



Farm Exposures to Deposited Arsenic and Lead on Vashon Island

Summary
February 17, 2003

J. Kissel, S. Weppner, J. Shirai
Department of Environmental Health
University of Washington

University of Washington personnel conducted a pilot study on Vashon and Maury Islands between March 2001 and February 2002. The study involved collection of samples of various types that were subsequently analyzed for arsenic and/or lead. Samples collected included tilled and yard soil, house dust, vegetables, and adult and child urine. Volunteers who participated in the study were recruited by UW personnel after they had indicated a willingness to be contacted to the Vashon Island Growers Association (VIGA). The total number of participants was 23 (15 adults, 8 children) who were associated with 9 farms. Because the number of participants was small and represents a convenience (non-randomly selected) sample, results may or may not apply to the larger Vashon/Maury population. The study was conducted primarily for the benefit of the participants and as an educational exercise.

Soil and House Dust Results

Table 1 summarizes arsenic and lead concentrations in Vashon Island soil and housedust samples. Observed soil concentrations were generally consistent with prior findings on the Island. Lead concentrations in housedust were found to be significantly higher than those in soils. This is a common observation and may be due to contribution from other indoor lead sources such as lead-based paint. It may also be due to track-in and selective retention (especially in carpets) of smaller soil particles that often have higher concentrations of lead. Concentrations of arsenic in housedust were not elevated relative to outdoor soil.

For reference, under the Model Toxics Control Act the Washington Department of Ecology has established "Level A" cleanup standards of 20 ppm for arsenic and 250 ppm for lead in residential areas. The 20 ppm standard for arsenic is based on natural background levels in Washington State. In the Puget Sound area, background levels are estimated to typically be below 7 ppm for arsenic and below 24 ppm for lead (WADOE, 1994). A recent evaluation of short term exposures to contaminated soils by the Washington State Department of Health concluded that arsenic concentrations below 37 ppm in commonly accessible soils should be protective of the health of children (WADOH, 1999). The same analysis found 175 ppm to be protective for an adult exposure scenario. Both results are based on assumed soil ingestion rates

that are probably conservative. The Environmental Protection Agency has established a soil lead concentration of 400 ppm as the level of concern in child-use areas (USEPA, 2001).

There are no specific concentration-based regulatory standards for either arsenic or lead concentration in housedust. However, EPA has recommended a guideline for lead surface load on floors of 40 micrograms of lead per square foot ($\mu\text{g}/\text{ft}^2$) (USEPA, 2001). Lead surface loads on floors in all participating households were well below the EPA guideline (Table 2).

Produce Results

Table 3 summarizes concentrations of arsenic and lead found in samples of Island-grown and control produce. Statistical tests were used to compare arsenic and lead concentrations in Island-grown and control produce. Of eight possible control vs. Island comparisons, two showed statistical differences. In one case (lead in rinsed potatoes) the control concentration was higher. In the other case (arsenic in lettuce) the Island sample concentration was higher. Given that 1) sample sizes were small, 2) the magnitude of the difference in concentrations was small, and 3) that we did multiple comparisons (which increases the likelihood of finding a difference simply by chance), we do not view the statistical differences between Island and control produce as important. Note that even if the increase in lettuce arsenic is real, the associated additional dose (based on EPA-estimated lettuce mean consumption rates among persons who eat lettuce) would be unimportant. We also did not find any evidence in this study that produce-cleaning method affected the metal concentrations in either Island-grown or control produce.

Caveat: During quality assurance procedures, it was discovered that lead could be leached from the ball mill cylinder lining into deionized water. Tests of the mill were subsequently conducted with purchased dehydrated potato flakes and dried parsley. Results revealed no detectable lead and no statistically significant increase in arsenic in milled samples. Since Island and control produce samples were milled dry, we do not think arsenic and lead levels were distorted by milling. However we cannot rule out completely the possibility that results in Table 3 overestimate true metal concentrations in both Island-grown and control produce samples.

Given the possible finding of elevated arsenic in Island-grown lettuce and the possibility that some arsenic may have been added to produce samples during processing, we estimated how much arsenic we would expect to find in lettuce samples based on measured arsenic levels in tilled Island soils. To do so, we consulted a recent metal uptake study by Kuo et al. (undated) at Washington State University. Metal uptake factors are calculated as the ratio of the concentration of the target metal in plant tissue to its concentration in the soil in which the plant grew. In the Kuo et al. study, lettuce was grown in soils that received repeated applications of fertilizers containing arsenic and lead. Results are summarized in Table 4. Measured arsenic levels in Island-grown lettuce actually appear a little lower than predicted based on Kuo et al.'s results.

Table 1: Arsenic and Lead Concentrations in Soil and Housedust (All Participating Households)

ARSENIC (ppm)				
SAMPLE TYPE	n	mean	median	range
Yard Soil 0-0.5"	18	17	12	5-61
Yard Soil 0.5-2"	18	18	12	6-71
Yard Soil 2-6"	18	22	16	6-91
Tilled Soil 0-6"	24	34	22	10-129
Housedust	18	14	12	8-33
LEAD (ppm)				
SAMPLE TYPE	n	mean	median	range
Yard Soil 0-0.5"	18	51	44	19-154
Yard Soil 0.5-2"	18	52	42	25-169
Yard Soil 2-6"	18	57	44	23-158
Tilled Soil 0-6"	24	65	47	30-204
Housedust	18	122	105	35-227

Table 2: Lead surface loading on floors.

LEAD ($\mu\text{g}/\text{ft}^2$) ^a				
SAMPLE TYPE	n	mean	median	range
Housedust	18	0.1	0.08	0.004-0.25

^abased on lead found in sub-150 μm dust

Table 3: Arsenic and Lead Concentrations in Lettuce and Potato Samples

PRODUCE TYPE	n	Mean Arsenic (ppm dry wt)		
		Rinsed	Washed	Peeled
Island-grown Potatoes	7	0.06	0.04	0.03
Control Potatoes	4	0.05	0.05	0.03
Island-grown Lettuce	7	0.21	na	na
Control Lettuce	4	0.10	na	na
	n	Mean Lead (ppm dry wt)		
		Rinsed	Washed	Peeled
Island-grown Potatoes	7	0.5	0.8	1.5
Control Potatoes	4	1.2	1.4	1.5
Island-grown Lettuce	7	0.4	na	na
Control Lettuce	4	0.2	na	na

Table 4: Predicted versus Measured Arsenic Concentrations in Island-Grown Lettuce

Metal Uptake Factor	Measured Mean Soil Concentration (ppm) ^a	Predicted Mean Lettuce Concentration (ppm dry wt)	Measured Mean Lettuce Concentration (ppm dry wt)
0.015 ^b -0.027 ^c	23	0.3-0.6	0.2

^aincludes both fall and spring data, but only from farms growing lettuce; ^bfrom 1999 field study described in Kuo et al. (undated); ^cfrom 2000 field study described in Kuo et al. (undated).

Urine Results

Table 5 summarizes total and speciated urinary arsenic concentrations by age group and season. Speciated urinary arsenic refers to arsenic compounds that are believed to be derived primarily from exposure to inorganic arsenic. Total arsenic includes both speciated arsenic and organic arsenic compounds that are of less concern.

The World Health Organization has set an action level for total urinary arsenic of 100 µg/L and the Center for Disease Control and Prevention has established a more conservative action level for total urinary arsenic of 50 µg/L. However, these action levels for total urinary arsenic were established before analytical methods to measure speciated urinary arsenic levels were commonly available and are therefore somewhat out of date. There is currently no established action level for speciated arsenic in urine. Since organic arsenic is considered relatively nontoxic, a high level of total urinary arsenic does not clearly represent a health risk. Analysis of urine for speciated arsenic provides a measure primarily of exposure to inorganic arsenic. Inorganic arsenic is the most common form of arsenic found in contaminated soil and produce. However, it is also naturally elevated in some dietary sources (such as shellfish and seaweed) which are also sources of organic arsenic. The presence of inorganic arsenic in some foods makes it more difficult to interpret possible links between speciated arsenic in urine and soil contamination. Nevertheless speciated arsenic is viewed as a better indicator of risk than total arsenic.

Because young children often put their hands and objects in their mouths, it is thought that they are more likely to ingest soil than are older children. In order to test whether age affected urinary arsenic levels in this study, we compared arsenic levels in children six years or older with those in children younger than six years. We did not see a statistical difference in urinary arsenic levels between these age groups. This could mean 1) that children younger than six years old in this study are not ingesting significantly larger amounts of soil than older children, 2) that arsenic concentrations in soil are not sufficiently greater than background levels to produce clearly higher urinary concentrations, or 3) that no difference was observed due to small sample size.

For comparison, Table 6 summarizes speciated urinary arsenic levels in populations from two similar studies. Kalman et al. (1990) have provided speciated arsenic levels in the urine of persons living in the vicinity of the former Ruston smelter and in the urine of individuals living in Bellingham and Tacoma in areas of low exposure. The Ruston population was sampled as the smelter was being shut down, lived in high soil contamination areas, and represents a relatively highly exposed group. The Bellingham-Tacoma population should represent background exposures. Results from the Tacoma-Pierce County Health Department (TPCHD) study cited in Table 6 were obtained from persons living near the smelter two to three years after the smelter ceased operation and reflect lower exposures. (Removal of an arsenic exposure source will be reflected in reduced urinary concentrations within days.) These studies are relevant because they involve regional populations and because the analytical work was conducted in the University of Washington's Environmental Health Laboratory as was the case for the current study (although about 15 years has elapsed since the earlier analyses were conducted).

Table 5: Summary of Urinary Arsenic Concentrations (All Participating Households)

	Total Urinary Arsenic ($\mu\text{g/L}$)				Speciated Urinary Arsenic ($\mu\text{g/L}$)			
	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
CHILD								
n	7 ^a	8	8 ^b	8	7 ^a	8	8 ^b	8
mean	29	38	28	26	17	15	17	16
median	29	24	21	21	13	14	16	14
max	55	134	81	69	31	28	37	47
min	5.9	6.9	12	7.0	3.3	6.4	7.4	4.0
ADULT								
n	15	15	15	15	15	15	15	15
mean	28	29	24	48	11	13	13	19
median	18	22	18	31	7.8	13	10	15
max	80	76	53	162	35	30	45	75
min	3.9	6.9	7.1	7.0	2.3	5.2	4.6	4.0

^amissing one composite sample; ^bone sample is not a composite, but consists of a single spot sample

Table 6: Speciated Urinary Arsenic in Various Populations Including Current Study Population

Population	Age	Gender	n	Mean Speciated Arsenic (ppb)	Median Speciated Arsenic (ppb)
Kalman et al. (1990) ^a					
Ruston	0-6	both	108	52.9	n/r ^b
	7-13	both	50	15.3	n/r
	20+	both	337	11.2	n/r
Bellingham-Tacoma controls	0-6	both	87	11.7	n/r
	7-13	both	133	8.1	n/r
	20+	both	403	9.3	n/r
TPCHD (1988) ^c					
Ruston (<0.5 mi ASARCO)	2-8	both	88	16.2	9.7
Current study ^d					
Vashon/Maury Island	0-6	both	15	18.3	18.0
	7-13	both	16	14.1	14.0
	20+	both	60	14.0	11.2

^aexcludes individuals who reported consuming seafood prior to urine sampling; ^bn/r = not reported; ^cparticipants asked to avoid seafood for three days prior to urine collection; ^dsamples from all four seasons

An additional factor makes comparison more difficult. In the cited comparison studies, attempts were made to eliminate potential contributions of seafood consumption to urinary arsenic excretion. In the Kalman et al. study, participants were segregated on the basis of survey responses and results shown are for non-seafood consumers only. In the TPCHD study, all

participants were asked to refrain from seafood consumption for three days prior to urine collection. Since results obtained from seafood consumers were not removed from the current study due to small overall numbers of participants, somewhat lower urinary arsenic levels in some of the comparison sub-populations might reasonably be expected. (Forty percent of the adults in the current study reported recent seafood consumption in the two quarters in which the question was asked.) In the current study, urine samples found to either have a high absolute speciated arsenic content or low relative (to total arsenic) speciated arsenic content were reanalyzed for arsenobetaine, an organo-arsenic compound known to be present in some seafood. A strong correlation between arsenobetaine and the difference between total and speciated arsenic was found in those samples. This is positive evidence that the study population is exposed to organic arsenic from seafood and may therefore also derive some inorganic arsenic from that source.

Given the potential difference in populations discussed in the preceding paragraph, the small numbers of subjects in the current study, variability in individual results, and the time lapsed since the comparison studies were conducted, formal statistical tests of difference should be interpreted cautiously. It is reasonable to conclude that speciated arsenic concentrations in the urine of children six and under in the current study population are significantly lower than in the urine of the comparable Ruston population. Other differences are less certain. There is some suggestion of elevated urinary arsenic in the study population versus the Bellingham-Tacoma controls among older children and among female adults. The former difference is dependent upon data from only four children in the current study. The latter difference is not statistically significant when genders are combined.

For perspective, the urinary speciated arsenic concentrations found in the current study population are roughly equivalent to what would be expected to be found in populations routinely consuming drinking water at the new (lowered) drinking water standard of 10 µg/L that is currently being phased in. (The old standard was/is 50 µg/L.)

OVERALL CONCLUSIONS

We did not see consistent seasonal trends in environmental levels of arsenic and lead or urinary levels of arsenic which leads us to conclude that seasonal changes in farming activity do not lead to varying exposures to soil contaminants in the study population. Housedust lead surface loadings were well below applicable guidelines.

Arsenic levels in Island-grown produce were not consistently or substantially higher than levels in produce grown off-Island. Although arsenic levels in a small sample of Island-grown lettuce were found to be slightly elevated, the dietary intake of arsenic associated with ingestion of Island-grown lettuce appears unimportant. Lead levels in Island-grown produce did not exceed those found in control samples.

We did not find any obvious links between environmental and urinary arsenic levels in this study and therefore we believe that soil, housedust and Island-grown produce are not

dominant sources of urinary arsenic in the study population. While there is some indication that urinary arsenic levels in the study population may be slightly elevated relative to comparative non-agricultural populations elsewhere, it is possible that this difference is attributable to dietary inputs unrelated to local produce (i.e., seafood) or to drinking water. A limited follow-up study to investigate the latter factor is underway.

Limitations of study

An important limitation of this study is the small number of participating farms. Small sample size generally reduces the statistical power associated with analyses and increases the risk of misleading findings. One direct consequence of the small sample size in this study was inability to exclude individuals who ate seafood prior to urine sampling. Because there may be inorganic arsenic in some seafoods, speciated arsenic found in urine cannot be solely attributed to local soil or produce ingestion.

A second limitation is potential bias in the study population due to self-selection. The study was proposed at the request of individuals associated with the Vashon Island Growers' Association and presented to the whole organization. Some VIGA members may have declined to participate due to preconceptions regarding their own exposures. Participants in the study may have consciously altered their behavior to reduce exposure. Also, significant differences in soil contaminant concentrations between north and south Vashon/Maury are well documented. Participating farms in this study were located disproportionately on the northern (less contaminated) part of the Island.

Drinking water was not tested for arsenic or lead content. In retrospect, water testing appears reasonable, especially for those on private wells that would not otherwise be tested. An offer to test water supplies was made to participants at the time they received their individual results. Water samples have been received from some farms, but analytical results were not available as of the date of this document.

Finally, some potential for metal contamination of produce samples as a result of laboratory procedures was identified as noted above. Interpretation of those results must reflect this caution.

The overall effect of these limitations is that the results should be viewed as most pertinent to the participating farms and that firm conclusions regarding exposure levels in the larger Vashon/Maury Island community cannot be made.

REFERENCES

- Kalman, D. A., J. Hughes, G. V. Belle, T. Burbacher, D. Bolgiano, K. Coble, N. K. Mottet and L. Polissar (1990). "The Effect of Variable Environmental Arsenic Contamination on Urinary Concentrations of Arsenic Species." *Environmental Health Perspectives* 89: 145-151.
- Kuo, S., J. B. Harsh, W. L. Pan, R. G. Stevens, A. Kashani, D. LaFlamme, D. Bowhay, and D. Delistraty. (Undated) "Influence of Metal Rates and Forms of Crop Productivity and Metal Uptake in Some Washington Soils." Report from Washington State Department of Agriculture in conjunction with Washington State University.
- Tacoma-Pierce County Health Department (TPCHD) and Washington Department of Ecology (WADOE) (1988). Urinary Arsenic Survey, North Tacoma, Washington. Tacoma, WA.
- Washington Department of Ecology (WADOE) (1994). Natural Background Soil Metals Concentrations in Washington State, Publ. No. 94-115, Toxics Cleanup Program, Olympia, WA.
- Washington Department of Health (WADOH) (1999). Hazards of short-term exposure to arsenic contaminated soil, Office of Environmental Health Assessment Services, Olympia, WA.
- USEPA (1997). Exposure Factors Handbook. Washington DC, United States Environmental Protection Agency.
- USEPA (2001). Lead; Identification of dangerous levels of lead; Final Rule, 40 CFR Part 745.6 (c).