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Survey of Selected Activities Relevant to Exposures to Soils

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In the summer and fall of 1996, a survey of randomly selected U.S. households was conducted by computer assisted telephone interview (CATI). The primary purpose of the survey, dubbed Soil Contact Survey (SCS-I), was quantification of behavioral patterns pertinent to dermal exposure to soil. Results of the survey and a follow-up (SCS-II) conducted in 1998 have been applied to estimation of a metric of dermal soil exposure termed the soil contact rate (SCR). Partial results have been presented elsewhere (Garlock et al., 1999; Wong et al., in press). The purpose of this paper is dissemination of selected data gathered in SCS-I that have not been formally incorporated in SCR estimation, but are of potential interest to exposure assessors. In SCS-I, respondents were questioned regarding multiple activities potentially relevant to evaluation of residential exposure to soil. Data presented here describe frequency of consumption of homegrown produce, frequency of shoe removal prior to residence entry, type of floor covering, indoor/outdoor pet ownership, occurrence of bare yard soil and residential proximity to vacant lots or fields.

Ingestion of foods grown in home gardens is of concern because local soil contamination may lead to elevated exposures (USEPA, 1997a). Chemical contaminants in soil may be transferred to plant tissues by absorption or adsorption (McKone, 1994). Produce may also be a vehicle for ingestion of soil not washed from edible plant surfaces. A survey performed by the National Gardening Association reported that 34 million U.S. households (38 percent of the total) participated in vegetable gardening in 1986 (USEPA, 1997a). Tomatoes, peppers, onions, cucumbers, lettuce, beans, carrots, and corn are the most commonly grown vegetables. EPA analysis of USDA Nationwide Food Consumption Survey (NFCS) data from 1987-88 produced estimates that 18% of U.S. citizens $\geq$ 1 year of age consume homegrown vegetables and 8% consume homegrown fruit (USEPA, 1997a).

Residential exposures to contaminants in outdoor soils may occur indoors if house dust is impacted by track-in of soil. House dust is considered to be a mixture of biologically-derived material, deposited aerosols and soil particles brought in by foot traffic (Thatcher and Layton, 1995; USEPA, 1997b). The fraction attributable to outdoor soil has been estimated to be 30 to 40 percent (Fergusson and Kim, 1991). Outdoor soil and indoor dust lead levels have been found to be positively associated (Rabinowitz and Bellinger, 1988; Thornton et al, 1990; Berny et al., 1994). Thatcher and Layton (1995) studied "tracked" and "untracked" areas of floor surfaces and found that areas subject to foot traffic showed higher accumulation (mass/area) of dust. Nishioka et al. (1996) demonstrated transfer of herbicide from treated turf to carpet in a track-in simulation. Due to size selection, lack of degradation indoors or

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other factors, contaminants may become enriched in house dusts. For instance, pesticide levels in indoor dust were found to be much higher than in outdoor soils in an agricultural community in Washington state (Simcox et al., 1995). Shoe removal has been hypothesized to reduce soil track-in (Ott and Roberts, 1998; Roberts et al., 1999).

Pets may assist children with access to soil by digging or by accumulating soil and dust in their fur. Pets with access to both the indoors and outdoors can also bring outdoor soil and dust into the home. Thomas et al. (1976) linked increased blood lead levels in dogs with increased blood lead levels in children aged 1 to 6 in the same households. Berny et al. (1995) found a similar result for dogs and/or cats. The strongest association occurred in the youngest age group (children $\leq$ 6) with "mostly inside" pets.

Type of floor covering may also be important in assessing exposure to house dust and related contaminants. Carpets appear to act as storage reservoirs for some persistent contaminants (Lewis et al., 1994; Whitmore et al., 1994; Roberts et al., 1999). Carpeted areas also typically have higher dust mass per unit area than uncarpeted areas (Thatcher and Layton, 1995).

Patches of bare soil in yards provide easy access to soil. Hwang et al. (1997) reported an association between urinary arsenic in children and soil arsenic in bare spots in yards. Residential proximity to vacant lots or fields is of interest because vacant land represents a possible opportunity for exposure to bare soils for children who are otherwise locally restricted to well maintained yards or to paved surfaces. Vacant lots may also have a history of use as dumping grounds due to lack of oversight.

MATERIALS AND METHODS

In the summer of 1996, the SCS-I was administered via CATI. A national sample of 450 households was queried on behavior that could lead to dermal soil exposures. Households were chosen through random-digit dialing and respondents were required to be 18 or older. Demographic characteristics of the sample are discussed below and further described elsewhere (Garlock et al., 1999; Wong et al., in press).

The first section included a brief introduction and description of the survey. The second section was comprised of questions regarding residential activities of both adults and children and clothing and bathing choices. This component included questions on participation in gardening. Persons reporting gardening were asked what sorts of homegrown produce they personally consumed. Responses were recorded for 1) any tree fruit (such as apples or cherries), 2) any root vegetables (such as potatoes or carrots), and 3) any other garden vegetables (such as lettuce, tomatoes or beans). The next section contained questions about employment of family members that could lead to soil exposure. The fourth section included miscellaneous questions about other characteristics potentially relevant to soil exposure in the home. Respondents with minor children were asked if there were areas of bare soil in their yards (other than gardens) or if there were any accessible vacant lots or fields within walking distance of the residence. All respondents were queried regarding whether street shoes were regularly removed prior to entry or worn in the home. Questions were also presented regarding predominant floor coverings in the home, the presence of pets, and whether those pets spent time both indoors and outdoors. The last section of the SCS dealt with demographics of the population. Geographic location (region and zip code) and socioeconomic status

were determined, as well as age, race, and type of dwelling. Results reported here are taken from the second and fourth sections of the survey.

Statistical analyses were performed in SPSS (SPSS Inc., 1997). Most results are presented as simple summaries. Chi-square contingency tables were used to compare demographic characteristics and to test for trends in participation in one or more of the selected activities. Spearman rank correlation was used to test variable dependence on respondent age and household income.

RESULTS AND DISCUSSION

Comparison of some demographic characteristics of the SCS-I respondents with U.S. census data has been presented previously (Garlock et al., 1999). No significant differences with respect to gender, race or ethnicity were found. The distribution of respondents' ages deviated slightly, but significantly, from that of U.S. adults (fewer persons 18-35 and $\geq$ 65, more persons 35-64). The SCS-I sample also included fewer households of lower income (< $25,000/yr) and more of higher income than the general population. Spearman rank correlations with age and income were examined for all variables presented here. No significant relationships (p=0.06-0.75) with household income were found. Two significant relationships with respondents' age were found. Floor covering (p=0.002) and presence of vacant lots or fields (p=0.046) were negatively correlated with age. However correlation was weak ($|\rho|<0.17$) in each case. Consequently, weighting for either age or income was not viewed as appropriate and was not conducted.

Almost 50% of the national sample reported gardening (Table 1). The fraction of gardening households is larger than revealed by the National Gardening Association survey noted above, but was not restricted to vegetable gardening. Three quarters of the (adult) respondents reporting gardening in SCS-I households (37% of the national sample) reported personal consumption of homegrown produce. This figure is somewhat higher than estimated by EPA based on NFCS data (USEPA, 1997a). However, consumption rates are limited to adults who may be more likely to eat produce than children. The SCS-I data provide some indication of interdependence among patterns of consumption. Only about 44% of consumers restricted themselves to a single category of produce (tree fruit, root vegetables or other vegetables). Most (55% of consumers, 20% of respondents nationally) reported eating at least two types of produce and 22% of consumers (8% nationally) all three types. Although much more detailed with respect to food categories considered, EPA's analysis of NFCS data (USEPA, 1997a) provides no information on the likelihood of consumption of more than one type of homegrown food.

Regular shoe removal prior to entry was reported by about 40 percent of all respondents (Table 2). Simcox et al. (1995) reported 28% shoe removal in a non randomly selected population in an agricultural community. Carpets and rugs were the dominant floor covering in about two thirds of the SCS-I households and represented a substantial portion of floor covering in more than 80% of households sampled. Less than 15% reported predominantly bare floors.

Of those homes with children, a little more than half of respondents report an absence of bare spots (other than gardens) in their yards while the remainder reported some bare spots (Table 3). A majority ($\approx$ 64%) of SCS-I homes with children did report a vacant lot or field within walking distance of the home. A

Table 1. Consumption of homegrown fruits and vegetables

Response	n	%[a]	% national[b]
Tree fruit only	7	3.2	1.6
Root vegetables only	2	0.9	0.4
Other vegetables only	64	29.2	14.2
Tree fruit & root vegetables	1	0.5	0.2
Tree fruit & other vegetables	13	5.9	2.9
Root & other vegetables	41	18.7	9.1
Tree fruit, root & other vegetables	36	16.4	8.0
None of the above	55	25.1	12.2
Total	**219**	**100.0**	**48.7**

[a]Percent of gardeners (n=219)
[b]Percent of total sample (n=450)

Table 2. Home and family characteristics

Response	n	%
Shoe removal		
Regular removal of shoes at entry	175	38.9
Street shoes regularly worn indoors	209	46.4
Both/varies	65	14.4
Don't know/refused	1	0.2
Total	**450**	**100.0**
Primary floor covering		
Area rugs	26	5.8
Wall-to-wall carpeting	273	60.7
Bare wood	57	12.7
Equal rugs/carpet and bare wood	82	18.2
Other	8	1.8
Don't know/refused	4	0.9
Total	**450**	**100.0**

Table 3. Children's potential access to soil[a]

Response	n	%	% national[b]
Bare soil in yard			
Yes	80	44.7	17.8
No	97	54.2	21.6
Don't know/refused	2	1.1	0.4
Total	**179**	**100.0**	**39.8**
Vacant lots or fields within walking distance			
Yes	114	63.7	25.3
No	63	35.2	14.0
Don't know/refused	2	1.1	0.4
Total	**179**	**100.0**	**39.8**

[a]Asked only of households with children under 18 (n=179)
[b]Percent of all households (n=450)

Table 4. Pets which spend time both inside and outside the home

Response	n	% of category	% national[a]
Presence of indoor/outdoor pets			
At least one I/O dog	111	54.7	24.7
At least one I/O cat	35	17.2	7.8
I/O cat(s) and dog(s)	17	8.4	3.8
Pets, but always indoors	22	10.8	4.9
Pets, but always outdoors	18	8.9	4.0
No pets	246	-	54.7
Don't know/refused	1	-	0.2
Total	**450**	**100.0[b]**	**100.0**
Number of indoor/outdoor dogs			
One	86	67.2	19.1
Two	29	22.7	6.4
Three	8	6.3	1.8
Four	2	1.6	0.4
Five	2	1.6	0.4
More than five	1	0.8	0.2
Total	**128**	**100.0[c]**	**28.4**
Number of indoor/outdoor cats			
One	36	69.2	8.0
Two	7	13.5	1.6
Three	5	9.6	1.1
Four	3	5.8	0.7
Five	1	1.9	0.2
More than five	0	0.0	0.0
Total	**52**	**100.0[d]**	**11.6**

[a]Percent of national sample (n=450)
[b]Percent of households with pets (n=203)
[c]Percent of households with indoor/outdoor dogs (n=128)
[d]Percent of households with indoor/outdoor cats (n=52)

review of the literature produced little prior information relevant to either of these statistics. A survey in a neighborhood of Phoenix, Arizona (USEPA, 1997b) yielded an estimate that 7% of primary school (K-3) students and 1% of preschool children played in vacant lots.

Indoor/outdoor dogs and cats were reported by about 36% of the SCS-I households (Table 4). Another 9% reported pets that live exclusively indoors or outdoors. Survey personnel were instructed that, in the context of the questionnaire, "pets" meant cats or dogs, but wording on the CATI screen was unfortunately not entirely unambiguous. Nevertheless overall results appear in good agreement with Gehrke (1997) who previously reported that about 46% of U.S. households have dogs, cats or both. Gehrke did not distinguish indoor/outdoor status making further comparison more difficult. Whether pets are sources of children's exposures or merely useful as sentinels of those exposures in contaminated neighborhoods is uncertain. Berny et al. (1995) found that pet blood lead levels and child blood lead levels were correlated and that pet owners' blood lead levels significantly exceeded

Table 5. Co-occurrence of shoe removal and indoor/outdoor pets

Indoor/outdoor pets	*Removal of shoes*										
	Yes			*No*			*Mixed behavior*			*DK/R*[b]	
	n	% doer	% nat.[a]	n	% doer	% nat.	n	% doer	% nat.	n	total n
At least one I/O dog	39	22.3	8.7	51	24.4	11.3	21	32.3	4.7		111
At least one I/O cat	15	8.6	3.3	15	7.2	3.3	5	7.7	1.1		35
I/O cat(s) and dog(s)	6	3.4	1.3	11	5.3	2.4	0	0.0	0.0		17
Pets, but always indoors	9	5.1	2.0	8	3.8	1.8	5	7.7	1.1		22
Pets, but always outdoors	6	3.4	1.3	10	4.8	2.2	2	3.1	0.4		18
No pets	100	57.1	22.2	114	54.5	25.3	32	49.2	7.1		246
Don't know/refused	0			0			0			1	1
Total	**175**	**100.0**	**38.9**	**209**	**100.0**	**46.4**	**65**	**100.0**	**14.4**	**1**	**450**

[a]Percent of national sample (n=450)
[b]Don't know/refused

Table 6. Co-occurrence of shoe removal and floor covering

Primary floor covering	*Removal of shoes*										
	Yes			*No*			*Mixed behavior*			*DK/R*[b]	
	n	% doer	% nat.[a]	n	% doer	% nat.	n	% doer	% nat.	n	total n
Area rugs	12	6.9	2.7	9	4.3	2.0	5	7.7	1.1		26
Wall-to-wall carpeting	104	59.4	23.1	130	62.2	28.9	39	60.0	8.7		273
Bare wood	23	13.1	5.1	28	13.4	6.2	6	9.2	1.3		57
Equal carpet/ wood	33	18.9	7.3	35	16.7	7.8	14	21.5	3.1		82
Other	3	1.7	0.7	4	1.9	0.9	1	1.5	0.2		8
Don't know/refused	0			3	1.4	0.7	0			1	4
Total	**175**	**100.0**	**38.9**	**209**	**100.0**	**46.4**	**65**	**100.0**	**14.4**	**1**	**450**

[a]Percent of national sample (n=450)
[b]Don't know/refused

those of non owners (even though the pet owners group included fewer young persons). However, they concluded that pets were not sources of "exposure" because pet owners (all ages lumped) did not exceed the 10 μg/dl blood lead threshold more often than non pet owners. Possible differences among age groups or pet types ("mostly outside" or "mostly inside") were not considered in drawing this conclusion even though effects were seen in blood lead correlations. This definition of exposure also does not preclude the possibility that some portion of sub 10 μg/dl blood lead is attributable to contact with pets. Finally, Berny et al. did not examine the effect of multiple pets. From Table 4, it can be estimated that about one third of owners of cats or dogs with indoor/outdoor habits report owning more than one such pet.

Since both shoe removal and pet ownership may influence track-in of outdoor soil, comparisons of these behaviors (Table 5) were conducted using chi-square contingency tables. No significant trend ($p=0.57$) was found among pet ownership and shoe removal as characterized in Table 5 or ($p=0.70$) when pet ownership was restricted to two possibilities (any indoor/outdoor or all other). Shoe removal behavior and ownership of indoor/outdoor pets are apparently independent variables. Interestingly about one third of respondents reporting regular removal of street shoes prior to entry also report the presence of a pet with access to both indoors and outdoors.

Shoe removal habits were also compared to floor coverings (Table 6) using contingency tables. No significant trend was found whether floor covering was characterized as shown in the table ($p=0.89$) or reduced to three possibilities (rugs/carpet/half rugs or carpet; bare wood; other) ($p=0.92$). Persons who choose to remove shoes prior to entry apparently do so without regard to floor coverings.

Data presented here were gathered from the U.S. population via random digit dialing. Dissemination of the data is intended to provide some insight into behaviors relevant to exposures to soils and dusts that are currently not well characterized in the literature. Given concern in probabilistic exposure and risk assessment regarding a general lack of knowledge of correlation among exposure variables, patterns of consumption of multiple forms of homegrown produce and the apparent independence of shoe removal and either pet ownership or floor covering are especially noted.

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