Evaluation of Potential Exposure To Metals In Laundered Shop Towels

By Leslie A. Beyer MS, Mara R. Seeley PhD, and Barbara D. Beck PhD, Gradient Corporation, 238 Main Street, Cambridge, MA

Key words: dermal transfer, dislodgeable residues, worker exposure, ingestion, occupational, risk assessment, Cal EPA Prop 65, metals, lead, cadmium, antimony, shop towels, reproductive effects, cancer

Overview

Gradient estimated oral intake of metals in laundered shop towels for two potential exposure pathways: one involving hand contact with laundered shop towels and subsequent transfer to the mouth, and one involving direct contact of laundered shop towels with the lips. We estimated potential exposure to metals for both of these pathways, based on metal loading on the laundered shop towels, and estimates of transfer efficiencies for towel-to-hand, towel-to-lip, and hand-to-mouth.

Metal loading on the laundered shop towels was estimated for laundered shop towels collected from 23 companies and at least 18 different laundry facilities (the launderer was not known for each sample – see *Table 1*). The shop towels were analyzed by TestAmerica Incorporated (Nashville, TN) [1]. Concentrations were reported for 27 metals and oil/grease. Some samples had high concentrations, especially for oil/grease which ranged from 814 to 362,000 mg/kg. Certain metals, such as iron and lead, were found frequently on the laundered shop towels. For example, iron was detected in all samples (with concentrations ranging from 29 to 15,700 mg/kg), while lead was detected in 21/23 samples. Gradient reviewed quality control (QC) sample results, including matrix spikes/matrix duplicates, laboratory control samples, and method blanks, to determine whether the data required qualifications based on exceedances of TestAmerica's QC criteria. Gradient's QC analysis determined that all of the metals data were usable, with only minor data qualifications.

Exposure involving hand contact with laundered shop towels and subsequent transfer to the mouth was nearly three orders of magnitude greater than exposure involving direct contact of laundered shop towels with the lips. Assuming typical usage of 2.5 laundered shop towels per day, Gradient's analysis indicated that the maximum estimated exposure to cadmium, due to hand contact with laundered shop towels and subsequent transfer to the mouth, was essentially equivalent to California Environmental Protection Agency's (CalEPA) Maximum Allowable Daily Level (MADL), for reproductive toxicity, under Proposition 65 (Prop 65). Both the average and maximum estimated exposure to lead, due to hand contact and subsequent transfer to the mouth, exceeded CalEPA's MADL by 27-fold and 69-fold, respectively. The maximum estimated exposure to lead on the shop towels also exceeded CalEPA's No Significant Risk Level (NSRL), for cancer, by 1.3-fold.

Assuming high-end use of 10 laundered shop towels per day, Gradient's analysis indicated that both the maximum and the average estimated exposure to cadmium, due to hand contact with laundered shop towels and subsequent transfer to the mouth, exceeded CalEPA's MADL by 4-fold and 1.3-fold, respectively. The maximum estimated exposure to cadmium on the laundered shop towels also exceeded the Agency for Toxic Substances and Disease Registry's (ATSDR) Oral Minimal Risk Level (MRL), for non-cancer health effects, by 1.2-fold. The average and maximum estimated exposure to lead, due to hand contact and subsequent transfer to the mouth, exceeded CalEPA's MADL by 106-fold and 268-fold, respectively. The maximum estimated exposure to lead on the laundered shop towels also exceeded CalEPA's NSRL, by 5-fold. In addition, the maximum estimated exposure to antimony on the laun-

1. 10-12 laundered shop towels were collected at each laundry and one of these 10-12 towels was selected for metals analysis.

Table 1
ACCOUNT NAME, TYPE, LOCATION, AND LAUNDERER FOR SHOP TOWELS COLLECTED FOR METALS ANALYSIS

Account Name	City/State	Account Type	Launderer	Estimated Usage
M&M Precision	Dayton, OH	Precision Measuring Equipment	Cintas	200/week
CSS Int'l Corp	Phila, PA	MFR Machine Shop	Domestic Linen	300/week
Avibank	N. Hollywood, CA	Aerospace	Mission Linen	2000/week
Tie Down Engineering	Atlanta, GA	Steel fabrication	Aramark	500/week
Select Tool & Die Corp	Dayton, OH	Manufacturing	Unknown	5000/yr
Ames Safety Envelope	Somerville, MA	Printing	Coyne Textile Serv.	400,000/yr
Integrated Aerospace	Santa Ana, CA	Manufacturing of landing gear for airplanes/helicopters	Cintas	350/week
North Star Steel Co.	Wilton, IA	Steel fabrication	Gik Services	600/week
Johnson Controls	West Union, SC	Injection molding	Aramark	250/week
Hydroform USA	Carson, CA (near LA)	Aerospace	Prudential Overall	1000/week
PAK 2000	Lancaster, PA	Specialty packaging	E & R Cleaners	75,000 per year
Porter Engineered Systems	Westfield, IN	Automotive	G&K Services	375/week
AW North Carolina Inc.	Durham, NC	Automotive Bearings	Cintas	1000/week
Intermet	Minneapolis, MN	Metal fabrication	Leaf Brothers	4-5000/week
Minnesota Nat'l Guard	St. Paul, MN	Aircraft	Unknown	500-1000/week
Briggs & Stratton	Auburn, AL	Small engine manufacturing	Cintas	1000/week
Boral Bricks	Phoenix City, AL	Brick manufacturing	Unknown	1000/week
Marvin Engineering	Inglewood, CA	Purchasing Manager	Unknown	200 per week
HXM Motor Express	Harrisonburg, VA	Transportation	Cintas	500/week
Parker	Manitowoc, WI	Hydraulics	Unknown	8000/week
KC X80 Wiper (control sample)				

dered shop towels exceeded the United States Environmental Protection Agency's (USEPA) Oral Reference Dose (RfD), for non-cancer health effects, by 1.6-fold.

We also evaluated uncertainties associated with our exposure assumptions that could result in our estimated intakes of metal from contact with the shop towels being either less than or greater than actual intakes. Although use of alternative exposure assumptions could result in lower estimated intakes, intake of lead from the shop towels would likely still exceed CalEPA's MADL. [2]

Analysis

There are no standard methodologies for evaluating exposure to metals in laundered shop towels. Therefore, we developed an approach, based on empirical data in the literature, to estimate the amount of metal that could be transferred from the laundered shop towels either directly to the lips or to the lips from the hands, both ultimately leading to ingestion of metals.

For ingestion exposure via hand contact with the laundered shop towels, we estimated transfer of metals from laundered shop towels to hands based on empirical data regarding transfer of pesticide residues from surfaces to hands, data regarding the number of laundered shop towels used daily per person, as well as an estimate of the percentage of the towel surface area that would contact the hand. The amount of metal transferred to the hand that could ultimately be ingested was based on a hand-to-mouth transfer efficiency, using methodology developed by the U.S. Consumer Products Safety Commission (CPSC) for evaluating exposure to dislodgeable residues on treated wood surfaces (CPSC, 1990). *Figure 1* illustrates exposure occurring via hand contact with the laundered shop towels.

[2] DISCLAIMER: The conclusions in this report are derived from the exposure assumptions provided herein. Utilization of different exposure assumptions, or comparison to different laundered shop wipes (which may contain different concentrations of metals), could affect the conclusions.

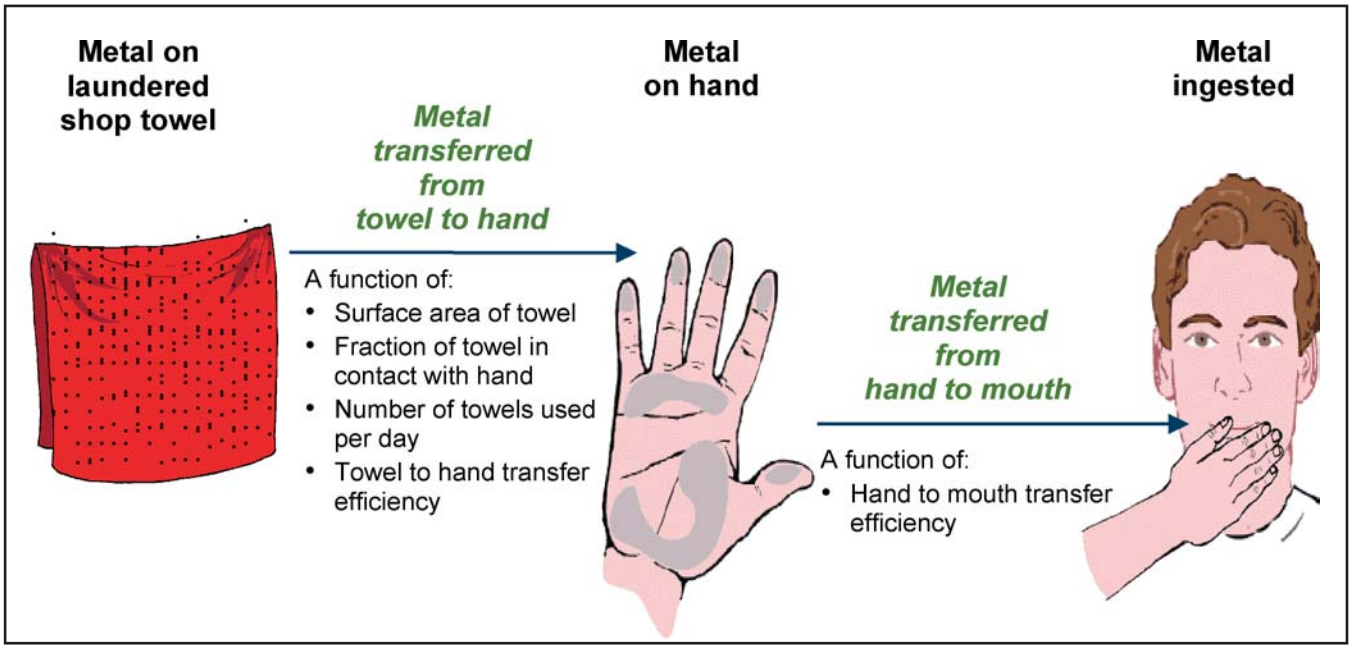


Figure 1
ORAL EXPOSURE TO METALS IN LAUNDERED SHOP TOWELS VIA HAND CONTACT

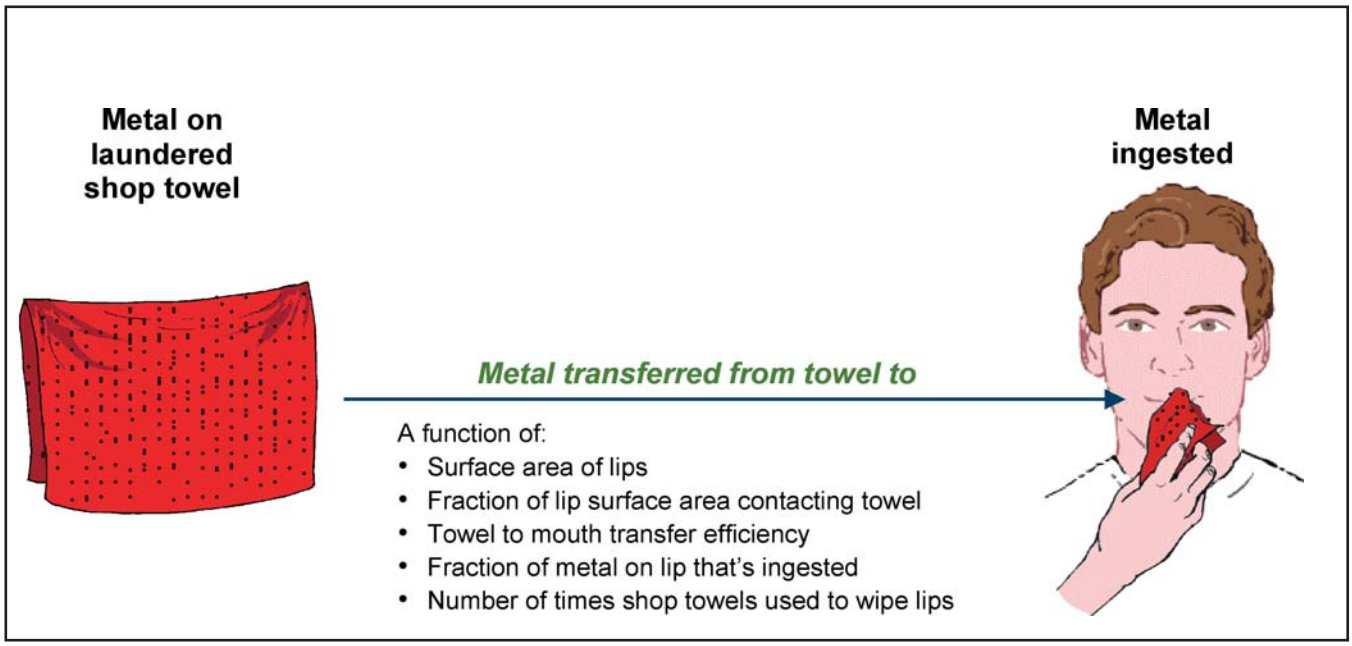


Figure 2
ORAL EXPOSURE TO METALS IN LAUNDERED SHOP TOWELS VIA DIRECT MOUTH CONTACT

For exposure via direct contact with the lips, we estimated transfer of metals from laundered shop towels to the lips based on empirical data regarding transfer of pesticide residues from surfaces to hands, empirical data regarding surface area of the lips, as well as estimates of the fraction of the lip surface area contacting the laundered shop towels, fraction of the metal on the lip that is ultimately ingested, and the number of times per day that lips are wiped with laundered shop towels. *Figure 2* illustrates exposure occurring via direct contact of the laundered shop towels with the lips. The equations used for estimating intake, as well as the input parameters, are outlined and described below.

Exposure via Hand Contact

Intake of metals in laundered shop towels via hand contact was estimated using the following equation:

$$Intake\ (mg/kg-day) = \frac{[Load_{towel} \times SA_{towel} \times F_{towel} \times N \times T_{t/h} \times HTE \times EF \times ED]}{BW \times AT}$$

where:

$Load_{towel}$ = Metal loading on towel surface (mg/cm^2);

SA_{towel}	=	Surface area of towel (cm^2);
F_{towel}	=	Fraction of towel in contact with hand (unitless);
N	=	Number of towels used daily per person;
$T_{t/h}$	=	Towel to hand transfer (unitless);
HTE	=	Daily hand to mouth transfer efficiency (day^{-1});
EF	=	Exposure frequency (days/year);
ED	=	Exposure duration (years);
BW	=	Average adult body weight (kg);
AT	=	Averaging time (days).

This equation assumes that metals are transferred from the towels to the mouth in a two-step process. First, metals are transferred from the towels to the hands as a function of the metal loading on the laundered shop towels, the surface area of the towel in contact with the hands, and a towel-to-hand transfer efficiency. Once the metals are on the hands, they are transferred to the mouth, as estimated by a daily hand-to-mouth transfer efficiency. The parameters used in the above equations are described below.

Metal Loading on Towel Surface. The concentration of the metals in the laundered shop towels was based on metals analysis for 23 used laundered shop towels, from 23 different companies (based on information from INDA member accounts), and at least 18 different laundry facilities (the launderer was not known for all samples – see *Table 1*). Average metal concentrations from three control (unused) laundered shop towels were subtracted from average and maximum metal concentrations for the 23 used, laundered shop towels [3]. The weight of the laundered shop towels was estimated at 1 oz. (0.0283 kg), based on an average weight for three laundered shop towels. An average surface area of 2,268 cm^2 was based on measurements from five laundered shop towels.

Table 2 lists metal concentrations (maximum and average in mg/kg), the standard deviation, the 95% upper confidence limit on the mean (UCLM), and calculated metal loadings (mg/cm^2) for the laundered shop towels. Metal loading on the surface of the laundered shop towels was estimated as the concentration of metals in the towel (mg/kg) times the weight of the towel (kg), divided by the total surface area (front and back) of the towel (cm^2). We calculated intakes using both average and maximum metal loadings. For our analysis we assumed that half of the total metals detected in the laundered shop towel would be available for transfer to hands on each side of the towel.

Surface Area of Towel. The total surface area of the laundered shop towels (front and back) was assumed to be 2,268 cm^2, based on the average surface area (length x width) of five laundered shop towels.

Fraction of Towel in Contact with Hands. We assumed, based on professional judgment, that the hands would contact approximately 75% of the total surface area of a laundered shop towel, under typical laundered shop towel usage.

Number of Towels Used Daily Per Person. We estimated exposure to metals on laundered shop towels assuming typical use and high-end use of towels. For typical usage, we assumed an average of 2.5 laundered shop towels per day, based on data collected by an INDA member from 53 manufacturing facilities, and 137 auto shops (INDA member, 1996). We based our estimates on data for the auto shops, which use more towels per employee than the manufacturing facilities. According to the data provided by an INDA member, monthly towel usage at auto shops is 641 towels, for an average of 13 employees, or 49 towels per employee per month. This results in an average daily usage of 2.5 towels per day (assuming an average of 21.6 workdays per month). However, not all employees at a facility actually use the towels (e.g., purchasing, plant manager, secretaries, etc.), so this approach underestimates the number of towels used by employees who actually use the towels. We further assumed that 100% of shop towel usage involves direct contact with bare hands (INDA member, 2002).

High-end use was estimated to be 10 towels a day, based on information received from an INDA member (INDA member, 2003), who indicated that workers engaged in activities such as auto repair, manufacturing, printing, and metal fabricating commonly use 10 towels daily.

Towel to Hand Transfer. We assumed that towel-to-hand transfer would be approximately 0.05, or 5%, based on results from three studies which investigated the transfer of pesticides from various surfaces to hands. The three studies are: Camann *et al*. (1996), Lu and Fenske (1999), and Clothier (2000). Briefly, Camann *et al.* (1996) examined transfer of pesticide residues (including chlorpyrifos, pyrethrin I, and piperonyl butoxide) from new, nylon, plush carpet to hands moistened with human saliva, artificial saliva, or dioctyl sulfosuccinate (DSS). Lu and Fenske (1999) examined transfer of chlorpyrifos residues from either carpets or furniture to hands. Clothier (2000) examined transfer of residues from a pesticide formulation containing chlorpyrifos, pyrethrin I, and piperonyl butoxide from new, vinyl sheet flooring, to dry, water-wetted, or saliva-wetted hands. These studies are described in more detail in the text that follows.

Camann *et al.* (1996) measured transfer of pesticide residues from new, nylon, plush carpet to hands using a single hand-press technique, which involved pressing the palm of the hand onto the treated carpet for one second, at a pressure of approximately one psi. Hand transfer was measured on day 1, approximately five hours after application of a pesticide formulation containing chlorpyrifos, pyrethrin I, and piperonyl butoxide. Hand transfer was measured again on days 2 and 3. Transfer was determined for both the right and left hand on each sampling day, with each hand moistened with

[3] Ten metals were detected in the control RSTs (labeled as Dennis 1, Dennis 2, and unused RST in the dataset) with the average control value (mg/kg) found in parentheses after each compound: aluminum (30.9), calcium (677), iron (31.3), magnesium (164), manganese (3.5), potassium (652), sodium (1910), strontium (114), titanium (95.1), and zinc (15.5). All other metals for which the towels were tested, including lead, were not detected.

Table 1
CONCENTRATIONS OF METALS IN LAUNDERED SHOP TOWELS

Metal	Maximum (mg/kg)	Average (mg/kg)	Standard Deviation	95% UCLM	Maximum (mg/cm^2)	Average (mg/cm^2)
Aluminum	1,179	368	335	696	1.47E-02	4.59E-03
Antimony	44	23	14	35	5.53E-04	2.92E-04
Arsenic	3	3	0	3	3.36E-05	3.36E-05
Barium	1,140	137	240	371	1.42E-02	1.70E-03
Beryllium	0	0	0	0	0.00E+00	0.00E+00
Boron	33	29	4	33	4.06E-04	3.67E-04
Cadmium	17	5	5	9	2.12E-04	6.60E-05
Calcium	4,123	941	1,007	1,737	5.14E-02	1.17E-02
Chromium	608	87	146	328	7.59E-03	1.09E-03
Cobalt	681	97	170	325	8.50E-03	1.21E-03
Copper	1,010	285	302	1,010	1.26E-02	3.56E-03
Iron	15,669	4043	4,336	7,976	1.96E-01	5.04E-02
Lead	138	53	39	94	1.72E-03	6.65E-04
Magnesium	1,776	277	328	571	2.22E-02	3.46E-03
Manganese	1,487	128	321	630	1.85E-02	1.60E-03
Molybdenum	145	38	34	95	1.81E-03	4.75E-04
Nickel	878	108	210	325	1.10E-02	1.35E-03
Potassium	178	178	0	178	2.22E-03	2.22E-03
Selenium	5	3	1	4	6.61E-05	3.55E-05
Silver	24	6	7	16	3.01E-04	7.64E-05
Sodium	0	0	234	538	0.00E+00	0.00E+00
Strontium	0	0	9	27	0.00E+00	0.00E+00
Thallium	0	0	0	0	0.00E+00	0.00E+00
Tin	126	31	29	46	1.57E-03	3.86E-04
Titanium	0	0	20	41	0.00E+00	0.00E+00
Vanadium	179	97	116	179	2.23E-03	1.21E-03
Zinc	1,925	406	419	1,018	2.40E-02	5.06E-03

Notes:
Concentration (mg/cm^2) = [mg/kg x weight of towel (kg)]/surface area of towel (cm^2)
Weight of towel (kg) = 2.83E-02
Surface area (cm^2) = 2,268
Assume weight of towel = ~ 1 oz.

Ten metals were detected in the control RSTs (labeled as Dennis 1, Dennis 2, and unused RST in the dataset): aluminum, calcium, iron, magnesium, manganese, potassium, sodium, strontium, titanium, and zinc. All other metals for which the towels were tested, including lead, were not detected. Control values were subtracted from individual measurements to calculate the UCLMs and standard deviations for the compounds listed above. ProUCL and MTCA Stat were used to calculate the 95% UCLMs.

human saliva, artificial saliva, or DSS on any given sampling day. Deposition coupons consisting of aluminum-backed alpha-cellulose pads were used to determine the amount of pesticide residue available for transfer to hands. Carpet-to-hand transfer was comparable among all three moistening media, ranging from 0.7–1.3% for chlorpyrifos, 2.9–4.8% for pyrethrin I, and 1.5–2.8% for piperonyl butoxide.

In the study by Lu and Fenske (1999), hand transfer was measured using both hand press and hand drag sampling techniques, for six study participants. For both sampling techniques, study participants were instructed to apply enough pressure on the entire palm surface of their hand (excluding fingertips) to deflect a platform scale by 5.4 kg (12 lbs). For the hand press sampling technique, study participants pressed each hand in 10 different locations on a 30 cm x 50 cm sampling frame. For drag sampling, study participants dragged each hand down three separate columns within the sampling frame. Chlorpyrifos removed from hands was adjusted using hand wash removal and extraction efficiency factors determined from previous studies. The amount of

chlorpyrifos available for transfer to hands was estimated with deposition coupons, consisting of a double layer of 12 ply, 7.6 cm^2 surgical gauze pad placed on top of aluminum foil. Mean hand transfer from 0.64 cm-thick nylon pile carpet was less than 0.3%, ranging from 0.04 to 0.26%, and mean hand transfer from furniture (i.e., a hard surface) was more than double that of carpet at 0.69%.

Clothier (2000) estimated surface-to-hand transfer from new, sheet vinyl flooring using a single hand press technique, which was conducted by pressing the palm of one hand onto the sheet flooring, applying a pressure of approximately 1 psi for 1 second. A pesticide formulation containing chlorpyrifos, pyrethrin I, and piperonyl butoxide was applied on study days 1 and 3 to separate test sections, and surface-to-hand transfer efficiency was determined for two separate sampling blocks on days 1 and 3 (4 hours after pesticide application) and for one sampling block on days 2 and 4 (24 hours after pesticide application). Surface-to-hand transfer was determined for a dry palm, a water-wetted palm, or a saliva-wetted palm, for three study participants. Surface-to-hand transfer was only determined once per day, for each palm. On study days 1 and 3, surface-to-hand transfer was determined for both the right and left palm of each subject, on study day 2 transfer was only determined for the left palm, and on study day 4, only for the right palm. Pesticide transferred to the hands was removed by wiping the palms two times with a gauze dressing sponge soaked in isopropanol. The amount of pesticide available for transfer to hands was determined with deposition coupons, similar to those used in the study by Lu and Fenske (1999). Surface-to-hand transfer for individual hands ranged from 0.71%, for transfer of chlorpyrifos to a dry palm determined at 24 hours post-application, to 19.2% for transfer of pyrethrin to a water-wetted palm determined at 4 hours post-application.

The minimum floor-to-hand transfer of chlorpyrifos to a dry hand observed by Clothier (2000) (0.71%) was comparable to the furniture-to-hand transfer of chlorpyrifos to a dry hand of 0.69% observed by Lu and Fenske (1999). Carpet-to-hand transfer for chlorpyrifos to moistened hands observed by Camann *et al.* (1996) were approximately 5-fold greater than carpet-to-hand transfer for chlorpyrifos to dry hands observed by Lu and Fenske. Overall, transfer from a floor to a saliva-moistened hand observed by Clothier was approximately 1.4- to 4-fold greater than transfer from a carpet to a saliva-moistened hand observed by Camann *et al*. Thus, transfer is generally greater to moist hands versus dry and from hard surfaces (such as a floor or furniture), versus porous surfaces (such as a carpet).

For our analysis, we only considered hand transfer from hard surfaces. This is because a significant portion of pesticides applied to carpet may become lodged within the carpet pile, and thus could be unavailable for transfer to hands. We considered the whole range of transfer rates determined for hard surfaces by Lu and Fenske (1999) and Clothier (2000), described above. These two studies indicate a range of hand transfer rates from hard surfaces of < 1% to approximately 20%. Transfer from a porous surface, such as a laundered shop towel, would be less than from a hard surface, as indicated by the low transfer rate from carpet measured by Lu and Fenske (1999). Therefore, we chose the midpoint of the range for transfer rates from hard surfaces (10%) and further assumed that hand transfer from laundered shop towels would be approximately 50% of the hand transfer from a hard surface. This resulted in an estimated hand transfer of 5%. Note that this value is at the upper end of the range for transfer of pesticides from carpet to hands, and thus is a plausible value for transfer of material from porous surfaces, such as shop towels, to hands.

Daily Hand to Mouth Transfer Efficiency. To estimate the amount of metal on the hands that might be ingested via hand-to-mouth contact, we used a hand transfer efficiency, or HTE parameter, of 0.13. The HTE parameter quantifies the fraction of material on the hands that is likely to be transferred to the mouth and ultimately ingested. The HTE methodology was originally developed by the Consumer Products Safety Commission (CPSC, 1990), and used again by the CPSC in 2003 (CPSC, 2003). Gradient Corporation adapted the HTE for estimating exposure to dislodgeable residue on treated wood surfaces (Gradient, 2001). The HTE transfer is based on estimates of the amount of soil transferred by children from the surface of their hands to the mouth, where it is subsequently ingested.

CPSC (1990) determined lead loading onto hands based on a study by Roels *et al.* (1980), which evaluated children's exposures to lead in the vicinity of a smelter. In this study, researchers measured the mass of lead adhering to children's hands by rinsing the front surface of the children's hands and analyzing the rinsate for lead. CPSC then used the average lead concentrations in soil samples to estimate the average amount of soil adhering to the hands. Gradient (2001) then divided the average amount of soil adhering to the hands by the "available" skin surface of the hands for the average age of the children included in the Roels *et al.* study (i.e., 11-year-olds) to generate a soil adherence factor (AF) of 1.1 mg/cm^2 for both boys and girls. The skin surface area of the hands available for contact with soil is assumed to be approximately one-third of the total surface area of both hands. Gradient used the median skin surface area data specific to a 1- to 6-year-old child and applied the soil AF derived from Roels *et al.* (1980) to estimate the average mass of soil on the hands for a 1- to 6-year-old child, which is approximately 145 mg for both hands. Gradient used the median hand surface area for a 1- to 6-year-old child to be consistent with soil ingestion rates, which have been estimated for this age group (discussed in the following paragraph).

Gradient (2001) then combined the estimate of soil loading on the hand with an estimated soil ingestion rate to derive the hand transfer efficiency (HTE) value, which is an estimate of the fraction of the mass of soil adhering to the hands that would need to be ingested to yield the estimated daily soil ingestion rate. A median soil ingestion rate of 38 mg/day for children ages 1 to 6 years was calculated based on a soil ingestion study conducted in Amherst, Massachusetts (Calabrese *et al.*, 1989; Stanek and Calabrese, 1995). This soil ingestion rate

Table 3a
EXPOSURE VIA HAND CONTACT –
EXPOSURE ASSUMPTIONS TYPICAL USAGE

Exposure *via* Hand Contact

$INTAKE(mg/kg\text{-}day) = [Load_{towel}(mg/cm^2) \times SA_{towel}(cm^2) \times F_{towel}(unitless) \times N \times T_{t/h}(unitless) \times HTE(day^{-1}) \times EF(days/year) \times ED(years)]/BW(kg) \times AT(days)$

$Load_{towel}$ (mg/cm²)	=	Concentration of metal on towel surface, estimated from concentration (mg/kg) in towels, weight of towels, and surface area of towels. Assume : *Half of total metal in towel is available on each side of towel surface.*		
SA_{towel} (cm²)	=	Surface area of towel (front and back).	2,268	*Based on average dimensions for 5 rental shop towels.*
F_{towel} (unitless)	=	Fraction of towel in contact with hand.	75%	*Professional Judgment*
N	=	Number of towels used daily per person. *Based on information provided by an INDA member (1996, 2002)*	2.5	
$T_{t/h}$ (unitless)	=	Towel to hand transfer. *Based on a range of transfer rates from wood, wood furniture, and vinyl flooring, ranging from <1% to 20%; (Clothier, 2000; Lu and Fenske, 1999); and assumption that transfer from shop towel is approximately 50% less than transfer from hard, smooth surfaces.*	5%	
HTE (day^{-1})	=	Hand to mouth transfer efficiency. *and Roels et al. (1980). This parameter integrates hand to mouth transfer occurring throughout the day.*	13%	*Based on Calabrese et al. (1989), Stanek and Calabrese (1995),*
EF (days/year)	=	Exposure frequency. *Based on CalEPA recommendations of a 5 day work week for 49 weeks per year (3 weeks vacation) (2002a)*	261	
ED (years)	=	Exposure duration.	40	*Based on CalEPA recommendation (2002a)*
BW (kg)	=	Body weight.	70	*Based on CalEPA recommendation (2002a)*
AT (days)	=	Averaging time. non cancer hazard	14,600	*Based on CalEPA recommendation (2002a)*
		cancer risk	25,550	*Based on CalEPA recommendation (2002a)*

Table 3b
EXPOSURE VIA HAND CONTACT – NON-CANCER HAZARDS TYPICAL USAGE

Metal	Average Concentration (mg/cm²)	Maximum Concentration (mg/cm²)	Average Intake (mg/kg-day)	Maximum Intake (mg/kg-day)	USEPA Oral RfD (mg/kg-day)	ATSDR Oral MRL (mg/kg-day)	CalEPA MADL[2] (mg/kg-day)	HEAST[3,4] Oral RfD (mg/kg-day)
Aluminum	4.6E-03	1.5E-02	1.3E-03	4.2E-03		2.0E+00		
Antimony	2.9E-04	5.5E-04	8.2E-05	1.6E-04	4.0E-04			
Arsenic[1]	3.4E-05	3.4E-05	9.5E-06	9.5E-06	3.0E-04	3.0E-04		
Barium	1.7E-03	1.4E-02	4.8E-04	4.0E-03	7.0E-02			
Cadmium	6.6E-05	2.1E-04	1.9E-05	6.0E-05	1.0E-03	2.0E-04	5.9E-05	
Chromium	1.1E-03	7.6E-03	3.1E-04	2.1E-03	1.5E+00			
Cobalt	1.2E-03	8.5E-03	3.4E-04	2.4E-03				
Copper	3.6E-03	1.3E-02	1.0E-03	3.6E-03				3.7E-02
Iron	5.0E-02	2.0E-01	1.4E-02	5.5E-02				
Lead	6.6E-04	1.7E-03	1.9E-04	4.9E-04			7.1E-06	
Manganese	1.6E-03	1.9E-02	4.5E-04	5.2E-03	1.4E-01			
Molybdenum	4.7E-04	1.8E-03	1.3E-04	5.1E-04	5.0E-03			
Nickel	1.3E-03	1.1E-02	3.8E-04	3.1E-03	2.0E-02			
Selenium	3.6E-05	6.6E-05	1.0E-05	1.9E-05	5.0E-03	5.0E-03		
Silver	7.6E-05	3.0E-04	2.2E-05	8.5E-05	5.0E-03			
Strontium	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.0E-01			
Tin	3.9E-04	1.6E-03	1.1E-04	4.4E-04				6.0E-01
Titanium	0.0E+00	0.0E+00	0.0E+00	0.0E+00				
Vanadium	1.2E-03	2.2E-03	3.4E-04	6.3E-04	9.0E-03			7.0E-03
Zinc	5.1E-03	2.4E-02	1.4E-03	6.8E-03	3.0E-01	3.0E-01		

[1] *Only one shop towel analyzed for arsenic*
[2] *CALEPA's MADL in ug/day converted to mg/kg-day, using body weight of 70 kg*
[3] *Health Effects Assessment Summary Tables (USEPA, 1997b).*
[4] *HEAST represents a database of EPA toxicity criteria as developed by various EPA offices. Not all values in HEAST have been peer reviewed*

Intake exceeds toxicity criterion *Criteria exceeded*

is the mean estimate for the 50th percentile child. This soil ingestion rate was divided by the hand soil-loading estimate for a child resident (approximately 145 mg on both hands), for a daily HTE value of approximately 0.26 hand loads per day.

In this report, we used half of 0.26 as the HTE value for adults, or 0.13. The smaller HTE value used for adults reflects the reduced hand-to-mouth behavior in people greater than 6 years of age. Using a smaller HTE for adults as compared to children is further supported by the United States Environmental Protection Agency's (USEPA) soil ingestion rates: their recommended mean soil ingestion rate for adults is exactly one-half of the value for children less than 6 years of age (USEPA, 1997a).

Exposure Frequency. We used an exposure frequency of 261

Table 3c
EXPOSURE VIA HAND CONTACT – CANCER RISKS TYPICAL USAGE

Metal	Average Concentration (mg/cm^2)	Maximum Concentration (mg/cm^2)	Average Intake (mg/kg-day)	Maximum Intake (mg/kg-day)	CalEPA NSRL[3] (mg/kg-day)
Aluminum	4.6E-03	1.5E-02	7.4E-04	2.4E-03	
Antimony	2.9E-04	5.5E-04	4.7E-05	8.9E-05	
Arsenic[1,2]	3.4E-05	3.4E-05	5.4E-06	5.4E-06	1.4E-04
Barium	1.7E-03	1.4E-02	2.8E-04	2.3E-03	
Cadmium	6.6E-05	2.1E-04	1.1E-05	3.4E-05	
Chromium	1.1E-03	7.6E-03	1.8E-04	1.2E-03	
Cobalt	1.2E-03	8.5E-03	1.9E-04	1.4E-03	
Copper	3.6E-03	1.3E-02	5.7E-04	2.0E-03	
Iron	5.0E-02	2.0E-01	8.1E-03	3.2E-02	
Lead	6.6E-04	1.7E-03	1.1E-04	2.8E-04	**2.1E-04**
Manganese	1.6E-03	1.9E-02	2.6E-04	3.0E-03	
Molybdenum	4.7E-04	1.8E-03	7.7E-05	2.9E-04	
Nickel	1.3E-03	1.1E-02	2.2E-04	1.8E-03	
Selenium	3.6E-05	6.6E-05	5.7E-06	1.1E-05	
Silver	7.6E-05	3.0E-04	1.2E-05	4.9E-05	
Strontium	0.0E+00	0.0E+00	0.0E+00	0.0E+00	
Tin	3.9E-04	1.6E-03	6.2E-05	2.5E-04	
Titanium	0.0E+00	0.0E+00	0.0E+00	0.0E+00	
Vanadium	1.2E-03	2.2E-03	2.0E-04	3.6E-04	
Zinc	5.1E-03	2.4E-02	8.2E-04	3.9E-03	

[1] USEPA's unit oral cancer risk (mg/kg-day) for arsenic for a 10^{-6} risk is the same as CALEPA's NSRL
[2] Only one shop towel analyzed for arsenic
[3] CALEPA's NSRL in ug/day converted to mg/kg-day, using body weight of 70 kg

Intake exceeds toxicity criterion *Criteria exceeded*

days per year, as recommended by CalEPA for occupational exposures (CalEPA, 2002a). This exposure frequency assumes exposure would occur 5 days/week, for 49 weeks/year.

Exposure Duration. We used an exposure duration of 40 years, as recommended by CalEPA for occupational exposures (CalEPA, 2002a).

Body Weight. We used a body weight of 70 kg, which is average adult body weight, as recommended by CalEPA for occupational exposures (CalEPA, 2002a).

Averaging Time. For comparing intakes with the MADL, we used an averaging time of 14,600 days (40 years x 365 days/year). For comparing intakes with the NSRL, we averaged exposures over a 70-year lifetime, as recommended by CalEPA (2002a), for an averaging time of 25,550 days.

Average and maximum intake for exposures occurring via hand contact are listed in *Tables 3 and 4*, at the end of the report, assuming either typical or high-end use of laundered shop towels, respectively. These tables include a comparison of the intakes to established toxicity criteria. Note that these tables only show intakes for metals that have established toxicity criteria. The toxicity criteria in the tables include Oral Reference Doses (RfDs) from USEPA's Integrated Risk Information System (IRIS) database, the Agency for Toxic Substances and Disease Registry's Oral Minimal Risk Level (ATSDR MRL), CalEPA's Prop 65 No-Significant Risk Level (NSRL) and Maximum Allowable Daily Level (MADL), and Oral RfDs from USEPA's Health Effects Assessment Summary Tables (HEAST) (USEPA, 1997b).

Table 3a lists the exposure assumptions used to estimate metal intake from laundered shop towels for exposure occurring via hand contact, assuming typical usage of 2.5 towels per day. *Table 3b* and *Table 3c* list estimated intake for non-cancer health effects and cancer, respectively. As shown in *Table 3b*, the maximum estimated intake of cadmium from the laundered shop towels assuming typical usage was essentially equivalent to the CalEPA Prop 65 MADL, for reproductive toxicity, of 5.9×10^{-5} mg/kg-day; while both the average and maximum estimated intake of lead exceeded the Prop 65 MADL of 7.1×10^{-6} mg/kg-day. As shown in *Table 3c*, the maximum estimated intake of lead from the laundered shop tow-

Table 3c
EXPOSURE VIA HAND CONTACT – CANCER RISKS TYPICAL USAGE

Metal	Average Concentration (mg/cm^2)	Maximum Concentration (mg/cm^2)	Average Intake (mg/kg-day)	Maximum Intake (mg/kg-day)	CalEPA NSRL[3] (mg/kg-day)
Aluminum	4.6E-03	1.5E-02	7.4E-04	2.4E-03	
Antimony	2.9E-04	5.5E-04	4.7E-05	8.9E-05	
Arsenic[1,2]	3.4E-05	3.4E-05	5.4E-06	5.4E-06	1.4E-04
Barium	1.7E-03	1.4E-02	2.8E-04	2.3E-03	
Cadmium	6.6E-05	2.1E-04	1.1E-05	3.4E-05	
Chromium	1.1E-03	7.6E-03	1.8E-04	1.2E-03	
Cobalt	1.2E-03	8.5E-03	1.9E-04	1.4E-03	
Copper	3.6E-03	1.3E-02	5.7E-04	2.0E-03	
Iron	5.0E-02	2.0E-01	8.1E-03	3.2E-02	
Lead	6.6E-04	1.7E-03	1.1E-04	2.8E-04	**2.1E-04**
Manganese	1.6E-03	1.9E-02	2.6E-04	3.0E-03	
Molybdenum	4.7E-04	1.8E-03	7.7E-05	2.9E-04	
Nickel	1.3E-03	1.1E-02	2.2E-04	1.8E-03	
Selenium	3.6E-05	6.6E-05	5.7E-06	1.1E-05	
Silver	7.6E-05	3.0E-04	1.2E-05	4.9E-05	
Strontium	0.0E+00	0.0E+00	0.0E+00	0.0E+00	
Tin	3.9E-04	1.6E-03	6.2E-05	2.5E-04	
Titanium	0.0E+00	0.0E+00	0.0E+00	0.0E+00	
Vanadium	1.2E-03	2.2E-03	2.0E-04	3.6E-04	
Zinc	5.1E-03	2.4E-02	8.2E-04	3.9E-03	

[1] USEPA's unit oral cancer risk (mg/kg-day) for arsenic for a 10^{-6} risk is the same as CALEPA's NSRL
[2] Only one shop towel analyzed for arsenic
[3] CALEPA's NSRL in ug/day converted to mg/kg-day, using body weight of 70 kg

Intake exceeds toxicity criterion *Criteria exceeded*

els, assuming typical usage, exceeded the CalEPA Prop 65 NSRL, for cancer, of 2.1 x 10^{-4} mg/kg-day (CalEPA, 2001, 2002b). Exposure to lead exceeded the Prop 65 NSRL for two laundered shop towels, and exceeded the Prop 65 MADL for all 21 of the laundered shop towels in which lead was detected [4].

Table 4a lists the exposure assumptions used to estimate metal intake from laundered shop towels for exposure occurring via hand contact, assuming high-end use of 10 towels per day. *Table 4b* and *Table 4c* list estimated intake for non-cancer health effects and cancer, respectively. As shown in *Table 4b*, both the maximum and the average estimated intake of cadmium from the laundered shop towels exceeded the CalEPA Prop 65 MADL of 5.9 x 10^{-5} mg/kg-day. The estimated exposure to cadmium exceeded the Prop 65 MADL for 6 of the 18 laundered shop towels in which cadmium was detected. The estimated maximum intake of cadmium also exceeded the ATSDR Oral MRL of 2.0 x 10^{-4} mg/kg-day. The maximum and average estimated intake of lead from the laundered shop towels exceeded the CalEPA Prop 65 MADL of 7.1 x 10^{-6} mg/kg-day. As shown in *Table 4c*, both the maximum and the average estimated intake of lead exceeded the CalEPA Prop 65 NSRL of 2.1 x 10^{-4} mg/kg-day. Assuming high-end use of laundered shop towels, exposure to lead exceeded the Prop 65 MADL in all 21 of the laundered shop towels in which lead was detected, and exceeded the Prop 65 NSRL in 16 of the 23 laundered shop towels, or in approximately 70% of the towels. In addition, the estimated intake of antimony, assuming high-end use, exceeded the USEPA Oral RfD of 4.0 x 10^{-4} mg/kg-day in three of the laundered shop towels.

[4] Lead was not detected in 2 of the 23 laundered shop towels.

Exposure via Direct Mouth Contact

Exposure to metals in laundered shop towels via direct mouth contact was estimated using the following equation:

$$Intake\ (mg/kg-day) = \frac{(Load_{towel} \times T_{t/m} \times SA_{lips} \times F_{lip} \times F_{ing} \times WL \times EF \times ED)}{BW \times AT}$$

where:

$Load_{towel}$ = Metal loading on towel surface (mg/cm^2);
$T_{t/m}$ = Towel to mouth transfer (unitless);
SA_{lip} = Surface area of lips (cm^2);

Table 4a
EXPOSURE VIA HAND CONTACT – EXPOSURE ASSUMPTIONS HIGH-END USE

Exposure *via* Hand Contact

$INTAKE(mg/kg\text{-}day) = [Load_{towel}(mg/cm^2) \times SA_{towel}(cm^2) \times F_{towel}(unitless) \times N \times T_{t/h}(unitless) \times HTE(day^{-1}) \times EF(days/year) \times ED(years)]/BW(kg) \times AT(days)$

$Load_{towel}$ (mg/cm²)	=	Concentration of metal on towel surface, estimated from concentration (mg/kg) in towels, weight of towels, and surface area of towels. Assume : *Half of total metal in towel is available on each side of towel surface.*		
SA_{towel} (cm²)	=	Surface area of towel (front and back).	2,268	*Based on average dimensions for 5 rental shop towels.*
F_{towel} (unitless)	=	Fraction of towel in contact with hand.	75%	*Professional Judgment*
N	=	Number of towels used daily per person. *Based on professional judgement.*	10	
$T_{t/h}$ (unitless)	=	Towel to hand transfer. *Based on a range of transfer rates from wood, wood furniture, and vinyl flooring, ranging from <1% to 20%; (Clothier, 2000; Lu and Fenske, 1999); and assumption that transfer from shop towel is approximately 50% less than transfer from hard, smooth surfaces.*	5%	
HTE (day^{-1})	=	Hand to mouth transfer efficiency. *and Roels et al. (1980). This parameter integrates hand to mouth transfer occurring throughout the day.*	13%	*Based on Calabrese et al. (1989), Stanek and Calabrese (1995),*
EF (days/year)	=	Exposure frequency. *Based on CalEPA recommendations of a 5 day work week for 49 weeks per year (3 weeks vacation) (2002a)*	261	
ED (years)	=	Exposure duration.	40	*Based on CalEPA recommendation (2002a)*
BW (kg)	=	Body weight.	70	*Based on CalEPA recommendation (2002a)*
AT (days)	=	Averaging time. non cancer hazard	14,600	*Based on CalEPA recommendation (2002a)*
		cancer risk	25,550	*Based on CalEPA recommendation (2002a)*

Table 4b
EXPOSURE VIA HAND CONTACT – NON-CANCER HAZARDS HIGH-END USE

Metal	Average Concentration (mg/cm²)	Maximum Concentration (mg/cm²)	Average Intake (mg/kg-day)	Maximum Intake (mg/kg-day)	USEPA Oral RfD (mg/kg-day)	ATSDR Oral MRL (mg/kg-day)	CalEPA MADL[2] (mg/kg-day)	HEAST[3,4] Oral RfD (mg/kg-day)
Aluminum	4.6E-03	1.5E-02	5.2E-03	1.7E-02		2.0E+00		
Antimony	2.9E-04	5.5E-04	3.3E-04	6.2E-04	**4.0E-04**			
Arsenic[1]	3.4E-05	3.4E-05	3.8E-05	3.8E-05	3.0E-04	3.0E-04		
Barium	1.7E-03	1.4E-02	1.9E-03	1.6E-02	7.0E-02			
Cadmium	6.6E-05	2.1E-04	7.5E-05	2.4E-04	1.0E-03	**2.0E-04**	**5.9E-05**	
Chromium	1.1E-03	7.6E-03	1.2E-03	8.6E-03	1.5E+00			
Cobalt	1.2E-03	8.5E-03	1.4E-03	9.6E-03				
Copper	3.6E-03	1.3E-02	4.0E-03	1.4E-02				3.7E-02
Iron	5.0E-02	2.0E-01	5.7E-02	2.2E-01				
Lead	6.6E-04	1.7E-03	7.5E-04	1.9E-03			**7.1E-06**	
Manganese	1.6E-03	1.9E-02	1.8E-03	2.1E-02	1.4E-01			
Molybdenum	4.7E-04	1.8E-03	5.4E-04	2.0E-03	5.0E-03			
Nickel	1.3E-03	1.1E-02	1.5E-03	1.2E-02	2.0E-02			
Selenium	3.6E-05	6.6E-05	4.0E-05	7.5E-05	5.0E-03	5.0E-03		
Silver	7.6E-05	3.0E-04	8.6E-05	3.4E-04	5.0E-03			
Strontium	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.0E-01			
Tin	3.9E-04	1.6E-03	4.4E-04	1.8E-03				6.0E-01
Titanium	0.0E+00	0.0E+00	0.0E+00	0.0E+00				
Vanadium	1.2E-03	2.2E-03	1.4E-03	2.5E-03	9.0E-03			7.0E-03
Zinc	5.1E-03	2.4E-02	5.7E-03	2.7E-02	3.0E-01	3.0E-01		

[1] *Only one shop towel analyzed for arsenic*
[2] *CALEPA's MADL in ug/day converted to mg/kg-day, using body weight of 70 kg*
[3] *Health Effects Assessment Summary Tables (USEPA, 1997b).*
[4] *HEAST represents a database of EPA toxicity criteria as developed by various EPA offices. Not all values in HEAST have been peer reviewed*

Intake exceeds toxicity criterion *Criteria exceeded*

Flip	=	Fraction of lip in contact with towel (unitless);
F_{ing}	=	Fraction of metal on lip that is ingested (unitless);
WL	=	Number of times shop wipes used to wipe lips per day (day^{-1});
EF	=	Exposure frequency (days/year);
ED	=	Exposure duration (years);
BW	=	Average adult body weight (kg);
AT	=	Averaging time (days).

These parameters are described below.

Metal Loading on Towel Surface. We used the same values as described above for exposure via hand contact.

Towel to Mouth Transfer. We assumed towel to mouth transfer would be similar to towel to hand transfer, and thus used the same value of 0.05, or 5%, as described above.

Surface Area of Lips. We used a surface area of 5.2 cm², based on a study by Ferrario et al. (2000). This study used a three dimensional facial morphometry method, which estimates surface area based on distances between specific landmarks,

Table 4c
EXPOSURE VIA HAND CONTACT – CANCER HAZARDS HIGH-END USE

Metal	Average Concentration (mg/cm^2)	Maximum Concentration (mg/cm^2)	Average Intake (mg/kg-day)	Maximum Intake (mg/kg-day)	CalEPA NSRL[3] (mg/kg-day)
Aluminum	4.6E-03	1.5E-02	3.0E-03	9.5E-03	
Antimony	2.9E-04	5.5E-04	1.9E-04	3.6E-04	
Arsenic[1,2]	3.4E-05	3.4E-05	2.2E-05	2.2E-05	1.4E-04
Barium	1.7E-03	1.4E-02	1.1E-03	9.2E-03	
Cadmium	6.6E-05	2.1E-04	4.3E-05	1.4E-04	
Chromium	1.1E-03	7.6E-03	7.0E-04	4.9E-03	
Cobalt	1.2E-03	8.5E-03	7.8E-04	5.5E-03	
Copper	3.6E-03	1.3E-02	2.3E-03	8.1E-03	
Iron	5.0E-02	2.0E-01	3.3E-02	1.3E-01	
Lead	6.6E-04	1.7E-03	4.3E-04	1.1E-03	**2.1E-04**
Manganese	1.6E-03	1.9E-02	1.0E-03	1.2E-02	
Molybdenum	4.7E-04	1.8E-03	3.1E-04	1.2E-03	
Nickel	1.3E-03	1.1E-02	8.7E-04	7.1E-03	
Selenium	3.6E-05	6.6E-05	2.3E-05	4.3E-05	
Silver	7.6E-05	3.0E-04	4.9E-05	1.9E-04	
Strontium	0.0E+00	0.0E+00	0.0E+00	0.0E+00	
Tin	3.9E-04	1.6E-03	2.5E-04	1.0E-03	
Titanium	0.0E+00	0.0E+00	0.0E+00	0.0E+00	
Vanadium	1.2E-03	2.2E-03	7.8E-04	1.4E-03	
Zinc	5.1E-03	2.4E-02	3.3E-03	1.5E-02	

[1] USEPA's unit oral cancer risk (mg/kg-day) for arsenic for a 10^{-6} risk is the same as CALEPA's NSRL
[2] Only one shop towel analyzed for arsenic
[3] CALEPA's NSRL in ug/day converted to mg/kg-day, using body weight of 70 kg

Intake exceeds toxicity criterion *Criteria exceeded*

which for the lips includes the outermost portion of the upper and lower lips, and the outer right and left side of the lips. Using this method the estimated outer lip surface area for 105 men and 96 women (ages 18 to 32) was 5.59 and 4.80 cm^2, respectively. We used the average lip surface area for men and women, of 5.2 cm^2.

Fraction of Lip in Contact with Towel. We assumed that the laundered shop towel would contact 50% of the lip surface area, based on professional judgment.

Fraction of Metal on Lip that is Ingested. We assumed that 50% of metal on the lip would be ingested, based on professional judgment.

Number of Times Laundered Shop Towels Used to Wipe Lips Per Day. We assumed that a worker would wipe their lips with the laundered shop towel two times on any given day, based on professional judgment. Note that we used the same assumption regarding the number of times per day the laundered shop towels are used to wipe lips, regardless of whether we assumed typical usage of 2.5 towels per day, or high-end use of 10 laundered shop towels per day (for exposure via contact with hands and subsequent transfer to the mouth).

Table 5a lists the exposure assumptions used to estimate metal intake occurring via direct mouth contact. Average and maximum intakes for exposures occurring via direct mouth contact are listed in *Table 5b* and *Table 5c*, at the end of the report. These exposures are lower than exposure occurring via hand contact by nearly three orders of magnitude, and thus do not exceed any of CalEPA's toxicity criteria.

Results

Based on this analysis, the estimated exposure to lead in laundered shop towels exceeds CalEPA's Prop 65 limits, if we assume typical usage of 2.5 laundered shop towels per day. The average concentration of lead in the 23 used, laundered shop towels results in estimated intakes that exceed the Prop 65 MADL, for reproductive toxicity, by 27-fold. The maximum lead concentration in the laundered shop towels results in estimated intakes that exceed the MADL, for reproductive toxicity, by 69-fold, and the NSRL, for cancer, by 1.3-fold. Exposure to lead exceeded the Prop 65 NSRL, for cancer, for two laundered shop towels, and exceeded the Prop 65 MADL, for reproductive toxicity, for all 21 laundered shop towels in

Table 5a
EXPOSURE VIA MOUTH CONTACT
– EXPOSURE ASSUMPTIONS

Exposure *via* Mouth Contact

$INTAKE(mg/kg\text{-}day) = [Load_{towel}(mg/cm^2) \times T_{t/m}(unitless) \times SA_{lips}(cm^2) \times F_{lip}(unitless) \times F_{ing}(unitless) \times WL(day^{-1}) \times EF(days/year) \times ED(years)]/BW(kg) \times AT(years)$

$Load_{towel}$ (mg/cm^2)	=	Concentration of metal on towel surface, estimated from concentration (mg/kg) in towels, weight of towels, and surface area of towels. Assume : *Half of total metal in towel is available on each side of towel surface.*			
$T_{t/m}$ (unitless)	=	Towel to mouth transfer. *Based on a range of transfer rates from wood, wood furniture, and vinyl flooring, ranging from <1% to 20%; (Clothier, 2000; Lu and Fenske, 1999); and assumption that transfer from shop towel is approximately 50% less than transfer from hard, smooth surfaces.* ***Note:*** *this is same value as towel-hand transfer.*		5%	
SA_{lips} (cm^2)	=	Surface area of lips.		5.2	*Ferrario et al. 2000; Average for men/women*
F_{lip} (unitless)	=	Fraction of lip surface area contacting towel.		50%	
F_{ing} (unitless)	=	Fraction of metal on lips that's ingested.		50%	*Professional Judgment*
WL (day^{-1})	=	Number of times shop towels used to wipe lips.		2	*Professional Judgment*
EF (days/year)	=	Exposure frequency. *Based on CalEPA recommendations of a 5 day work week for 49 weeks per year (3 weeks vacation) (2002a)*		261	
ED (years)	=	Exposure duration.		40	*Based on CalEPA recommendation (2002a)*
BW (kg)	=	Body weight.		70	*Based on CalEPA recommendation (2002a)*
AT (days)	=	Averaging time.	non cancer hazard	14,600	*Based on CalEPA recommendation (2002a)*
			cancer risk	25,550	*Based on CalEPA recommendation (2002a)*

Table 5b
EXPOSURE VIA MOUTH CONTACT – NON-CANCER HAZARDS

Metal	Average Concentration (mg/cm^2)	Maximum Concentration (mg/cm^2)	Average Intake (mg/kg-day)	Maximum Intake (mg/kg-day)	USEPA Oral RfD (mg/kg-day)	ATSDR Oral MRL (mg/kg-day)	CalEPA MADL[2] (mg/kg-day)	HEAST[3,4] Oral RfD (mg/kg-day)
Aluminum	4.6E-03	1.5E-02	6.1E-06	2.0E-05		2.0E+00		
Antimony	2.9E-04	5.5E-04	3.9E-07	7.3E-07	4.0E-04			
Arsenic[1]	3.4E-05	3.4E-05	4.5E-08	4.5E-08	3.0E-04	3.0E-04		
Barium	1.7E-03	1.4E-02	2.3E-06	1.9E-05	7.0E-02			
Cadmium	6.6E-05	2.1E-04	8.8E-08	2.8E-07	1.0E-03	2.0E-04	5.9E-05	
Chromium	1.1E-03	7.6E-03	1.4E-06	1.0E-05	1.5E+00			
Cobalt	1.2E-03	8.5E-03	1.6E-06	1.1E-05				
Copper	3.6E-03	1.3E-02	4.7E-06	1.7E-05				3.7E-02
Iron	5.0E-02	2.0E-01	6.7E-05	2.6E-04				
Lead	6.6E-04	1.7E-03	8.8E-07	2.3E-06			7.1E-06	
Manganese	1.6E-03	1.9E-02	2.1E-06	2.5E-05	1.4E-01			
Molybdenum	4.7E-04	1.8E-03	6.3E-07	2.4E-06	5.0E-03			
Nickel	1.3E-03	1.1E-02	1.8E-06	1.5E-05	2.0E-02			
Selenium	3.6E-05	6.6E-05	4.7E-08	8.8E-08	5.0E-03	5.0E-03		
Silver	7.6E-05	3.0E-04	1.0E-07	4.0E-07	5.0E-03			
Tin	3.9E-04	1.6E-03	5.1E-07	2.1E-06	6.0E-01			
Vanadium	1.2E-03	2.2E-03	1.6E-06	3.0E-06				6.0E-01
Zinc	5.1E-03	2.4E-02	6.7E-06	3.2E-05				
Titanium	0.0E+00	0.0E+00	0.0E+00	0.0E+00	9.0E-03			7.0E-03
Strontium	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.0E-01	3.0E-01		

[1] *Only one shop towel analyzed for arsenic*
[2] *CALEPA's MADL in ug/day converted to mg/kg-day, using body weight of 70 kg*
[3] *Health Effects Assessment Summary Tables (USEPA, 1997b).*
[4] *HEAST represents a database of EPA toxicity criteria as developed by various EPA offices. Not all values in HEAST have been peer reviewed*

Intake exceeds toxicity criterion *Criteria exceeded*

which lead was detected.

If we assume high-end use of 10 laundered shop towels per day, our analysis indicates that the estimated exposure to lead and cadmium exceed CalEPA's Prop 65 limits, and the estimated exposure to antimony exceeds USEPA's RfD. Estimated exposure to cadmium also exceeds ATSDR's MRL. The average and maximum concentration of cadmium in the laundered shop towels results in estimated intakes that exceed the Prop 65 MADL by 1.3-fold and 4-fold, respectively. Exposure to cadmium exceeded the Prop 65 MADL for 6 of 18 towels in which cadmium was detected. The maximum concentration of cadmium in the towels also results in an estimated intake that exceeds the ATSDR MRL, for non-cancer health effects, by 1.2 fold. Assuming high-end use of 10 laundered shop towels per day, the average and maximum concentration of lead in the laundered shop towels results in estimated intakes that exceed the Prop 65 MADL by 106-fold and 268-fold, respectively. The maximum lead concentration in the laundered shop towels results in estimated intakes that exceed the Prop 65 NSRL, by 5-fold. Exposure to lead exceeded the Prop 65 MADL for all 21 laundered shop towels in which lead was detected, and exceeded the Prop 65 NSRL for 16 of the 23 laundered shop towels, or 70% of the towels. In addition, the maximum antimony concentration in the laundered shop towels results in estimated intakes that exceed the USEPA RfD, for non-cancer health effects, by 1.6-fold. Exposure to antimony exceeded the USEPA RfD for three of the laundered shop towels.

Table 5c
EXPOSURE VIA MOUTH CONTACT – CANCER RISKS

Metal	Average Concentration (mg/cm^2)	Maximum Concentration (mg/cm^2)	Average Intake (mg/kg-day)	Maximum Intake (mg/kg-day)	CalEPA NSRL[3] (mg/kg-day)
Aluminum	4.6E-03	1.5E-02	3.5E-06	1.1E-05	
Antimony	2.9E-04	5.5E-04	2.2E-07	4.2E-07	
Arsenic[1,2]	3.4E-05	3.4E-05	2.5E-08	2.5E-08	1.4E-04
Barium	1.7E-03	1.4E-02	1.3E-06	1.1E-05	
Cadmium	6.6E-05	2.1E-04	5.0E-08	1.6E-07	
Chromium	1.1E-03	7.6E-03	8.2E-07	5.8E-06	
Cobalt	1.2E-03	8.5E-03	9.2E-07	6.4E-06	
Copper	3.6E-03	1.3E-02	2.7E-06	9.6E-06	
Iron	5.0E-02	2.0E-01	3.8E-05	1.5E-04	
Lead	6.6E-04	1.7E-03	5.0E-07	1.3E-06	2.1E-04
Manganese	1.6E-03	1.9E-02	1.2E-06	1.4E-05	
Molybdenum	4.7E-04	1.8E-03	3.6E-07	1.4E-06	
Nickel	1.3E-03	1.1E-02	1.0E-06	8.3E-06	
Selenium	3.6E-05	6.6E-05	2.7E-08	5.0E-08	
Silver	7.6E-05	3.0E-04	5.8E-08	2.3E-07	
Tin	3.9E-04	1.6E-03	2.9E-07	1.2E-06	
Vanadium	1.2E-03	2.2E-03	9.2E-07	1.7E-06	
Zinc	5.1E-03	2.4E-02	3.8E-06	1.8E-05	
Titanium	0.0E+00	0.0E+00	0.0E+00	0.0E+00	
Strontium	0.0E+00	0.0E+00	0.0E+00	0.0E+00	

[1] USEPA's unit oral cancer risk (mg/kg-day) for arsenic for a 10^{-6} risk is the same as CALEPA's NSRL

[2] Only one shop towel analyzed for arsenic

[3] CALEPA's NSRL in ug/day converted to mg/kg-day, using body weight of 70 kg

Intake exceeds toxicity criterion *Criteria exceeded*

Discussion

Because calculation of exposure requires the use of assumptions, there are uncertainties inherent in the exposure estimates, which could result in the actual exposures being either greater or less than the estimated values presented here. For example, due to a lack of empirical data, there is significant uncertainty regarding the transfer of metals from the towel to the hands, and from the hands to the mouth. Additional areas of uncertainty include (but are not limited to) surface loading of metals on the shop towels, number of towels used daily per person, the fraction of towels in contact with the hands, and suitability of the toxicity criteria for evaluating potential risks associated with metals on the shop towels. These areas of uncertainty, and their potential impact on our analysis, are discussed in more detail below.

Metal Loading on Towel Surface. For estimating surface loading of metals on the shop towels, we assumed metals would be evenly distributed on the laundered shop towels. However, it is more likely that the distribution of metals in the towels would correspond with the fraction of the laundered shop towel in contact with the hands. This would result in a higher metal loading for the portion of the laundered shop towel in contact with the hands, and would thus result in a higher actual exposure. We also note that the number of shop towels analyzed by a laboratory is modest. Thus, the representativeness of the estimates of metal concentrations on these shop towels with respect to shop towels from the same or other laundries is uncertain. Nonetheless, the use of the maximum and the average concentrations of metals in the towels provides an estimate of a plausible range of values, although it is possible that analysis of a larger number of shop towels could yield both higher and lower metal concentrations, and hence surface loadings.

Number of Towels Used Daily Per Person. We estimated exposure to metals on laundered shop towels assuming either typical or high-end use of towels. For typical usage, we used 2.5 laundered shop towels per day, based on data for auto shops. The estimate of 2.5 towels per day was calculated by dividing the total number of towels used at a facility by the total number of employees. We used 10 towels as a plausible number of towels used daily by the high-end user based on information received from an INDA member (INDA member, 2003).

We assumed that exposure increases linearly as the number of shop wipes used increases. However, this might not be the case. It is possible that using more towels per day results in less metals per towel. Consequently, the total amount of metals on 10 towels could be less than four times the total exposure to metals on 2.5 towels (10/2.5). If the exposure did not increase linearly based on the number of towels used, intake associated with 10 towels a day would be less than we calculated, although the intake would still, in all likelihood, exceed that associated with 2.5 towels per day.

Fraction of Towel in Contact with Hands. Another area of uncertainty in this analysis is the fraction of the towel in contact with the hands. For this analysis, we assumed 75% of the total surface area of the towel would contact the hands, based on professional judgment. According to information provided by an INDA member, women use between 30-60% of the towel surface area in any given hand drying event, and men use approximately 25% more of the towel surface area than women, or between 38 and 75%. Thus, 75% could be considered a maximum estimate for the fraction of towel in contact with hands. However, other uses of the towel, such as cleaning shop equipment, may involve contact with different portions of the towel, such that the fraction of the towel in contact with the hands for all uses throughout the day may be greater than the fraction contacted for drying hands. In addition, using a towel multiple times would likely increase the total surface area used.

Towel to Hand Transfer. For this analysis, we estimated transfer of metals from the towel to the hands based on data regarding transfer of pesticides from surfaces to hands. We chose these data, because they were the only reliable data we found regarding transfer of substances to hands. However, use of the pesticide transfer data introduces considerable uncertainty, notably potential differences in transfer rates for organics (pesticides) vs. inorganics (metals); differences in transfer rates for the relatively small sized pesticide residues vs. the larger sized metal particles; as well as differences in adherence of recently applied pesticide residues vs. metal particles on a laundered shop towel. In spite of these uncertainties, there is a precedent for estimating transfer rates for inorganics based on pesticide data. For example, USEPA used pesticide transfer data to estimate transfer (to hands) from arsenic on wood structures treated with copper chromated arsenic (USEPA, 2002). Basing the towel to hand transfer rate on data for hard surfaces also introduces uncertainty for estimating transfer from a porous surface, such as the shop towel. However, the value that we used for towel to hand transfer was at the upper end of the range of values observed for transfer of pesticides from carpets (also a porous surface) to hands, and is thus a plausible value.

An additional area of uncertainty for this factor is use of the entire range of transfer rates, including transfer rates to water-wetted hands, and including transfer rates at 4-hours post-application. As noted above, transfer rates were greater to water-wetted hands than to saliva-wetted hands, and greater at 4-hours post-application than at 24-hours post-application. Although use of transfer rates at 4-hours post-application may overestimate transfer of metals from the shop towels, it is conceivable that some usage of the shop towels may involve hands that are water-wetted (e.g., for drying hands).

Daily Hand to Mouth Transfer Efficiency. This parameter was based on data regarding lead loading onto hands and soil ingestion rates in children, to estimate the amount of dislodgeable material on the hand surface that is transferred to the mouth, throughout the entire day. The estimate for children ages 1-6 years is 0.26, which means that 26% of the mass of dislodgeable material on the surface of a child's hand would be transferred to the mouth, and subsequently ingested. Because soil ingestion rates for adults are approximately 50% of soil ingestion rates for children, we used a hand-to-mouth transfer efficiency of 0.13, which means that 13% of the mass on an adult's hand is estimated to be transferred to the mouth and subsequently ingested. It should be noted that the surface area of a typical adult's hand is greater than that of a child's hand by a factor of 1.6 (904 vs. 550 cm^2), and that typical soil loadings (when expressed on a per cm^2 basis) on an adult's hand are about 0.28 of those of a child's (0.19 vs. 0.66 mg/cm^2) (USEPA, 1997a). This means that the total mass of soil on the adult's hand is about half of the total mass on the child's hand (i.e., $1.6 \times 0.28 = 0.45$). To achieve an estimated soil ingestion rate for adults (50 mg/day) which is half that of the child (100 mg/day), implies using the same hand-to-mouth transfer efficiency for both adults and children. Using a lower transfer rate for adults could potentially underestimate actual intake of metals by approximately two fold (0.28/0.13).

An additional aspect of uncertainty regarding the HTE parameter is the time frame of exposure. The HTE parameter integrates exposure due to hand-to-mouth activity occurring throughout a 12-hour day (approximately). Although hand-to-mouth activity may be more likely to occur at work, it will also occur while away from work. Using the HTE parameter without adjusting for the length of a typical 8-hour workday could overestimate actual intake of metals from the shop towels, by approximately 50% (12 hours/8 hours). Thus, overestimating HTE partially offsets the use of the lower transfer rate discussed above. Taken together, these two aspects of uncertainty in the HTE parameter could result in estimated intakes being slightly lower than actual intakes. Note that inherent in use of this hand-to-mouth transfer efficiency for this analysis, is the assumption that transfer of metals from hands to mouth is comparable to transfer of soil from hands to mouth.

Bioavailability. Because no data are available regarding the bioavailability [5] of metals on laundered shop towels, our analysis assumes that the bioavailability of the metals in the shop wipes is comparable to the bioavailability of metals in the studies used as the basis for the toxicity criteria. However, the metals present in the laundered shop towels may be in a relatively insoluble, metallic form, and hence may be less bioavailable than the more soluble forms of metals typically used in studies that serve as the basis for most toxicity criteria, including those used in this analysis. To directly compare estimated intakes with toxicity criteria, both the estimates and the toxicity criteria should be adjusted to represent an absorbed dose. Reduced bioavailability would result in a lower absorbed dose and hence reduced likelihood of exceeding the Prop 65 toxicity criteria, if adjusted to represent an absorbed dose.

Table 6 summarizes the impact of the uncertainties discussed above on the likelihood of exceeding CalEPA's Prop 65 toxicity criteria. It can be seen that one assumption was estimated to either decrease or increase the likelihood of an exceedance, three were estimated to decrease the likelihood, and one was estimated to slightly increase the likelihood of an exceedance. Where we were able to make quantitative estimates of the magnitude of these impacts, the impact was relatively modest – on the order of at most two-fold.

---

[5] In evaluating the potential for toxicity, it is important to consider the amount of a chemical that is absorbed into the bloodstream, since it is the absorbed form of the chemical that is typically of toxicological concern. Following ingestion, a chemical may not be completely absorbed into the bloodstream; some fraction of the dose may pass through the gastrointestinal tract unabsorbed. This phenomenon is reflected in the term relative bioavailability. Bioavailability is dependent on a number of factors, including chemical form, solubility, and particle size (Valberg et al., 1997).

Taking the uncertainties into consideration as a whole is unlikely to change conclusions regarding lead. This is due to the relatively large exceedance of the Prop 65 MADL for lead, where all towels in which lead was detected exceeded the Prop 65 MADL, for reproductive toxicity, by an average of 26-fold – an exceedance which is likely greater than the magnitude of the uncertainties (for those uncertainties that could be quantified).

Conclusion

Concentrations of metals in laundered shop wipes can result in exposures (as evaluated using the methodology presented in this report) which exceed toxicity criteria for certain metals.

Specifically, the overall conclusions of this analysis are:

- Laundered shop towels contain a variety of heavy metals
- Metals on shop towels can get onto hands and then inadvertently get into the mouth and be swallowed
- The amount of lead that someone might accidentally ingest from the laundered shop towels may exceed a CalEPA Proposition 65 limit (based on using 2.5 towels per day)
- If the number of towels used increases to 10 per day, exceedances of Prop 65 limits, USEPA toxicity criteria, or ATSDR toxicity criteria may occur for antimony, cadmium, and lead.

Table 6
IMPACT OF ALTERNATIVE EXPOSURE ASSUMPTIONS ON LIKELIHOOD OF EXCEEDING PROP 65 TOXICITY CRITERIA

Parameter with Uncertainty	Likelihood of Exceeding Prop 65 Toxicity Criteria
Metal Loading on Towel Surface	Increase or decrease
Fraction of Towel in Contact with Hands	Slightly decrease
Towel to Hand Transfer	Decrease by a factor of 2
Hand to Mouth Transfer Efficiency	Slightly increase
Bioavailability	Decrease

References

Calabrese, E.J., R. Barnes, E.J. Stanek, H. Pastides, C.E. Gilbert, P. Veneman, X. Wang, A. Lasztity, and P.T. Kostecki. 1989. How much soil do young children ingest: an epidemiologic study. Reg. Toxicol. and Pharmacol. 10:123-137.

California Environmental Protection Agency (CalEPA). 2001. "Prop. 65 MADL for Reproductive Toxicity for Cadmium (Oral Route)." May.

California Environmental Protection Agency (CalEPA). 2002a. "Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments." June 6. Downloaded from http://oehha.ca.gov/air/hot-spots/HRSguide.html, on May 27, 2003.

California Environmental Protection Agency (CalEPA). 2002b. "Prop. 65 Status Report: No Significant Risk Levels for Carcinogens (NSRL) and Maximum Allowable Daily Levels (MADL) for Chemicals Causing Reproductive Toxicity." September.

Camann, D.E., T.K. Majumdar, and H.J. Harding. 1996. Transfer efficiency of pesticides from carpet to saliva-moistened hands. In Measurement of Toxic and Related Air Pollutants; Proceedings of an International Specialty Conference, Research Triangle Park, NC, May 7-9. VIP-64 Air and Waste Management Association.

Clothier, J.M. 2000. "Dermal Transfer Efficiency of Pesticides from New, Vinyl Sheet Flooring to Dry and Wetted Palms." U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C. EPA/600/R-00/029. February.

Consumer Product Safety Commission (CPSC). 1990. "U.S. Consumer Product Safety Commission Project Report: Playground Equipment – Transmittal of Estimate of Risk of Skin Cancer from Dislodgeable Arsenic on Pressure Treated Wood Playground Equipment." Provided by Hickson Corporation, Atlanta, GA.

Consumer Products Safety Commission (CPSC). 2003. Memorandum to P.M. Bittner, from K.M. Hatlelid, re: Cancer Risk Assessment for Arsenic Exposure from CCA-treated Wood Playground Structures. January 23.

Ferrario, V.F., C. Sforza, J.H. Schmitz, V. Ciusa, and A. Colombo. 2000. Normal growth and development of the lips: A 3-dimensional study from 6 years to adulthood using a geometric model. J Anat. 196:415-423.

Gradient Corporation (Gradient). 2001. "Evaluation of Human Health Risks from Exposure to Arsenic Associated with CCA-treated Wood." Cambridge, MA. October 5.

INDA member. 1996. "Textile Replacement on Site Product Test Rental Shop Towels vs. 2 Layered vs. Heavy Duty Workhorse vs. Wypall." Prepared for an INDA member. December.

INDA member. 2002. Letter from INDA member to Barbara Beck, re: Background Information on the Rental Shop Towel Testing Program, and Wiper Usage. November 21.

INDA member. 2003. Personal communication from INDA member to Barbara Beck, regarding towel usage. September 15.

Lu, C. and R.A. Fenske. 1999. Dermal transfer of chlorpyrifos residues from residential surfaces: comparison of hand press, hand drag, wipe, and polyurethane foam roller measurements after broadcast and aerosol pesticide applications. Environ Health Perspect. 107:463-467.

Roels, H.A., J.P. Buchet, R.R. Lauwerys, P. Bruaux, F. Claeys-Thoreau, A. Lafontaine, and G. Verduyn. 1980. Exposure to lead by the oral and pulmonary routes of children living in the vicinity of a primary lead smelter. Environ. Research 22:81-94.

Stanek, E.J. and E.J. Calabrese. 1995. Daily estimates of soil ingestion in children. Environ. Health Perspect. 103(3):276-285.

U.S. Environmental Protection Agency (USEPA). 1997a. "Exposure Factors Handbook. Volume I: General Factors; Volume III: Activity Factors." Office of Research and Development, Washington, D.C. EPA/600/P-95/002Fa; EPA/600/P-95/002Fc. August.

U.S. Environmental Protection Agency (USEPA). 1997b. "Health Effects Assessment Summary Table, FY 1997 Update." Office of Solid Waste and Emergency Response. EPA-504-R-97-036. July.

United States Environmental Protection Agency (USEPA). 2002. "Technical Manual: Using SHEDS-Wood for the Assessment of Children's Exposure and Dose from Treated Wood Preservatives on Playsets and Residential Decks." Office of Prevention, Pesticides and Toxic Substances.

Valberg, P.A., B.D. Beck, T.S. Bowers, J.L. Keating, P.D. Bergstrom, and P.D. Boardman. 1997. Issues in setting health-based cleanup levels for arsenic in soil. Regul. Toxicol. Pharmacol. 26:219-229.

— INJ

FACT SHEET

Gradient
CORPORATION

Gradient is an environmental consulting firm with nationally recognized specialties in risk assessment and toxicology, contaminant transport and fate, and environmental chemistry.

Samples of laundered shop towels which had been used and then laundered, were collected from 23 locations in 14 states throughout the U.S. The laundered shop towels were then submitted to an independent lab, which analyzed them for 27 metals and for oil and grease. All of the laundered shop towels contained oil and grease, and many contained elevated levels of metals, such as lead.

To assess the significance of the possible exposure to elevated levels of metals in the laundered shop towels, we estimated how much of the metals people might ingest, using 2.5 laundered shop towels per day in a manner involving relatively frequent contact as might occur in an auto body shop or maintenance area. We compared the amounts ingested to various criteria, including California Environmental Protection Agency (CalEPA) Proposition 65 regulatory limits. The Proposition 65 limits are exposure limits based on health endpoints such as cancer or reproductive effects. If a chemical exposure exceeds the limit, manufacturers may be required to notify the public of this exceedance. We also compared estimated intakes to toxicity criteria of the U.S. Environmental Protection Agency (USEPA) and the Agency for Toxic Substances and Disease Registry (ATSDR).

The results of this evaluation for lead are presented in the bar chart below. We calculated the lead intakes using the maximum amount of lead and the average amount of lead on the laundered shop towels tested, which represents the plausible range of exposure to lead found in laundered shop towels.

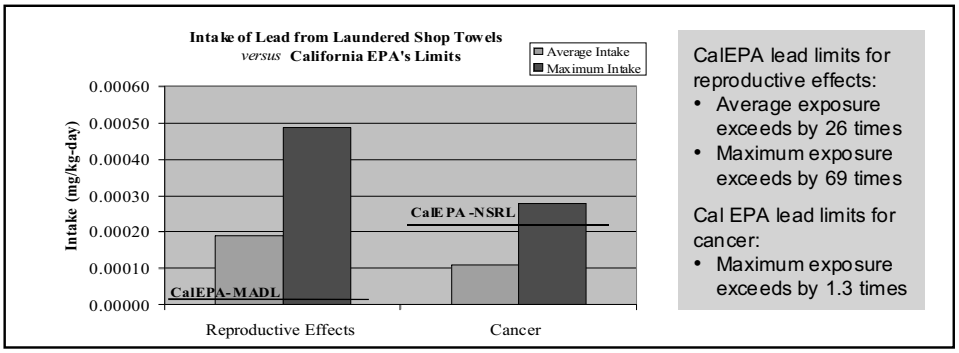
The bar chart compares the estimated lead exposure levels to CalEPA's Proposition 65 levels for reproductive effects (called Maximum Allowable Daily Levels, or MADLs) and cancer (called No Significant Risk Levels, or NSRLs).

These estimates are based on an assumed use of only 2.5 laundered shop towels per day per individual. Should individuals use 10 laundered shop towels per day the following exceedances could occur:

- The maximum intake for antimony may exceed USEPA's oral reference dose (RfD) for noncancer effects
- The maximum intake for cadmium may exceed ATSDR's oral Minimal Risk Level (MRL) for noncancer effects; the average intake and the maximum intake for cadmium may exceed CalEPA's MADL for reproductive effects
- Both the average intake and the maximum intake for lead may exceed CalEPA's NSRL for cancer

The overall conclusions of this analysis are:

- Laundered shop towels contain a variety of heavy metals
- Metals on shop towels can get onto hands and then inadvertently get into the mouth and be swallowed
- The amount of lead that someone might accidentally ingest from the laundered shop towels may exceed a CalEPA Proposition 65 limit (based on using 2.5 towels per day)
- If the number of towels used increases to 10 per day, exceedances of Prop 65 limits, USEPA toxicity criteria, or ATSDR toxicity criteria may occur for antimony, cadmium, and lead



CalEPA lead limits for reproductive effects:
- Average exposure exceeds by 26 times
- Maximum exposure exceeds by 69 times

Cal EPA lead limits for cancer:
- Maximum exposure exceeds by 1.3 times

DISCLAIMER: The bases for the conclusions summarized here are presented in their entirety in the companion report "Evaluation of Potential Exposure to Metals in Laundered Shop Wipes," which is available in the International Nonwovens Journal (INJ) on the INDA website at http://www.inda.org/subscript/. Use of different exposure assumptions, or comparison to different laundered shop wipes (which may contain different concentrations of metals), could affect the conclusions.

Return to Table of Contents