oil removed 90.1% of the applied dose, while soap and water removed 70.8%. At 10 minutes and at all subsequent time intervals, soap and water was able to decontaminate the same amount of PCBs as mineral oil. Most important is that as the time of skin washing progressed away from initial application, less and less PCBs could be removed from the skin. It is assumed that the PCBs penetrated deeper into the skin with time and that the process of percutaneous absorption removed the chemical from the surface of the skin.

Table 22. *in vivo* Skin Decontamination of 42% PCBs Applied in Mineral Oil (n=4)

Time Interval of washing postapplication of PCBs	Applied dose removed (%)	
	Soap (20% v/v Ivory liquid soap) and water decontamination	Mineral oil decontamination
0.0	70.8 ± 18.3	90.1± 9.7
10 min	70.7± 26.8	68.2 ±19.3
1 hr	71.3 ± 33.0	63.1 ± 28.1
3 hr	68.2 ± 13.2	63.6 ± 15.3
6 hr	51.2 ± 29.6	64.8 ± 22.1
24 hr	30.0 ± 14.3	44.8 ± 40.2

Kazen et al. (1974) did hexane hand rinsing on occupationally exposed people. The rinses were analyzed to determine if chemicals persisted on their skin long after exposure. Chlordane and dieldrin apparently persisted on the hands of a former pest control operator for at least 2 years after exposure. Methoxychlor, captan and malathion persisted for at least 7 days on the hands of a fruit and vegetable grower. Parathion was found on the hands of one man 2 months after his last known contact with this pesticide. Endosulfan, DDD, kelthane, imidan and guthion have persisted on the hands of some exposed workers from less than one day to 112 days after exposure.

For compounds that may have a long residence time in/on skin, it is not clear if these residues are removed/shed as the stratum corneum is replenished. The stratum corneum (outer layer of skin) is replenished over the course of 3 to 4 weeks (Casarett and Doull's Toxicology, Fifth Edition

In Table 21, it appears that increased loading from 45% to 54% of PCBs may slow dermal absorption, but as absorption slows, due to more of the substance being applied to the skin, the substance should be easier to extrace by hygiene washes or saliva. In addition, the longer the time the chemical resides on the skin, the less it becomes available for extraction by washing or by saliva.

- Fenske, R.A. and Lu, C. 1994. Determination of Handwash Removal Efficiency: Incomplete Removal of the Pesticide Chlorpyrifos from Skin by Standard Handwash Techniques. Am. Ind. Hyg. Assoc. J. 55: 425-432.

  In this study, volunteers were asked to contact test tubes that had been spiked previously with a known amount of the pesticide chlorpyrifos. The test tube was then eluted with solvent to determine the amount of chlorpyrifos that was not transferred to the hand. The hands were washed following test tube contact according to a standard handwash protocol. Handwash solutions were extracted with solvent to determine the amount of chlorpyrifos from the skin. Removal efficiencies ranged from 21 to 43%.

  Table 23 indicates the average transfer efficiency, average skin loading, and average removal efficiency at each test-tube spiking level. Transfer efficiency was similar (45-65%) for the high spiking levels, but increased substantially (88 and 93%) when small amounts of chlorpyrifos were applied to the test tube. The lower transfer efficiencies at the higher test tube spike levels suggest that the skin became less efficient removing chlorpyrifos from the glass tube when skin loading exceeded 1 $\mu g/cm^2$.

  Residence time on skin did not affect removal efficiency significantly for the ethanol wash, whereas waiting one hour before washing with isopropanol/water reduced removal efficiency from 43% to 23%. At t=0, the isopropanol/water wash removed significantly more chlorpyrifos than the ethanol wash, although at t=1 hour the ethanol wash was more efficient. Skin loadings between 0.1-1 $\mu g/cm^2$ resulted in 21% to 22% removal efficiencies, approximately one-half that measured at the high loading level. However, removal efficiency increased to 38% at the lowest skin loading level. The effect of prewashing hands with solvent was examined for the ethanol handwash. Prewashing with ethanol doubled the removal efficiency at t=0 (54% vs 27%) and continued to demonstrate a significant effect at one hour.

Table 23. Transfer Efficiency of Chlorpyrifos from Spiked Test Tubes

Time (hr)	n	Test tube spike level (μg)	Transfer efficiency	Skin loading (144 cm^2)	# Washes	Removal efficiency (%)	
						mean	Std.Dev.
Ethanol							
0	12	2500	45.5	7.9	2	27.0	4.8
1	12	2500	54.7	6.2	2	31.3	6.2
Isopropanol and water							
0	12	2500	64.4	12.3	2	42.8	24.1
1	12	2500	60.8	11.1	2	22.6	9.0
0	10	250	52.9	0.97	1	21.2	7.1
0	12	25	87.6	0.13	1	23.1	7.2
0	12	2.5	92.9	0.024	1	38.5	4.8

❑ Fenske R.A., Simcox N.J., Camp J.E., Hines C.J., 1998. Comparison of Three Methods for Assessment of Hand Exposure to Azinphos-Methyl (Guthion) During Apple Thinning. Submitted to Occupational and Environmental Hygiene 3/26/98.

A total of 15 glove samples, 12 hand washes and 12 hand-wipe samples were collected from agricultural workers thinning apples in the Wenatchee region of central Washington. The apple trees were located in orchard treated with azinphos-methyl**.** Dislodgeable foliar residues measured from leaf punches ranged from 1 to 1.5 μg/cm^2. Exposure rates are reported as total exposure to two hands. Exposures were calculated by dividing the exposure mass by the sample time (2 hrs).

"For the glove exposure assessment method, each worker was supplied with two 100% cotton knit gloves (Photoco) commonly used in photographic darkrooms. For the handwash exposure assessment method, hands were washed in a polyethylene bag containing 250 ml of distilled water containing 1% Sur-Ten (sodium dioctyl sulfosuccinate), a surfactant. The worker's hand was inserted into the bag and vigorously agitated in the solution for 60 shakes in 30 seconds. The procedure was conducted twice for each worker's hands. For the hand wipe exposure assessment method, a researcher used three 3" by 3" 12 ply cotton surgical gauze pads sprayed lightly with the surfactant wash solution to wipe each hand: one pad was used for the palm, one for the back of the hand, and one for the fingers and thumb. The wipes of the left and right hands were combined."

"A laboratory study of the handwash removal efficiency of the fungicide, captan, found 78% removal upon immediate hand washing and 68% removal after one hour (Fenske 1991)." This study was conducted in the manner described in Fenske and Lu 1994 discussed above. "Although no similar study has been reported for azinphos-methyl, the captan value for one-hour exposure con be considered to be an appropriate surrogate for azinphos-methyl and the two hour sampling period in this study, with the caveat that temporal characteristics of the field exposure somewhat compromise the confidence with which this direct comparison can be made. The comparable log octanol:water partition coefficients of azinphos-methyl and captan (azinphos-methyl log K_{ow} = 2.75; captan log K_{ow} = 2.35) support the assumption that azinphos-methyl is at least as sorptive to skin as is captan. It is important to note that matching of pesticide characteristics including partition coefficient, pesticide formulation, and handwash protocol is critical to making appropriate comparisons of handwash removal efficiencies. In contrast to captan and azinphos-methyl, chlorpyrifos (log K_{ow} = 4.96) is typically formulated as a liquid concentrate, while the other two pesticides are formulated as wettable powders."

Table 24. Mean Measured Exposure Rate for Each Exposure Assessment Method (mg/hr), with Comparison to Estimated True Exposure Level

Method	n	Mean measured exposure rate (mg/hr)	CV(%)	Percent of estimated true exposure rate
Glove	15	6.48	28	240
Wash	12	1.83	27	68
Wipe	12	0.28	33	10

In many studies using Jazzercise™ (including those discussed in this document), gloves were used as dosimeters for hand exposure. This may explain, why in 20 minutes the ratio between transferable residues and gloves values are so high. In addition, this information has implications for interpreting dislodgeable residues obtained from pets treated with pesticides.

Physical chemical properties such as formulation type must be considered when addressing the extraction of a chemical from a child's hands along with other factors such as concentration and residence time.

❑ Geno P.W, Camann D.E., Harding H.J., Villalobos K., Lewis R.G. 1995. Handwipe Sampling and Analysis Procedure for the Measurement of Dermal Contact with Pesticides. Arch. Environ. Contam. Toxicol. 30: 132-138.

A handwipe sampling and analysis procedure was developed for the measurement of dermal contact to pesticides. This procedure utilizes cellulose dressing sponges wetted with 2-propanol. A 2 step wiping procedure is described that ensures that the entire hand is sampled. Removal efficiency experiments show that dry residues of the pesticides chlorpyrifos and pyrethrin are quantitatively removed by hands immediately following contact. Results suggest that the procedure may remove pesticide residues that are deeply embedded in the skin and not removed by soap and water washing.

Handwipes were performed using dressing sponges. Two sponges were removed from the package and placed on a surface of solvent-rinsed aluminum foil. One of the sponges was then wetted with 10 mL of pesticide grade 2-propanol. With the first sponge, the subject was instructed to perform a general wipe of the hands. The subject then placed the sponge in a solvent-rinsed and oven-dried jar. The second sponge was then wetted with 10 mL of 2-propanol and the subject was instructed to thoroughly wipe each digit and the palm of the hand. The second sponge was added to the container with the first sponge.

The volunteer was instructed to wash their hands with soap and water and place a latex glove over one hand (to protect from contamination as the other hand will also be used in the sampling). The subject were instructed to press their non-gloved hand onto an aluminum foil square spiked with a known amount of pesticide. After approximately 10 to 30 seconds, the hand was washed with soap and water. The glove was removed from the second hand and the process was repeated. Each subject performed the hand-press once a day.

Table 25. Wipe Removal Efficiency of Isopropanol Handwipe Method for Pyrethrins

	Foil spike level (μg)	Transfer Efficiency (%)	Hand Loading (μg)	Removal Efficiency (%)
Subject A				
Day 1 left	40.5	84	34.1	**56**
Day 1 right	40.5	90	36.4	**68**
Day 2 left	51.1	93	47.7	**92**
Day 2 right	51.1	74	38.0	**77**
Day 3 left	44.8	81	36.2	**128**
Day 3 right	44.8	94	42.2	**102**
Subject B				
Day 1 left	40.5	81	32.8	**63**
Day 1 right	40.5	93	37.5	**68**
Day 2 left	51.1	86	43.8	**87**
Day 2 right	51.1	71	36.3	**101**
Day 3 left	44.8	77	34.4	**116**
Day 3 right	44.8	74	33.3	**144**
Mean (n=12)				**92±28**

Table 26. Wipe Removal Efficiency of Isopropanol Handwipe Method for Chlorpyrifos

	Foil spike level (μg)	Transfer Efficiency (%)	Hand Loading (μg)	Removal Efficiency (%)
Subject A				
Day 1 left	4.32	85	3.96	**85**
Day 1 right	4.32	94	4.07	**103**
Day 2 left	4.20	94	3.96	**119**
Day 2 right	4.20	80	3.36	**105**
Day 3 left	4.26	87	3.70	**115**
Day 3 right	4.26	96	4.11	**117**
Subject B				
Day 1 left	4.32	82	3.54	**89**
Day 1 right	4.32	94	4.06	**101**
Day 2 left	4.20	86	3.62	**97**
Day 2 right	4.20	77	3.36	**111**
Day 3 left	4.26	79	3.70	**98**
Day 3 right	4.26	84	4.11	**112**
Mean (n=12)				**104±11**

Lipophilic compounds such as chlorpyrifos and pyrethrins reportedly will not be removed completely by hand rinses using surfactant based rinses (Fenske and Lu, 1994). It is interesting that percent removal increases with each day's measurement (most notedly in the pyrethrin example, Table 25). This point is noted in the investigator's concerns regarding the drying out of hands due to the use of solvent hand wipe/ rinses. The drying of hands is thought to influence transfer and this increased transfer was also noted in Fenske and Lu (1994). Again, note the generally higher removed efficiency in this study where there was short time period between the pressing the palm on the spiked aluminum foil and wiping. These data, appear to agree with those studies previously discussed with respect to the influence of residence time on the skin.

- ❑ D.E. Camann, T. K. Majumadar, and P. Geno, Determination of Pesticide Removal Efficiency from Human Hands Wiped with Gauze Moistened with Three Salivary Fluids, Final Report to EPA by ManTech under Contract 68-D5-0049, Sept. 1995.

- ❑ D.E. Camann, T. K. Majumadar, W.D. Ellenson, and R.G. Lewis, "Transfer Efficiency of Pesticides from Carpet to Saliva-Moistened Hands", in Measurement of Toxic and Related Air Pollutants: Proceeding of an International Specialty Conference, Publication VIP-64, Air & Waste Management Association, Pittsburgh, PA, 1996, pp. 532-540.

  In these publications, the investigators evaluated the efficiency of removal of pesticides from the skin by saliva using saliva-moistened gauze wipes. Chlorpyrifos, piperonal butoxide and pyrethrins are removed from freshly spiked human hands at about 50% efficiency by human saliva, artificial dental saliva and Surtan surfactant solution. Dr. Lewis suspects that 50% represents the maximum mouthing removal rate for dried pesticide residue. Dust particles should be more efficiently removed. Dr. Lewis also asserts that saliva-moistened hands are about 3 times more efficient than dry hands at removing pesticide residues from carpeted and vinyl floors.

The limited data discussed in this section show removal of residues is influenced by amount on the hand and residence time. It appears that residues on hands may not easily be removed by mouthing.

3.4 Hand Loading and the Concept of Equilibrium (as exposure to contaminated surfaces continues, do hand concentrations reach a steady state with environmental concentrations?)

The hands contribute to two routes of exposure (oral and dermal). Keeping track of the contribution of the hand to both routes accomplished by using two separate algorithms. This process is further complicated by the fact that amount of pesticide added hand may be lower with each succesive contact. As hands or fingers enter the child's mouth, only a portion of those residues may be removed in the process. Currently, the SOP assumes complete removal and complete replenishment.

- ❏ Brouwer D.H., Kroses R., Van Hemmen J.J. 1998. Transfer of a Contaminant from Surface to Hands: Experimental Assessment of the Linearity of the Exposure Process, the Adherence to the Skin, and the Area Exposed During Fixed Pressure Repeated Contact with a Powdery Contaminated Surface. Annals of Occupational Hygiene, 42: 467-475.

  “This study examines the effect of one single hand press contact versus repeated contacts with a contaminated glass plate with respect to the area of skin exposed, and the subsequent loading of the skin. Three adult volunteers participated in the study. The investigators used a fluorescent whitening agent (Tinopal CBS-X 4,4'-bis(2-sulfosteryl)biphenyl) with concentrations being measured using a video imaging technique as described by Fenske and Birnbaum (1997) utilizing images recorded under illumination with a UV-A light in a dark room. This fluorescent whitening agent was used to study the process of exposure, and to determine the increase of the area exposed as well as adherence of the compound to the skin after 1 to 12 consecutive contacts.

  The “loading of the skin after 12 contacts was compared to loading of a cotton glove dosimeter with similar hand pressures. The results showed that after one single hand contact only 4 to 16% of the total surface of the palm of the hand was exposed (7 to 27 cm^2). After 12 contacts, this increased up to 39% (62 cm^2). The contact surfaces of the hand are primarily the finger tops, and the ball and the knuckles of the palm of the hand. During contact with a more flexible surface, e.g., soil, other parts of the hand may be exposed compared to the stiff surface in the present study.”

According to Lu and Fenske, (1999), residues are more easily removed from hard surfaces than surfaces such as carpets. These data suggest only a portion of the hand contacts a hard surface.

Brouwer et al. reports that efficiency of transfer was 2% of the contamination of the surface. The adherence at the skin was 1.07 $\mu g/cm^2$ after 12 contacts and tended to increase non-linearly with the increase in contacts.” Average adherence of Tinopal after one single hand pressure, respectively 0.11 and 0.27 $\mu g/cm^2$ in trial #1 and #2, was very low compared to adherence of soil observed by Kissel et al. (1996). Those authors reported a range of 60 to 10,200 $\mu g/cm^2$, however in these experiments the exposure process, e.g., placement of a hand palm down in a pan containing soil followed by gentle agitation for 30 seconds, differed very much from this experiment with a single hand pressure without a movement of the hand on the surface.

“Comparison of the loading at the skin after 12 pressure contacts with loading of the glove (approximately 65 μg trial #2 and 4500 μg trial #3, respectively) revealed an approximately 70 times higher adherence to the glove. This results deviates from observations in pesticide re-entry studies, where comparison of two indirect techniques to assess dermal exposure, e.g., a removal technique (hand washes) with surrogate skin technique (cotton glove monitoring) showed differences up to a factor to 2.4 or 5 ((Fenske et al., 1989) and (Davies et al., 1983)). Cotton fabrics tend to have high retention properties compared to the skin surface, since the effect of penetration into and absorption at the fibers is a more efficient process then adhesion of a contaminant to the skin. In the present study, this phenomenon may be enhanced, since the contaminant is a powder with low adhesion to the hard surface compared to pesticide residues on foliage or crops.”

❑ Smith C.R., Welsh A.M., Saiz S.G., Haskell D.M., Dong M.H., Begum S., Carr J.C.: Comparison of Three Methods Used to Monitor Hand Exposure to Pesticides in Grape Vineyard Workers. California Department of Pesticide Regulation HS-1630, October 11, 1991.

“Three recommended methods of measuring field worker hand exposure to pesticide residues were compared in grape vineyard workers. Residue collections on knit nylon and rubber gloves and in bare hand washes collected at four intervals from one-half to four hours were compared for sensitivity to exposure time. Collections of two pesticide chemicals, dimethoate and fenarimol averaged 2.7 times higher on rubber gloves, and 9.5 times higher on knit gloves, than in bare hand washes.

Spencer et al., 1995 observed hand residues remaining virtually constant regardless of the number of bins of peaches picked while monitoring field workers harvesting peaches in Sutter County, California. These data suggest that estimates using transfer coefficients derived from short term monitoring periods (typically 2 to 4 hours) can overestimate exposure by more than 50 to 80% when estimating exposure for a full day of work.

❑ Durkin P.R., Rubin L., Withey J., Meylan W. Methods of Assessing Dermal Absorption with Emphasis on Uptake from Contaminated Vegetation. Toxicology and Industrial Health, Vol. 11 No. 1, 1995.

Hand measurements of field workers from 16 different reentry studies representing diverse activities and 16 different chemicals were evaluated in this study. “The data were re-analyzed using only uptake rates measured on hands, either from solvent washes or residues on gloves.

Unlike the data on whole body residues, the hand residue data show a reasonably clear relationship with DFR. The authors plotted measurements of DFR verses a transfer rate expressed as μg of chemical adhering to skin or glove per cm^2 exposed surface per hour of exposure [μg/(cm^2 hr)].

In converting reported hand measurements (expressed as μg/hr) to μg/(cm^2 hr), a surface area of 840 cm^2 was used for hands, which is consistent with the guidelines for exposure assessments (U.S. EPA, 1992). It is worth noting that the types of reentry tasks used in this analysis were varied. As shown in the table of potential transfer coefficients by Krieger, hands would be the common element, not whole body dosimeters.

The relationship between DFR and hand concentrations was suggested as being simple and descriptive:

$$\log TR = 1.09 \log DFR + 0.05$$

Where:

TR = transfer rate in μg/(cm^2 hr) and DFR = dislodgeable foliar residue (μg/cm^2).

"The squared correlation coefficient for this equation is reported to be 0.78, and the model is significant at $p < 0.00001$. The intercept is small and not statistically significant ($p=0.54$). Also the slope is very close to unity. This equation indicates that the transfer rate, expressed as μg/(cm^2 hr), is approximately equal to the DFR expressed as μg/cm^2. Additional analysis, not detailed in this report, using physical and chemical properties molecular weight and water solubility, did not significantly improve the correlation. In other words, the transfer rate from the vegetation to the skin surface appears to be sole dependent upon, and directly related to, the DFR on the vegetation."

These data suggest that once the skin is loaded, equilibrium is established, and additional exposure over time is not necessarily linear. Thus, Spencer's observations regarding the use of short-term monitoring periods (2 to 4 hrs) to estimate long-term exposure periods as having the potential to overestimate exposure is well worth considering with respect to extending the use of a 20 minute Jazzercise routine to represent more than 20 minutes of exposure. Table 27 illustrates the dosimeter loading of chlorpyrifos following 20 minutes of the activity Jazzercise™.

Table 27. Ratio = Garment Concentration (μg/cm^2) ÷ Transferable Residue from Ross et al., 1991 (μg/cm^2) Postapplication Jazzercise™ Routine.

Time post venting and Room ID	Tights	Shirt	Socks	Gloves
0 hr/rm A	3.1	2.5	10.9	6.4
0 hr/rm B	3.1	2.4	14.5	8
6 hr/rm A	4	3	16.6	8
6 hr/rm B	4	2.3	20.0	9
12 hr/rm A	3	1.7	13	5.2
13 hr/rm B	3	1.7	8.7	3.9

In summary, there are a number of issues to consider when making estimates of non-dietary exposure from hand-to-mouth events. In particular, when those estimates are based on micro activity models:

1. the characterization of hand-to-mouth events such as the amount of surface area of the hand that is inserted in the mouth;

2. the surface area of the hand that comes in contact with treated surfaces;

3. the amount or residues removed from the treated surface by the hand;

4. the non-linear relationship of repeated hand contacts, adherence to skin may decrease with each contact until equilibrium is reached;

5. the influence of amount of time the residues are on the skin;

6. the influence of physical chemical properties of a given pesticide;

7. and, the magnitude of residues on the skin.

Many of these issues apply to potential non-dietary exposure estimates from object-to-mouth behavior.

With respect to estimating a dose based on saliva extraction of the pesticide from the surface of the hand, the Agency recommends the consideration of chemical properties such as solubility when considering the amount of pesticides on a child's hands that may be available for non-dietary ingestion. For example borax may be 100 percent soluble while a synthetic pyrethroid may have far lower solubility. The more soluble the compound, the more likely it will be removed by saliva.

- ❑ Gurunathan S., Robson M., Freeman N., Buckley B., Roy A., Meyer R., Bukowski J., and Lioy P.J.; Accumulation of Chlorpyrifos on Residential Surfaces and Toys Accessible to Children, Environmental Health Perspectives, Vol. 106. Number 1, January, 1998.

In this paper, a model for non-dietary ingestion through contact with plastic and plush toys was suggested. The micro activity model is based on hand-to-object frequency data taken from video observational data of children from a dissertation of K. Reed, which is presumably the basis for Reed et al., (1998) discussed previously in this document. In the above study, broadcast applications of chlorpyrifos were made to the floors of two apartments (each 860 square feet) located on the Rutgers University campus. Approximately 12 grams of the active ingredient were applied to each of the apartments with estimated deposits being approximately 15 $\mu g/cm^2$.

The windows were kept closed during and for two hours after the application and remained closed for the two week duration of the study. Ventilation of the apartments was limited to a four hour period, two hours after the application. The four hour ventilation period consisted of the use of a fan located near an opened window. Each apartment had a self-contained heating, ventilation, and air-conditioning unit which operated during the study. The only other possible ventilation was from the movement of research personnel in and out the apartment during post application sampling periods.

Hard plastic and plush toys were set directly on the treated surfaces one hour after the broadcast application. One of each (plush and hard plastic) were removed from the apartment at post application periods of 8, 24, 72, 168, and 336 hour. “These items and their time or removal represented a situation in which a toy was placed and left in a pesticide-treated room and sequentially removed after the period of time recommended by the manufacturer labels for safe reentry.” Residues on the toys were compared with residues taken from a plastic laminate dresser top sample locations which were periodically resampled using the Lioy-Weisel-Wainman sampler. This study also was designed to observe the twophase process of deposition of chlorpyrifos and volatilization.

Both the filters and toys were extracted with hexane then sonicated prior to GC analysis. Exposure estimates were made for a 3 to 6 year old child playing in a room 7 days after the application. The model assumes that each time a child touches a dresser top or toy, the child would be able to extract the same amount of residue for each contact event. This is based on the assumptions of numerous surfaces in the environment, multiple contact sites on a toy or surface. Observational data used in the model were hand-surface touches of 366 times/hour and hand to mouth touches of 70 times per hour. A child weight of 25 kg was assumed with the surface area of both hands being 400 cm^2 (200 cm^2 for fingers). Other assumptions include 75% transfer of residues from surfaces to hand and 100% transfer from toys to hand (10 plastic and 3 plush toy surfaces contacted per day). The oral dose from insertion of the toy was assumed to be 100% of the residue associated with the toy.

The value of 70 hand-to-mouth touches appears to come from videotape data on one of the 20 children observed in day care centers. That child's range was 0 to 70 times per hour. The child with the nearest frequency to the 70 events was a child having a range of 17 to 41. Of the ten children observed at home, one of the children had range of 7 to 62 hand to mouth events. The remaining children in both groups had ranges between 0 and 35. Also of note, is that the child with the frequency of 0 to 70 hand-to-mouth events per hour had a frequency median, mean and range of 0 for object-to-mouth events. The child with the highest number of smooth surface contacts had a range of 61 to 366 events per hour had a range of 0 to 12 hand to mouth contacts per hour. Perhaps there is value to picking the highest values for purposes of screening level assessments. However, OPP has reservations about the mass balance of time with respect to hand-to-mouth, and object-to mouth events.

Lu and Fenske (1999) discussed Gurunathan's use of percent transfer of surface residues of 75% and 100% to the hand from surfaces and toys respectively. The authors noted " the study extrapolated environmental concentrations to child doses though a series of worst-case assumptions. Among these were that skin contact with furniture removed 75% of surface residues, and that skin contact with toys removed 100% of total residues in or on the toys. The results of our study present a contrasting picture, as indicated, skin contact was able to remove <1% of the chlorpyrifos deposited on carpets and able to remove 4 to 22% of the chlorpyrifos deposited on furniture."

**The Agency is considering the use of this model if realistic residue removal efficiencies as suggested by Lu and Fenske (1999) are used.
In addition, a ratio of hand-to-mouth and object-to-mouth events is needed.**

4 Issue 4: Calculating Exposure to Pesticides that May Result from Track-in, Bathing or Showering

The initial emphasis of OPP's Residential SOPs was to address potential exposures that may occur during and immediately following the purposeful use of a pesticide. Comments on OPP's residential SOPs, however, have argued that they are deficient because they did not consider exposure that occurs when pesticide residues are tracked into the home or are present in water used for bathing or showering. This chapter describes the scientific literature concerning both pathways and two new algorithms that could be used for estimating the exposure that could occur by each pathway.

OPP routinely estimates amounts of pesticide residue that may be present in drinking water as the result of leaching into groundwater and runoff into surface water sources of drinking water. People may be exposed to residues in water both by drinking water or consuming foods made with such water (e.g., coffee or orange juice prepared from frozen concentrate) and by showering or bathing in such water. OPP has long used models for estimating the exposure to residues in drinking water, but does not similar models for showering and bathing. EPA's Office of Water has a peer-reviewed model that they have used to generate reasonable upperbound estimates of exposure resulting from showering or bathing. OPP is adding that model to its Residential SOPs. See sec. 5.1.

Another potential pathway of exposure to pesticides, particularly for children, is through the movement of residues resulting from outdoor use into the home where the residues then become part of house dust. Available data strongly support the conclusion that pesticide residues become part of house dust when occupants track the residues into a building after having contacted pesticide-treated turf. (Various human activities could then lead to contact with and subsequent ingestion or dermal absorption of house dust that contains such pesticide residues. OPP would use the dermal exposure algorithm using the "Jazzercise transfer coefficient" and the hand-to-mouth algorithm to calculate the amount of house dust that could come into contact with and contribute to human exposure. See chapters 3 and 4.) As explained more fully below, a recent study has provided the basis for a quantitative estimate of the portion of turf residues that can eventually become a part of house dust. This study and other information indicate that indoor loadings of pesticide (in house dust) will be approximately 0.03% of the measured or estimated "transferable residues" present on turf following outdoor use. See sec. 5.2. Using the information presented in Nishioka et al., 1996, OPP will develop a new algorithm for estimating the contribution of house dust to overall exposure.

OPP requests that SAP comment on whether the proposed algorithm is appropriate to estimate both the amount of residues transferred from turf to house dust and the eventual contribution of house dust to overall exposure. If the algorithm is judged appropriate, OPP thinks that the overall contribution of this pathway is too small to justify routine evaluation.

The initial emphasis of the Residential SOPs was to address potential exposures that may occur from the purposeful use of a pesticide. Exposure potential from track-in or residues following residential applications and showering with pesticide contaminated water were not considered. The decision was based primarily on the assumption that these pathways were not expected to result in exposures comparable to those currently being evaluated as a result of direct exposure from the intentional use of a pesticide. Unintentional exposures that may result from showering with pesticide contaminated water or from postapplication exposure to residues caused by drift from residential applications are being considered in the revision of the SOPs. However, in a recent SAP meeting on aggregate exposure, it was pointed out that while exposure scenarios should be enumerated, they may not necessarily be included in an aggregate assessment, if those estimates prove to be of low significance.

4.1 Bathing/Showering

A model addressing exposure while showering is under development and not available for review at this time. The model is based on an approach used by the Agency in other programs, such as Superfund, and relies on physical/chemical properties of the pesticide and other parameters currently used in the SOP for addressing swimmer exposure.

4.2 House Dust

OPP has reviewed four studies that provide data that assist in a qualitative assessment of the contribution of house dust to overall exposure. Briefly, these studies show that house dust residues are relatively small compared to residues of pesticides remaining on surfaces. Residues on or in house dust comes from a variety of potential sources including track-in of transferable residues from applications made outside of the home, previous indoor applications, and migration of residues from agricultural fields, playgrounds, golf courses or similar sites. Migration of house dust from lawn applications correlating with household entry activity patterns of residents has been documented (Nishioka et al, 1999). House dust measurements have been observed to decrease over time as noted in Nishioka et al. (1999) and Lewis et al. (1994).

Investigators typically sample houses at the entryway and areas where children play. In some cases these data are pooled so it is difficult to know the concentration where children play and the extent of the area of contamination throughout the household's in those studies. Furthermore, the bioavailability of the residues in house dust has been questioned by investigators such as Simcox et al. (1995) and Bradman et al. (1997). The fact that some dusts may be situated in the carpet backing, and that residues may be strongly bound to soil or other particulates may influence the ability of the residues to be absorbed in the gut. Some investigators have suggested that house dust is of primary concern via the non-dietary ingestion pathway (Leidy, 1993). However, traditional methods to estimate potential exposure to children by using soil consumption estimates do not appear to be appropriate for estimating exposure to soil in households that need to be removed by exhaustive vacuuming and sieving.

Investigators collecting data on house dust concentrations typically rely on four measurement methods: The HVS3, PUF roller, hand press, and actual hand rinses from children living in homes contaminated with pesticides.

The High Volume Small Surface Sampler (HVS3) is a modified vacuum cleaner used to collect carpet dust from a known surface area. Values are expressed as μg/g (ppm) and also expressed as mass loading $\mu g/m^2$. Mass loading $\mu g/m^2$ = concentration of pesticide (μg/g) x grams of dust collected ÷ m^2 of the carpet area sampled. As already stated, the PUF roller and hand press (palm) may also be used, as well as the occasional child's hand rinses, when feasible.

House dust is a complicated substance consisting of many ingredients such as:

- ash (incinerator, cigarette)
- combustion products and oil soot
- fibers (synthetic, wool, cotton, paper and silk)
- fingernail filings
- food crumbs
- hair (human and animal)
- skin scales (human and animal)
- soil and other particles (stone, limestone, paint chips)
- fungal spores and pollen (Olkowski et al., 1991)

The collected dust is typically sieved to eliminate particles greater than 150μm. Analysis of dust is challenging due to many analytical interferences with waxes and other substances (Lewis et al., 1994, 1995).

- Lewis R.G., Fortmann D.E., and Camann D.E., Evaluation of Methods for Monitoring the Potential Exposure of Small Children to Pesticides in the Residential Environment, 1994, Archives of Environmental Contamination and Toxicology, 26, pages 37-46.

In a pilot study of 9 homes, concentrations of pesticides were identified in all houses except one, The highest concentrations of those pesticides were measured in house dust. Among the most frequently detected pesticides in those homes was chlorpyrifos. In a home that had been treated with chlorpyrifos, house dust residues (expressed as loading $\mu g/m^2$ and as ppm) declined from 0.30 $\mu g/m^2$ and 4.3 ppm at two days after application to 0.11 $\mu g/m^2$ and 2.9 ppm 8 days after application and 0.07 $\mu g/m^2$ and 2.1 ppm 15 days after application. These findings suggest that pesticide residues including those bound to dust decline or perhaps are removed over time.

At four of the nine homes, hand rinses to remove residues from children's hands were collected after the child had been at home for at least one hour. However, the investigators were unable to determine when the hands had been washed prior to the sample visit. Comparisons were made between the four samples on a nanogram per square centimeter of surface basis.

Table 28. Comparison of Surface Loadings on Children's Hands with Carpet Loadings, PUF Roller and Hand Presses/ (ng/cm^2)

Age of house	Pesticide	child's hands	carpet loading HVS3	PUF roller	hand press
1962	chlordane	1.2	1.6	1.5	0.4
	heptachlor	0.32	0.42	0.42	0.1
	pentachloro-phenol	0.06	0.02	0.04	0.04
1973	chlorpyrifos	0.21	0.44	0.64	0.1
	dieldrin	0.01	0.04	0.05	ND
1985	heptachlor	0.03	0.03	0.43	0.04
1987	pentachloro-phenol	0.09	0.02	0.11	ND

ND = not detected

As pointed out by the authors, there was relatively good agreement between the estimated loadings on children's hands and transferable residue measurements obtained by the other methods. This observation suggests that measurements with methods like the PUF roller can be used to estimate hand loading concentrations for potential non-dietary ingestion.

The authors considered estimating exposure via ingestion of soil at a rate of 100 mg/day citing literature values of 10 mg to 10 g by sources such as

Calabrese et al., 1989. However they noted those values are based largely on ingestion of outdoor soil rather than house dust. They suggest while children play indoors more than outdoors, there is no data available to estimate the amount of indoor dust a child may ingest. Estimates of ingestion for chlorpyrifos and chlordane were based on 100 mg dust ingested per day. The dose estimates ranged from 0.04 to 0.29 μg/kg/day and 0.03 to 0.27 μg/kg/day respectively.

In order to assess children's exposure to house dust contaminated with pesticides, we need a method to estimate how much residue from outdoor applications can be tracked-in.

❑ Measuring Transport of Lawn-Applied Herbicide Acids from Turf to Home: Correlation of Dislodgeable 2,4-D Turf Residues with Carpet Dust and Carpet Surface Residues: M. Nishioka, H. Burkholder, M. Brinkman, S. Gordon and R. Lewis; Environmental Science and Technology, Vol 30, No. 11, 1996.

The investigators evaluated the concept of track-in by designing a study where study participants walked over turfgrass treated with 2,4-D and Dicamba. After walking over treated grass, the cohorts either wiped their feet on mats or carpet situated on wooden platforms. The authors pointed out they intended to predict measurements of 2,4-D they found in an earlier study of 2,4-D dust measured in suburban homes. The data from that study is presented in the following table:

Table 29. Comparison of 2,4-D Levels in Suburban House Dust

HOME	Number of Children	Dust Concentration μg/g (ppm)	Area Loading $\mu g/cm^2$
1	5	4.85	0.000089
2	2	0.19	0.000032
3	1	0.62	0.000031
4	2	0.09	0.000019
5	2	0.15	0.000013
6	4	0.25	0.000012
7	2	0.05	0.000007
8	0	0.16	0.000002
9	0	0.97	0.000003

Turf transferable residues were reported as 0.1 - 0.2% of turf application levels using the PUF roller. Transfer of herbicides from turf to carpet dust was 3% of the turf transferable residues (PUF Roller). According to the authors, this study, based on number of footsteps and shoe sizes, showed that approximately 83% of the available turf area could have been covered by walking. The PUF roller appeared to contact soil to a limited extent. In contrast, the dirty footprints on the carpet in the study suggested that human track-in may result in the track-in of soil-bound residues in addition to turf residues.

In the study, levels of 2,4-D deposited on turf were reported at 26.7 $\pm$ 10. mg/m^2 or 2.67 $\mu g/cm^2$. This suggests that transferable residues of 2,4-D range from 0.003 to 0.005 $\mu g/cm^2$ and that of these residues, 3 percent are available as carpet dust or 0.0001 to 0.0002 $\mu g/cm^2$. These values approach the high value found in one of those suburban homes.

Dr. Robert Lewis in a letter to the Editor of the American Journal of Health suggests "low-cost methods are available for reducing track-in and exposure to house dust. These include removal of shoes at the entryway, use of well-designed doormats (33% reduction), efficient vacuuming cleaning, and proper use of air filters." (American Journal of Public Health, August 1995)

Other house dust measurements were collected as part of the Nonoccupational Pesticide Exposure Study (NOPES) conducted in two east coast metropolitan areas, Jacksonville, Florida and Springfield/Chicopee, Massachusetts. The Florida site was identified as a high pesticide use area. The primary focus of NOPES was on airborne concentrations of pesticides. However, a paper published in the Archives of Environmental Contamination and Toxicology presented indoor dust concentrations of selected pesticides from households in the Jacksonville, Florida area. Those concentrations were presented in the following paper:

❏ "Non-Occupational Exposure to Pesticides for Residents of Two U.S. Cities: R.W. Whitmore, F.W. Immerman, D.E. Camann, A.E. Bond, R.G. Lewis, J.L. Schaum; Arch. Environ. Contam. Toxicol. 26, 47-59 (1994).

In the study, levels of pesticides in carpet dust were measured (10 of 11 carpets had pesticide residues) in 9 homes and presented in the following table:

Table 30. Levels of Pesticides Detected Most Frequently in Carpet Dust (NOPES)

Analyte	Number of times detected in dust	Median of detectable μg/g	Mean of detectable μg/g	Mean air concentration μg/m3
Chlorpyrifos	11	4.7	1.3	0.31
Diazinon	9	0.4	1.7	0.01
Carbaryl	5	1.6	1.4	ND
Propoxyur	9	0.6	1.6	0.03
Atrazine	2	0.7	0.7	ND
Heptachlor	10	0.3	1.3	0.11
Aldrin	10	0.4	0.4	<0.01
Dieldrin	10	0.5	2.2	0.23
Chlordane	10	6.3	14.9	0.45
DDT	9	0.7	1.2	<0.01
Ortho-phenyl phenol	10	1.3	0.8	0.02

The mean values were elevated by residues found in an 18 year-old carpet, which had chlordane at 98.6 μg/g, chlorpyrifos at 21.9 μg/g, dieldrin at 18.2 μg/g and DDT at 6.3 μg/g. There was a one year old carpet in the same house as the 18 year old carpet which had relatively high levels of pesticides. The authors suggest this may be from cross-contamination from the older carpet.

❑ Distribution of 2,4-D in Floor Dust throughout Homes Following Homeowner and Commercial Lawn Applications: Quantitative Effect of Children, Pets, and Shoes; Nishioka M.G., Burkholder H.M., Brinkman M.C. and Lewis R.G.; Prepared for submission to Environmental Science and Technology June 1998 and revised January 1999.

In the two year study, the authors measured lawn-applied 2,4-D after applications were made. In the first year, the pesticide applications were made by the residents themselves. In the second year, the applications were made by professional lawn care operators (LCO). Thirteen household in the Columbus, Ohio area participated. Concentration gradients of 2,4-D from the household entryway and throughout the house were identified in this study. The authors suggest that the gradients represent the pathways taken by the residents.

Removal of shoes at the door and the macro activities of the children and pets, were the most significant factors affecting residue levels found indoors after the 2,4-D application was made. Spray drift and fine particle intrusion reportedly accounted for very little of the residues on floors. Median bulk floor dust loading was 0.00005 $\mu g/cm^2$ prior to the application and 0.00005 to 0.0002 $\mu g/cm^2$ in unoccupied homes one week after spraying by the LCO. In occupied homes, the median floor level in the living room was 0.0006 $\mu g/cm^2$ with a range of 0.0001 to 0.023 $\mu g/cm^2$. The authors assert, the transferable residue/dust was highly correlated with the bulk dust loadings and estimate that approximately 1% of the bulk dust measurements have the potential for dermal contact.

An important point in the above abstract was the limited effect of spray drift and fine particle intrusion noted in the study. This finding is consistent with findings by Solomon et al. (1992) where urine analysis of 2,4-D in bystanders living downwind from 2,4-D applications to lawns were non-detects.

In most cases, attempts to estimate exposure to tracked in residues will be made using the methods outlined by Nishioka et al., 1996. Movement throughout the household can be estimated using the information provided in Nishioka et al. (1999). However, in most cases, we believe the magnitude of concentration and subsequent exposure estimates from house dust contaminated with pesticides will be considerably lower than estimates made using transferable residues following conventional uses of pesticides.

5 Issue 5: Residential Exposure in Agricultural Areas - Children of Farmers and or Farm Workers

Drift from agricultural applications has the potential to be a source of non-occupational exposure to pesticides that are not marketed to the general public. Recent research has suggested that households in close proximity to farms have higher levels of agricultural pesticides in house dust. Measurements of urinary metabolites of organophosphates have also been identified in children living in close proximity to orchards having one or more parents involved in agricultural operations. These studies provide insight but not necessarily answers regarding this potential pathway since the bioavailability of pesticide contaminated house dust has not been established. In addition, biological monitoring with concurrent environmental sampling (dust, dislodgeable residues, air concentrations or residues in food) was not performed in any of the studies discussed in this section.

The Agency proposes to address this potential exposure pathway using deposition values taken from a spray drift model. The deposition values from the spray drift model, together with assumptions about transferability, may be used to estimate percent dislodgeable/transferable residues from turfgrass. These residues may be used with post application dermal exposure models and subsequent hand-to-mouth models to estimate exposure . Track-in will be addressed as previously discussed. If contaminated house dust proves to be a significant pathway, non-dietary ingestion estimates for certain periods of time may be needed to address this potential chronic scenario. For persons directly exposed to spray drift, surrogate exposure data based on exposure studies for flaggers (individuals guiding aircraft during aerial applications of pesticides) can be used with values from the spray drift model. Direct exposure to drift is presented in Issue 6.

❑ Pesticides in Household Dust and Soil: Exposure Pathways for Children of Agricultural Families; N. Simcox, R. Fenske, S. Wolz, I-Chwen Lee, and D. Kalman; Environmental Health Perspectives, 12/95, Vol 103, Number 12, pages 1126-1134.

Measurable residues of azinphos methyl were identified in 59 study homes in a major eastern Washington State orchard crop region (26 farming, 22 farm worker, and 11 non-farming or “reference” families). Azinphos methyl (Guthion) was the most recently applied pesticide (83%) by the farmers and was found in 100% of the dust samples and in 21% of the soil samples. Chlorpyrifos was applied 2 to 3 months previously, by 57% of the farmers, yet elevated soil levels of chlorpyrifos were not found. Phosmet was reportedly used by 22% of farmers, confounding the possibility of detecting differences between groups with respect to proximity.

Behavioral aspects of the individuals living within 200 feet of a farm:

- 69% were less than 50 feet from an orchard;
- ~85% vacuumed once or more than once per week;
- 33% had pets that go in and out of the house;
- 28% remove shoes and 69% have walk-off mats

The authors suggest likely sources of children's exposure not directly related to agricultural tasks are from contaminated soil, dust, work clothing, water and food, and drift. Pesticides have the potential to be tracked into the residence via shoes and pets and become part of the household dust "reservoir". OP's commonly applied in the study region include azinphos-methyl, chlorpyrifos, phosmet, and ethyl parathion (until its cancellation in 1991 (use of existing stock through 1992 season)).

Household dust was collected using high-volume, small-surface sampler (HVS-3) from two carpeted or rug covered areas in each of the homes (3 ft inside entryway and where children commonly played). Dusts were collected and sieved through 150-μm stainless mesh. Measurements are expressed as concentration of pesticide (ng/g) and mass loading where $\mu g/m^2$ = (ng/g) x grams of dust collected/m^2 of carpet x 1μg/1000 ng). These values were converted to $\mu g/cm^2$ when presented in table 28.

The mean outdoor soil concentrations(ng/g or ppb) of AZM in soil were **<32** for farm workers, 84 for farmers, and <**32** for reference families.

The mean soil concentrations (ng/g or ppb) for Chlorpyrifos in soil were **14** for farm workers, 38 for farmers, and **11** for reference families.

It appears that the soil concentrations of the farm worker families and the reference families were similar.

Table 31. OP Concentrations in Household Dust (μg/g (ppm))

Pesticide	Ag Family (n=48)	Ref Family (n=11)	Farmers (n=26)	Farm worker (n=22)	Applicator (n=28)	Nonapplicators (n=20)
Azinphos methly (AZM)						
mean	1.87	0.33	2.09	1.62	1.96	1.76
median	1.1*	0.28*	1.32	0.95	1.23	0.769
range	0.17-11.27	0.13-0.82	0.17-6.52	0.180-11.27	0.171-6.52	0.179-11.27
frequency	48(100)	11(100)	26(100)	22(100)	28(100)	20(100)
Phosmet						
mean	2.8	0.23	1.7	2.54	2.11	2.14
median	0.52	0.19*	0.42	0.52	0.52	0.52
range	<0.012-17.1	0.073-0.658	<0.012-14.5	0.019-17.1	0.006-17.1	0.006-14.5
frequency	46(96)	11(100)	24(92)	22(100)	27(96)	19(95)
Chlorpyrifos						
mean	0.43	0.17	0.51	0.34	0.51	0.32
median	0.27*	0.053*	0.37	0.17	0.395++	0.16++
range	<0.017-3.59	<0.017-0.48	<0.017-3.59	0.040-2.18	0.008-3.59	0.040-2.18
frequency	47(98)	9(82)	25(96)	22(100)	27(96)	20(100)
ethyl parathion						
mean	0.37	0.076	0.59	0.098	0.52	0.32
median	0.15*	<0.011*	0.31	0.020	0.27++	<0.011++
range	<0.011-2.79	<0.11-0.425	<0.011-2.79	<0.011-0.44	<0.011-2.79	<0.011-1.85
frequency	33(69)	3(27)	22(85)	11(50)	25(89)	9(45)

*significant difference across groups: azm *p*=0.001; chlorpy, *p*=0.01; para, *p*=0.02 (Mann-Whit U). +Significant difference :ethyl parathion, *p*=0.00007 (Mann-Whitney U test).

++ Significant difference: chlorpyrifos, *p*=0.02; ethyl parathion,*p*=0.0003 Mann-Whitney U test).

Table 32. OP Mass Loading ($\mu g/cm^2$): both samples (entryway and play area) were pooled by investigators

Pesticide	Ag Family (n=48)	Ref. Family (n=11)	Farmer Family (n=26)	Farm-worker Family (n=22)	Applicator Family (n=28)	Non-Ap Family (n=20)
Azinphos methyl						
mean	0.00166	0.00014	0.00166	0.00167	0.00193	0.00137
median	0.00099	0.000083	0.00107	0.0008	0.0014	0.00058
range	0.00008 - 0.0873	0.000039 - 0.000318	0.00008 - 0.0088	0.00011 - 0.0051	0.00008 - 0.0088	0.00013 - 0.0051
Phosmet						
mean	0.00271	0.000091	0.00184	0.00361	0.00268	0.00275
median	0.0003	0.000094	0.00021	0.00084	0.00052	0.00025
range	<MLOQ - 0.0289	0.000021 - 0.000193	<MLOQ - 0.0289	0.00002 - 0.0222	<MLOQ - 0.0289	<MLOQ - 0.0164
Chlor-pyrifos						
mean	0.00048	0.000059	0.00041	0.00054	0.00057	0.00035
median	0.00019	0.000047	0.000162	0.0002	0.00027*	0.00012*
range	<MLOQ - 0.00277	<MLOQ - 0.000162	<MLOQ - 0.00 25	0.000009 - 0.0028	<MLOQ - 0.00247	0.000012 - 0.00277
Ethyl parathion						
mean	0.0003.9	0.000035	0.00052	0.00024	0.00051	0.00022
median	0.00012	<MLOQ	0.00025	0.000057	0.00027*	0.000005*
range	<MLOQ - 0.00204	<MLOQ - 0.000243	<MLOQ - 0.0020	<MLOQ - 0.0017	<MLOQ - 0.00204	<MLOQ - 0.0017

Method Limits of Quantitation (MLOQ) in dust (ng/g): AZM - 40; phosmet - 12; chlorpyrifos - 17; ethyl parathion - 11; used ½ MLOQ for statistical analysis.
***** significant differences across groups: chlorpyrifos, p=0.04; parathion, p = 0.002 (Mann-Whitney U test).
Ag families combines data from farmers and farm workers groups.
Apps and non apps are groups within the Ag family group if engaged in handling activities.

The authors noted, “It is unclear whether the loading values obtained with the HVS-3 are representative of residues available to young children.”

A comparison of the individual measurements with respect to the entryway and play areas would provide interesting insight into the magnitude of track-in as in Nishioka et al., 1999. However, this is not possible because the data from the entryway and play areas were pooled. Of particular, interest in the data as presented was the difference between the house dust measurements of the houses of farmers and those of the farm workers.

❑ Pesticide Exposure to Children from California’s Central Valley: Results of a Pilot Study: M. Bradman, M. Harnly, W. Draper, S. Seidel, S. Teran, D. Wakeham, and R. Neutra; Journal of Exposure analysis and Environmental Epidemiology, Vol. 7. No. 2, 1997, pages 217 - 234.

In this study, researchers used the HVS3 vacuum with filters rather than the cyclone system typically used with the HVS-3 sampler due to too much turbulence caused by the vacuum when using the cyclone system. Like Simcox et al. (1995), the authors also questioned the bio-availability of dust measurements. The researchers selected 11 houses with five having at least one member of the household that was a field worker. The area sampled was south of Fresno.

Table 33. Pesticide Dust Concentrations in Homes in Agricultural Areas

Site	Surface sampled	Diazinon Con-centration $\mu g/g$	Diazinon Loading $\mu g/cm^2$	Chlorpyrifos Con-centration $\mu g/g$	Chlorpyrifos Loading $\mu g/cm^2$
FW home#9	carpet	20	0.0149	0.23	0.00017
FW home#9	sofa	4.9	0.00076	ND	ND
FW home#7	Linoleum	169	0.007	33	0.00052
FW home#3	carpet	0.7	0.0022	0.23	5.2
FW home#1	carpet	1.0	0.0031	ND	ND
NFW home#8	wood floor	0.19	0.000029	0.71	0.00011
Day Care Center#6	carpet	0.1	0.00017	ND	ND
hand measurement ng/hands for one child at houses 1, 7, and 9		#9 220 #7 125 #1 52		#9 ND #7 100 #1 20	

There were non-detects in hand rinses from two farmworker children and non-detects for six non farm worker children. House #1 was vacuumed 1 day before sampling, House #3 was vacuumed 7 days before sampling, House #7 (migrant housing) was mopped two days before sampling, House #9 was swept the day of sampling, House #10 was vacuumed 1 day before, and the day care center was vacuumed the day of sampling. The activities of the children for which there are hand measurements were not reported.

Given the potential variety of pathways that may contribute to exposure to agricultural chemicals, biological monitoring is a good way to confirm the magnitude of exposure anticipated from those sources. Since biological monitoring accounts for all routes of exposure (dietary, non-dietary, drinking water, inhalation and dermal), some view biological monitoring as the ultimate aggregation tool. However, unless environmental measurements and concurrent dermal and inhalation exposure measurements are taken, it is impossible to attribute the contribution of any one of those routes to total dose.

- ❑ Biological Monitoring of Organophosphorus Pesticide Exposure Among Children of Agricultural Workers in Central Washington State: C. Loewenherz, R. A. Fenske, N. J. Simcox, G. Bellamy, and D. Kalman; Environmental Health Perspectives, Vol 105, No. 12, December 1997.

  The study was conducted in the Chelan-Douglas County area of Washington State in June and July of 1995. Families were recruited based on having at least one child no older than six years, with other criteria including distance of home from orchard (< and > 200 ft.)and parental occupation (field worker or applicator, and non-agricultural) also being considered. However, a population of pesticide handlers living within 200 feet of an orchard could not be identified, so the study design was reduced to a single population of farm workers and farmers and a reference population. Approximately 21% of the households included more than one person employed in agriculture including field workers (thinning, picking, and bagging fruit) which have a high potential for exposure comparable to handlers (mixer/loaders and applicators) of pesticides. Applicators reported using at least one dimethyl OP (77%) and 38% reported using more than one. The most common (75%) was azinphos methyl (guthion/AZM). Many of the applicators (63%) sprayed within 200 feet of their homes at least once during the season. AZM applications timed with sampling ranged from the day of sampling to a maximum of 80 days. There was some discrepancy regarding the question of use meaning one application consisting of either days or events (one event may be more than one day).

  Characteristics of the study cohorts are:

  - ❑ 60 percent of applicator households lived within 50 feet of the orchard;
  - ❑ 17 percent of applicator households lived between 50 and 200 feet;
  - ❑ 8 percent lived 200 to 1/4 mile from the orchard;
  - ❑ 15 percent lived greater than 1/4 mile (reference population).

  Since this study focuses on young children, the participants in this study are expected to have similar micro activity patterns (such as hand-to-mouth) to those of the children observed by Reed et al. (1998), Zartarian et al. (1995, 1997) and Freeman (unpublished).

Table 34. Dialkylphosphate Metabolite Analysis - Dimethylthiophosphate (DMTP) concentrations in urine (μg/ml) of applicator and reference children by age of child

	Applicator Children		**Reference Children**	
Age (years)	Visit 1	Visit 2	Visit 1	Visit 2
		0-2		
Mean	0.028	0.045	0.017	0.026
Median	0.015	0.034	0.009	0.010
CV	136%	91.1%	182%	138%
Range	ND - 0.14	ND - 0.126	ND - 0.004	ND - 0.035
Number	19	20	8	3
		3-4		
Mean	0.029	0.059	0.020	0.015
Median	0.009#	0.033*#	0.005	0.009
CV	186%	168%	170%	120%
Range	ND - 0.196	ND - 0.435	ND - 0.070	ND-0.035
Number	25	25	4	3
		5-6		
Mean	0.025	0.035	0.004	0.021
Median	0.009	0.009*	0	0
CV	168%	171%	125%	224%
Range	ND - 0.176	ND - 0.189	ND - 0.009	ND - 0.104
Number	19	20	5	5

*Marginally significant difference for 3-4 year old and 5-6 year old applicator children $p = 0.060$ (Mann-Whitney U test).
#Significant differences across visits: $p = 0.047$ (Wilcoxon Signed Rank test).

Three applicators brought AZM home from work to use in the garden (a misuse). Two of the three children having DMTP concentrations greater than 0.2 μg/ml lived at these households. The dose estimated from this urinary concentration is as follows:

0.2 μg/ml * 500 ml (excreted/day) * 1.86 (MW ratio AZM 317/DMTP 170) ÷ 15kg =

12.4 μg/kg/day

EPA does not have access to the raw data from this study and find these two observations noted by the authors of considerable interest:

> 1) What would the difference be between the averages of reference population and the applicator children if the two values, potentially due to illegal use were removed? It is not clear if AZM was used in the garden thus contributing to dietary or used on some other manner.
>
> 2) There were increases in DMTP observed among both populations (farm and non-farm) by the end of the sampling period. Since OP's such as azinphos methyl and phosmet have been used in the study area for years, it can be hypothesized that levels of DMTP in both populations can be expected to fall after the spray season is over.

Many investigators relying on urinary metabolites for measuring dose correct for creatinine excretion. Esteban et al., 1996, suggests "Because the hydration state of the subject can affect the concentration of para nitrophenol (p-np) in the subject's urine, in this investigation we used creatinine corrected p-np (cp-np)" The measurements from Lowenhertz were also corrected for creatinine excretion and presented in the Journal as follows:

Table 35. Creatinine Adjusted DMTP (μg/g) in Applicator and Reference Children for Both Visits Combined

All Children	Applicator Kids (N-121)	Reference Kids (N-32)
mean+	0.097	0.043
median	0.03	0.000
CV	231%	221%
range	ND-2.006* (*0.0794μg/kg/day)	ND-0.493
frequency	58 (48%)	7 (28%)
Focus Children (one per household)	Applicator Kids (N-89)	Reference Kids (N-25)
mean	0.094	0.04
Median	0.037**	0.000**
CV	166%	253%
range	ND-0.768	ND-0.493
frequency	45 (51%)	7 (28%)

** Significant Difference p=0.011 Mann Whitney U Test and p=0.041 Chi^2 Test.
+ Mean includes trace values = ½ LOD.
*Dosages can be calculated as follows:

2.006 DMTP/gram creatinine * 0.32 grams creatinine excreted/day[a] * 1.86 (ratioAZM/DMTP)/ 15 kg bw
= 0.0794 μg/kg/day

[a]According to the Task Force for the Reference Man, children excrete 0.08 grams of creatinine per day per year of age up to age 7. Thus, a four-year old, as estimated above would excrete 0.32 grams per day.

The Agency proposes to address near farm exposures by using drift deposition estimates generated by the AgDrift model. The Environmental Fate and Effects Division (EFED) is currently in the process of developing deposition estimates based on Spray Drift Task Force data for aerial, orchard airblast and groundboom applications. The results are expected to be similar to the AgDRIFT model, but EFED has not defined a deposition level at the edge of the orchards because there are little or no data for edge-of-orchard and in-orchard deposition levels. EFED's proposed method; which was presented to the SAP on July 23, 1999, estimates the 95th percentile deposition value at 25 feet downwind of orchards with high drift potential to be 15%. The Health Effects Division intends to evaluate EFED's deposition estimates after they have undergone SAP review and use them as appropriate in estimating exposure levels.

Although the Agency plans to address exposure to drift by starting with deposition measurements estimated by AgDRIFT, there are several possible pathways and potential routes for exposure. Certainly we can predict levels observed by Lowenhertz et al. (1997), using dermal exposure models such as Jazzercise™ and assumptions regarding deposition and transferability. However, it is unclear if the doses measured by Lowenhertz were due to:

1) Exposure from direct contact by drift while applications were made;

2) Exposure to residues on lawns or play areas from off-site drift;

3) Exposure to contaminated indoor surfaces as a result of track-in of residues from lawns or play areas and/or take home residues;

4) Exposure from increased consumption of local produce;

5) Exposure to seasonal airborne concentrations of pesticides.

If the exposure is due to exposure to residues drifting on play areas, model imputs such as a transfer factor of 8,700 cm^2/hr (Jazzercise™ transfer factor from the current SOP scaled for a child's surface area) and 5% transferable residues of the off-site drift deposition and the Agency's dermal absorption rate of 43% for azinphos methyl.

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1 lb ai/acre (azinphos methyl rate) = @ 11.209 $\mu g/cm^2$

15%[a] = 1.7 $\mu g/cm^2$

1.7 $\mu g/cm^2$ x 5% transferability[b] x 8,700 cm2/hr[c] x 0.33 hr[d] x 43% dermal absorption[e] ÷ 15 kg[f] = @ 7 μg/kg/day

---

[a]Percentage of applied rate assumed to drift off-site [represents 95th percentile value of spray drift measurements, taken 25 feet downwind from application site].
[b]Amount of deposited pesticide available for human exposure through dermal contact (see Chapter 2).
[c]Transfer coefficient for children derived from adult Jazzercise™ activity and scaled to child's surface area (see Chapter 3).
[d]20 minutes of Jazzercise™.
[e]Dermal absorption of dermally deposited dose, assumed to be 100% unless value derived from animal dermal absorption study is available.
[f]Average weight of a 2 to 3 year old child.

To address non-dietary ingestion:

1.7 $\mu g/cm^2$ x 5% transferability x 400 cm^2[a] 2 hr ÷ 15 kg = 4.5 μg/kg/day or 2.3 μg/kg/day with 50% saliva extraction.

combined dermal and non-dietary ingestion exposure = 11.5 μg/kg/day (9.2 with 50% saliva extraction)

---

[a]400 cm^2 per hour is based on the pamlar surface area of two to three fingers and an frequency of hand-to-mouth exposure of 20 times per hour.

The estimates presented above appear similar to the high dose estimates reported by Lowenhertz et al. (1997) when the data were corrected for daily urinary volume excretion. However, when the data are corrected for creatinine clearance, internal dose estimates are several orders of magnitude lower. In an unpublished study currently in draft, Moses et al., measured urinary alkylphosphate metabolites for the same pesticide in farmworkers and their children working in agricultural regions from Florida to Ohio. When corrected for creatinine, Moses' values suggest levels similar to those reported by Lowenhertz et al. (1997). However, the urinary metabolite DMTP is an indicator of exposure to azinphos methyl, methyl parathion, malathion, dimethoate and methidathion. It can not be determined which pesticides the cohorts in Moses et al., were exposed to, as those measurements were not reported and were made during the 1990-1991 growing season.

While exposure estimates approaching real world doses from biological monitoring studies can be made, it is likely this is a coincidence. Other approaches may include the use of estimates of depostion, transferability and track-in ratios and non-dietary ingestion rates of contaminated house dust for a seasonal durations such as were shown in Lowenhertz.

Although exposures of individuals living near farms may be estimated using these simple algorithms, real world exposure monitoring of subpopulations living near agricultural operations is recommended. The Agency is currently conducting the following studies to assess these exposures:

Table 36. Anticipated Research to Assess Exposure to Farm Families

Title	Principle Investigator and Institution
Exposures of Health of Farm Worker Children in California	Brenda Eskenazi University of Southern California
Exposure of Children to Pesticides in Yuma, Arizona	Mary Kay O'Rourke University of Arizona
Total Organophosphorous Pesticide Exposure Among Children in Urban and Rural Environments	Richard Fenske University of Washington

6 Issue 6: Direct Exposure to Drift

This section addresses the possible exposure that an individual might experience as a result of drift of agricultural pesticide use into neighboring residential areas.

An approach to this potential pathway is to use unit exposure measurements from the Pesticide Handlers Exposure Database (PHED). The PHED subset for flagger exposure to liquid applications should be used. Unit exposures are expressed as micrograms exposure per pound active ingredient applied. This unit exposure measurement can be coupled with the percent drift offsite provided in AgDRIFT. The exposure scenario is based on dermal and inhalation exposure measurements of flaggers guiding aircraft into fields for pesticide applications.

The Agency proposes to develop upper bound estimates of exposure to people exposed directly through drift of pesticides by assuming that an individual is 25 feet from the edge of the field, and experiences exposure equal to a pesticide flagger, as reflected in PHED.

For dermal exposure, the total deposition (measurements made on the outside of clothing) is 52.8 μg/lb ai the individual is exposed to. The distribution of exposure for the flag set suggests 10% is to the head with approximate 84 percent to the upper and lower arm, chest, back, thigh and lower leg. Hands make up for the rest of the dermal exposure at approximately 5 percent. The amount estimated on the hands can be used to estimate non-dietary ingestion from hand-to-mouth events.

The potential exposure (total deposition):

$$52.8\ \mu\text{g/lb ai}^{a}\quad 1\ \text{lb ai}^{b}\quad 15\%^{c}\quad 1\ \text{acre}^{d} \div 70\ \text{kg}^{e}\quad 43\%\ \text{dermal absorption}^{f}$$
$$= 0.05\ \mu\text{g/kg/day}$$

PHED also has unit exposures for the inhalation exposure pathway that also will be used.

[a]Unit exposure from PHED
[b]Application rate for azinphos methyl
[c]Off-site drift
[d]area assumed to be adjacent to sensitive area
[e]body weight of an adult (these will be scaled for children)
[f]dermal absorption rate for azinphos methyl

For exposures of a given population living in an agricultural area, iInhalation exposure can be estimated using information provided by the California Department of Pesticide Regulation.

The California Department of Pesticide Regulation's Toxic Air Contaminant (TAC) Program routinely conducts air monitoring studies for the TAC program. The air monitoring is conducted by the California Air Resources Board (ARB). Reports from this program include one ambient study and one application site study. ARB staff collects a series of 24-hour samples at approximately three to five locations. These locations are usually schools or other public buildings in communities near agricultural areas expected to receive applications of the pesticide to be monitored. The samples are collected for four days per week for five or more consecutive weeks.

During the application-site study, samples are collected immediately before, during, and for approximately 72 hours after the pesticide application. For each study, ARB positions four samplers around the perimeter of the treated field. Each monitor is approximately 20 meters from the fields edge. On-site meteorological data are routinely collected during the application study site.

Values presented in those reports are expressed in $\mu g/m^3$ These data can be used to conduct inhalation studies using well established respiratory rates and time location information available in EPA's Exposure Factors Handbook.

7 Issue 7: Calculating Exposure from the Use of Pesticides in Schools, Day-Care Centers and other Public Places

The Agency recognizes that people may be exposed to pesticides non-occupationally in a variety of situations not limited to residential use. Although OPP's SOPs are described as "Residential SOPs" they actually encompass many use patterns that could occur at sites other than residences. For example, exposure to pesticides on turf are equally appropriate for playing on the lawn at home and at school. In sum, any residential exposure scenario presently in the SOP's can be used to assess exposure in other locations outside the home.

In the SOP, post application exposure to pesticides applied to the grassy areas around schools or applied as crack and crevice treatments to food handling areas, behind vending machines and classrooms are assumed to be equal to or less than those exposures experienced in the home from an intentional use of a pesticide. Many commercial applications to schools and other commercial/institutional facilities are made on Friday evenings or on weekends, Eitzer (1991). Aggregate exposure assessments of individuals in the home include reentry to treated areas immediately after the sprays have dried and often include combined exposures to treated lawns, carpets, and pets on the same day. Thus, the at-home scenario is expected to equal or exceed potential exposures at schools and daycare centers.

To be sure exposure at schools is addressed, exposure assessors will be instructed to:

1) determine if labeled uses for application to schools are registered for use in residences. If a pesticide is registered for schools but not residences, a separate exposure assessment must be conducted.

2) determine if a potential drift scenario from agricultural applications was conducted for the residential scenarios. If a drift exposure assessment was conducted for a residence, one is not needed for schools or other sites. Agricultural drift scenarios are still needed if the pesticide has an application to residential lawns that results in higher residue levels.

3) determine if the use pattern for schools or for other sites where the general public may be exposed differs significantly from the residential use pattern. If it differs significantly, a separate assessment for those is needed.

The inclusion of potential exposure at locations outside the home are expected to be conducted when calendar-based exposure models are developed. These models will include time and location variables by using surveys such as the National Human Activity Pattern Survey (NHAPS). Real world exposure measurements of children in day care centers are scheduled to be collected under a study entitled “Children’s Total Exposure to Persistent Pesticides and Other Persistent Organic Pollutants.” In this proposed study multimedia field monitoring of 250 young children in day care centers will be conducted. Concurrent video tapes, biological monitoring and environmental measurements are proposed for 20 of those children.

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