

Title:

10022 - Derivation of Risk Based Wipe Surface Screening Levels for Industrial Scenarios

Name of Authors:

Lisa M. May, USUHS; Bonnie Gaborek, USACHPPM EHRAP; Tony Pitrat, USACHPPM EHRAP

Affiliations:

Uniformed Services University of the Health Sciences, Department of Preventive Medicine and Biometrics, 4301 Jones Bridge Road, Room A-1044, Bethesda, MD 20814-4799, lmay@usuhs.mil; US Army Center for Health Promotion and Preventive Medicine, Environmental Health Risk Assessment Program, 5158 Blackhawk Road, Building E-1675, Room 108, Aberdeen Proving Ground,

Abstract:

Lisa M. May, Uniformed Services University of the Health Sciences, Department of Preventive Medicine and Biometrics, 4301 Jones Bridge Road, Room A-1044, Bethesda, MD 20814-4799

The environmental characterization of building interiors and other surfaces has generally been performed with wipe-sampling because it is a non-destructive technique. There is no consensus, however, as to the interpretation of the results of wipe-sampling. Specifically, there is not a standardized method to determine if chemicals found at sampled levels pose a threat to human health. A methodology was developed, based on acceptable health risk levels, to derive screening levels for evaluating wipe-sampling results pertaining to industrial scenarios. The methodology was based on the United States Environmental Protection Agency (USEPA) Region IX Preliminary Remediation Goal (PRG) approach; a multi-exposure methodology

commonly used for evaluating soil concentrations. PRGs are the USEPA determined health based goals for soil preliminary remediation efforts. Probabilistic techniques were used to conduct a sensitivity analysis of the methodology to determine which variables drive the ultimate screening levels. Discrete values were then selected based on standard industrial scenarios common to the US Army. The wipe surface screening levels reported are for use as preliminary guidelines which help to determine whether further sampling or cleanup are necessary. The levels are not meant as cleanup or compliance criteria.

10340 - Feasibility of Using The Macroactivity Approach to Assess Children's Dermal Exposure to Pesticides

Elaine A. Cohen Hubal¹, Gerry Akland², Kelly Leovic¹, James Raymer², Linda S. Sheldon¹

¹US EPA, National Exposure Research Laboratory, RTP, NC; ²Research Triangle Institute, RTP, NC

Results from an initial assessment of critical exposure pathways for children indicate that dermal contact may result in high residential exposures to pesticides. However, data on children's exposures and activities are insufficient to support quantitative assessments that do not rely heavily on major default assumptions as substitutes for missing information. In addition, approaches for measuring and assessing dermal exposure in a residential setting have not been evaluated. In the macroactivity approach, dermal exposure is estimated using empirically-derived transfer coefficients. This approach was developed to assess occupational exposure in an agricultural setting. To assess the feasibility of using the macroactivity approach for assessing children's exposure to pesticides, a screening-level study was conducted with young children in a daycare center where a known pesticide application had occurred. Children in the selected daycare were monitored the day following a regularly scheduled monthly application of esfenvalerate. Four or five children from each of two different age groups (6-12 months, and 2-3 years) were monitored for 30-60 minutes while involved in selected activities (e.g., storytime, playtime indoors). The children were clothed in full-body cotton suits to measure dermal loading. Transferable residues were sampled in the areas where the children spent time to measure the pesticide concentrations on classroom surfaces. In addition, videotaping was conducted to verify the children's activity levels and location during exposure monitoring. Monitoring of these two groups of children was repeated during two additional post-application visits. The dermal loading and transferable residue measurements were then used to calculate dermal transfer coefficients for each monitoring event. The results of this study demonstrate the inter- and intra-individual variability of dermal loading (and associated transfer coefficients) for children in two different age groups. Preliminary results show surface wipe concentrations ranging from 37-458 ng/cm² and total body suit concentrations ranging from 0.04-0.6 ng/cm². These data will be used to evaluate the default assumptions currently used by US EPA's Office of Pesticide Programs to assess children's residential exposure to pesticides.

Disclaimer

This work has been funded by the United States Environmental Protection Agency under contract no. 68-D-99-012 to Research Triangle Institute. It has been subjected to Agency review and approved for publication.

G. Korinth (1), Th. Goen (2), K. H. Schaller (1), H. Drexler (1)

(1) Institute of Occupational, Social & Environmental Medicine, University of Erlangen - Nuremberg, Germany

(2) Department of Occupational Medicine, University of Technology Aachen, Germany

Objectives:

For the evaluation of toxic effects caused by chemical substances very often data from animal experiments are transferred to human beings. Aim of our experiments was to compare with two different methods the assessment of percutaneous absorption of chemicals by the kinetic and penetration of absolute amounts.

Methods:

Fresh full-thickness, healthy human abdominal skin was obtained from surgery for experiments (reduction abdominoplasty). With the human skin 10 experiments were performed with the static diffusion cell and a new in vitro microdialysis technique. For comparison the microdialysis was carried out with 10 anaesthetized male Wistar rats and 10 experiments with freshly excised, shaved skin of Wistar rats. The percutaneous absorption was tested with 2-Butoxyethanol (BE), an excellent water-soluble glycol ether and toluene, a substance with dominant lipophilic properties. The experiments were performed under uniform conditions. The duration of exposure was 4 h, the interval for sampling was 0.5 h. The application volume for both test compounds was 100 µl on 0.64 cm² surface of the skin. For experiments with BE and toluene the receptor fluid was comparable with human serum and consist Ringer's solution, 4% human albumin, adjusted to pH 7.4.

Results:

The experiments with the diffusion cells showed for BE with the excised human skin a steady state at around 30 µg/0.5 h. These values were lower by factor 8.7 compared with the values for the rat experiments (263 µg/0.5 h). We were not able to detect a steady state after 4 h exposure. Regarding toluene with the diffusion the differences were not so high. For excised human skin the penetration rate of toluene was 1.2 µg/0.5 h, for the excised rat skin 2.2 µg/0.5 h.

The steady state for the experiments with the microdialysis was for both chemical substances around 2.5 h. At the end of the experiments with the microdialysis the hydrophilic BE showed a comparable penetration for the rat skin and the freshly excised human skin (16.6 µg/0.5 h versus 12.86 µg/0.5 h). For toluene significant differences could be demonstrated (2.09 µg/0.5 h for the rat versus 31.01 µg/0.5 h for human skin). These differences, however, can not be explained solely by the shaving procedure.

Conclusions:

The data of the animal experiments can not be transferred without any restrictions to the human beings taken into account the different experimental techniques. The correlation analysis showed that only the microdialysis technique gives comparable results for human skin and rat skin. The kinetic of absorption fits better with the pharmacokinetic experiences for the microdialysis as the diffusion cell experiments. The in vitro technique of microdialysis is suitable for dermal penetration experiments.

10911 - Understanding the Role of Carpeted Surfaces in Multiple Pathway Exposures to Particle-Phase Contaminants

Charles Rodes^a, Jonathan Thornburg^a, and Peter Ashley^b, ^aResearch Triangle Institute, Research Triangle Park, North Carolina; ^bU. S. Department of Housing and Urban Development (HUD), Washington, DC

Because of their prevalence in both residential and commercial buildings, carpeted surfaces have been studied extensively to understand their roles in the generation, transport and fate of contaminants. More recently, the transferability of residues and particles from smooth and carpeted surface have been characterized to allow the application of microactivity dermal exposure models. These results show that typical transfer rates from carpeting are small fractions of those experienced from smooth surfaces. Applying these models to multi-pathway risk analyses is not necessarily straightforward, however, since (a) carpeting can serve as both a sink and a source for a environmental contaminants for various scenarios, and (b) the amount of contaminant actually available for contact transfer must be considered finite, even if the carpeting contains an enormous contaminant reservoir within its structure. Particle-phase contaminants add (at least) two additional complexities that must be considered. Particle transport and fate mechanisms are highly dependent on particle size and character, compared to residues - which could be considered as a continuum of extremely small particles. Additionally, individual particles resident on carpet fibers and backing can serve as miniature reservoirs for vapor-phase contaminants (e.g. pesticides). Recent research conducted by RTI has developed new characterization methodologies (especially for carpeting) that have added enormously to our understanding of multiple pathway exposures. Key findings will be summarized and the implications discussed, including: (1) the mass of low-vapor pressure contaminants found in the backing and the base of fibers are essentially unavailable for exposure (but may become available thru a high energy event), (2) contact mass transfer rates of particles to both dermal and wipe surfaces are almost solely associated with carpet fiber loadings, (3) areal mass transfer rates are much less than 1% of the contaminant loading found on the fibers, (4) contaminant particle sizes smaller than about 1 μm (e.g. very prevalent for Pb-contaminated carpeting) are held tightly to fibers by surface charges and are minimally available for air resuspension or transfer to either skin or wipes, (5) particle-phase contaminant degradation indoors may include eventual oxidation to submicron sizes, (6) repeated contacts of the same contaminated carpet surface can rapidly remove the easily dislodged particles, substantially reducing the mass available for transfer relatively quickly, and (7) the areal particle loading capacity of the skin is finite, such that successive contacts exhibit exponentially smaller mass transfer rates. Current research uncertainties include the amount of energy that must be imparted to the carpeting (e.g. vacuuming, walking) to replenish fiber loadings from the carpet backing reservoir, after contact or cleaning events, and the role of wet contact surface films (e.g. hands, wipes) in altering the transfer of surface charges that are so dominant in bonding particles to the surfaces.

Topic Area: Dermal Exposure

This work has been funded in part by the HUD cooperative agreement XXX to the Research Triangle Institute.

10917 - Algorithm for Using Contact-Specific Surface Area Data in Dermal and Non-Dietary Exposure Models

Robert A. Canales, Kelly A. Naylor, James O. Leckie, Stanford University

Information on exposed skin surface area is necessary in models estimating dermal and non-dietary exposure to contaminants. Early models used conservative estimates (e.g., 100% surface area of exposed body part), while contemporary mechanistic models use randomly selected surface area fractions from a range of values. Both model types, however, are utilized with little or no empirical skin contact surface area data. Furthermore, both methodologies assume a uniform distribution of contaminant mass on skin which results in spatially averaged exposure estimates. This paper illustrates new algorithms to incorporate contact-specific surface area data into mechanistic models of dermal and non-dietary exposure. From previous work, substantial sequential micro-activities (i.e., location, object type contacted, duration of contact), collected via videography methods, exist for children's normal activities. Videotapes were reprocessed to record qualitative contact-specific surface area categories for each contact event. Examples of qualitative categories include side hand contacts, pinch grips, full front fingers, closed handgrips, and full hand immersions. Fractional contact surface area ranges for the mentioned qualitative categories were estimated as 2-4%, 4-8%, 9-16%, 23-35%, and 100%, respectively. Upon analysis, hand-to-mouth contacts yielded a range of 4-8% of total hand surface area. Contacts with smooth surfaces were bimodal (23-35% range and 4-8% range). These results indicate simulations for estimating dermal and non-dietary exposures can be refined by using more distinct and accurate surface area data. Qualitative surface area categories are defined by contact type (i.e., grip types, front and back fingers), thus spatial characteristics of contacts allow for estimates of contaminant mass over a particular skin surface. Spatial data were captured utilizing a hand trace as a template and transferring handprints representing the qualitative categories to the template. The prints were scanned and mapped on a grid with coordinates relevant to each grip. Since mechanistic models estimate the addition or removal of contaminant mass to skin, only relevant surface area coordinates are affected. If a micro-activity file indicates contact with a smooth surface with a full front palm and then hand-to-mouth contact with partial finger immersion, mass is first applied to coordinates representing the palm and mass is removed from the coordinates representing the finger tips. Contrary to current default approaches, the result is a non-uniform exposure across the skin surface. While the algorithm has limitations (number of grip types, precision of surface area measurements) it is an improvement on current approaches. This algorithm could result in more realistic modeled concentration gradients across the skin and better representation of dermal exposure due to multiple contacts. Such considerations are important in non-dietary exposure, where hand-to-mouth contacts are an essential component, and in accurately representing mass transfer and dermal dose. This methodology could also serve as a learning tool, coupled with experimental work, to investigate the issues of contact pressure and the implications of utilizing spatially averaged dermal exposure measurements (e.g., hand wipes, rinses).

11134 - Aerosol and Gas Deposition To Human Skin for Dermal Exposure
Alesia Ferguson, James Leckie, Stanford University

Aerosols and gases have traditionally been important pollutant media in terms of exposure and dose for the inhalation route. Understanding, for example, transport and deposition of various aerosol particle sizes in the human respiratory tract is important for health risk assessment. However, even low volatility pesticides and other pollutants that pose a health risk for the dermal exposure route can become airborne as gases, liquid/solid aerosols or as residues bound to dust particles or mist. Classical deposition theory can be applied to evaluate the relative importance of dry deposition to the skin and to identify data needs for more complete assessment. The mathematics describing dry deposition has been applied here to quantify the rate of aerosol and gas deposition to the skin while considering the special surface properties and dynamics of the air boundary layer above skin. Dry deposition occurs when gases or particles are removed at an air-surface interface by impacting, sticking to or reacting with the surface of the human skin. The velocity of dry deposition, for a gas ($V_{d, \text{gas}}$) and for a particle ($V_{d, \text{part}, i}$) is the inverse sum of a series of resistances:

$$V_{d, \text{gas}} (\text{ms}^{-1}) = (R_a + R_b + R_s)^{-1}$$
$$V_{d, \text{part}, i} = (R_a + R_b + R_a R_b V_{f,i})^{-1} + V_{f,i}$$

where R_a = the aerodynamic resistance between a specified height and the laminar sublayer, R_b = resistance to molecular diffusion through laminar sublayer, R_s = resistance to chemical, biological and physical interactions of surface and gas on impact, and $V_{f,i}$ = the sedimentation velocity of a particle. Calculations show that unless a gas is highly reactive (e.g., ozone), surface resistance (R_s) plays a minor role in deposition of a gas to skin. In addition, for a variety of compounds (e.g., aliphatics, aromatics, and xylenes) the velocity due to aerodynamics (R_a) and molecular diffusion (R_b) varies little. R_a is a constant for aerosols and gases and is dependent on the surface properties of the skin (e.g., skin roughness of 10 to 200 μm) and properties of the laminar layer above the skin (e.g., wind shear, thermal gradients). For aerosols, particle size and density govern their deposition (i.e., R_a and R_b are negligible unless particle size is well below 1 μm diameter). For a scenario where there is pesticide spray drift from a nearby agricultural field, pesticide liquid molecules can condense onto dust particles within a home. If the concentration of 2.5 μm particles is 100 ug/m^3 in that home and the velocity of deposition as calculated is 0.0014 m/s to the skin, then the mass deposition to skin over 10 minutes will be 84 ug/m^2 . However, increased wind shear due to body movements will produce a lower mass deposition to the skin. Dry deposition equations may help predict the magnitude of dermal exposure to aerosols and particles. Modeling deposition fluxes of aerosols and gases to the human body also highlights the need for experimental measurements of model parameters (e.g., friction velocity of skin caused from hand movements and atmospheric winds).

11135 - The adhesive forces in the transfer of contaminants to the skin for dermal exposure
Alesia Ferguson, James Leckie, Stanford University

During contact between a surface and human skin, contaminants can be transferred. The mass transfer is theoretically dependent on competitive adhesive forces between contaminant and the skin, contaminant and surface, and the cohesive forces within the media containing the contaminant. Theories of adhesion have been traditionally applied in a variety of fields such as the manufacture of glues, and in the biomedical field for the bioadhesion of foreign objects (e.g., artificial organs, drug delivery systems). The application of adhesion theory are explored here to help understand the chemical and physical mechanisms that govern the mass transfer efficiencies of contaminants from surfaces to the skin. The free energy of adhesion between any two contacting materials depends on the interaction mechanisms and the mechanical properties and can be defined as the sum of the surface energies of two contacting materials minus the interfacial energy: $\Delta G = \gamma_1 + \gamma_2 - \gamma_{12}$. The interfacial energy between two phases is then :

$\gamma_{12} = \gamma_1 - \gamma_2 \cos\theta_{12}$ and the surface tension or interfacial energy of any material(s) is: $\gamma_1 = \gamma_1^d + \gamma_1^p + \gamma_1^H$. Here subscripts 1 and 2 refer to the two contacting materials, γ_1 is the surface free energy, γ_{12} refers to the interfacial surface tension, ΔG is the free energy of adhesion and θ_{12} is the contact angle between the contacting materials. The subscripts d, P, and H refer to the van der Waals dispersive, polar, and hydrogen bonding forces, respectively and are often difficult to define for a particular system. Empirical studies for contact angle and surface tension measurements verify that variability in skin properties by anatomical site result in a range of adhesive forces with different chemicals. For example, glycerol has a greater adhesive attraction for the sebum rich area of the forehead than a wood or polystyrene surface (see table). This however, is not true for the sebum poor area of the forearm. Other important surface properties of human skin affecting adhesion include roughness, surface pH, charge, and hydration state. Roughness, for example, has the ability to affect the observed contact angles of liquids on the skin in several directions.

Adhesive Force, ΔG (mJ/m ²)				
Compound	Forearm	Forehead	Wood	Polystyrene
Water	23.85	43.44	52.81	55.16
Glycerol	10.21	78.76	62.91	47.62
Formamide	76.85	24.13	-	46.03

Estimating the amount that transfers to skin during a contact event is requisite for calculating dermal exposure. Typically, transfer amounts are obtained experimentally, under varying conditions and using varying techniques (e.g., transfer from carpet using puff rollers, vacuums, hand presses). A model prediction of mass transfer to the skin using theoretical laws of adhesion and empirical studies on contact angle provides a complementary tool for estimations of mass transfer efficiencies.

11140 - Dermal Absorption from Environmental Matrices: Fundamental Concepts Revisited

Kissel, JC

Department of Environmental Health
University of Washington
Seattle, WA

Bunge, AL

Department of Chemical and Petroleum Engineering
Colorado School of Mines
Golden, CO

Mackay and co-workers published a series of articles in the late 1970's and early 1980's describing a systematic approach to the modeling of the environmental behavior of organic chemical contaminants that they referred to as the Fugacity Approach. The physical chemical principles on which this approach was constructed had been established decades earlier, but the organization of those fundamental concepts and the terminology used were innovative. The Fugacity Approach is logically and readily adapted to investigation of the environmental transport and biological availability of chemical contaminants in the context of risk assessment. One potential route of human exposure of interest is dermal absorption. Absorption via the skin has been generally subjected to less extensive empirical investigation than competing routes of exposure to environmental contaminants. This situation is particularly acute with respect to absorption from soils and sediments. A relative handful of experiments involving only a few compounds have been conducted to date. In the absence of data, elucidation of general principles via modeling is often attempted. Not surprisingly, several research groups have explicitly adopted Mackay's terminology in proposing models of dermal absorption. Nevertheless, the utility of the fundamental concepts underlying the Fugacity Approach appears to be insufficiently appreciated. A recent review of the state of knowledge of dermal absorption from soil in a prominent handbook, for instance, describes the dermal bioavailability of several lipophilic compounds as "the same [from] soil and solvent." This conclusion and the experiments on which it is based merit scrutiny. Theoretical considerations and recent empirical findings are applied to this task and to analysis of additional experiments involving percutaneous absorption of soil-borne contaminants. Conclusions drawn are intended to be useful to persons assessing both dermal exposures and broader bioavailability issues.

Preferred format: POSTER