Prediction and Evaluation of Dietary Arsenic Exposure Estimates Using the SHEDS Model

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Introduction

Epidemiological studies reveal that arsenic can cause human cancers and many other adverse health effects. Ingestion of food especially seafood is a primary route for human arsenic exposure. Foods from endemic areas have higher arsenic concentrations. Sources of arsenic are plant or animal intake and/or contamination from food processing. An accurate probabilistic human exposure model for arsenic ingestion can help reduce uncertainty in arsenic risk assessments.

Table 1 As residue concentration (mg/kg) from selected food items

food_name	n	mean	std	p50	p5	p25	p75	p95	max	det_r
haddock, pan-cooked	19	5.538	2.336	5.643	1.360	3.814	6.780	10.430	10.430	100
tuna, canned in oil	39	0.929	0.326	0.910	0.463	0.730	1.147	1.490	1.710	97.436
fish sticks, frozen, heated	39	0.831	0.499	0.738	0.380	0.534	0.856	2.550	2.792	100
shrimp, boiled	38	0.752	0.537	0.634	0.244	0.361	0.962	1.982	2.681	100
salmon	13	0.640	0.236	0.609	0.349	0.518	0.777	1.193	1.193	100
fish sandwich on bun, fast-food	26	0.541	0.340	0.468	0.203	0.320	0.605	1.430	1.600	100
fish sandwich, fast-food	13	0.513	0.176	0.530	0.250	0.366	0.678	0.770	0.770	100
salmon, steaks or filets, fresh or frozen, bak	6	0.376	0.113	0.360	0.254	0.292	0.443	0.549	0.549	100
clam chowder, canned	13	0.162	0.051	0.159	0.072	0.131	0.185	0.279	0.279	100
crisped rice cereal	39	0.143	0.065	0.140	0.040	0.092	0.180	0.304	0.320	97.436
clam chowder, New England, canned, cond	26	0.137	0.046	0.135	0.046	0.119	0.168	0.199	0.206	96.154
tuna noodle casserole	13	0.128	0.054	0.121	0.068	0.088	0.136	0.239	0.239	100
tuna noodle casserole, homemade	26	0.107	0.058	0.084	0.050	0.068	0.131	0.211	0.244	96.154
mushrooms, raw	39	0.083	0.053	0.073	0.000	0.041	0.108	0.182	0.203	94.872
white rice, cooked	39	0.074	0.030	0.071	0.000	0.062	0.095	0.123	0.128	92.308
rice infant cereal, instant, w/whole milk	13	0.050	0.013	0.052	0.019	0.047	0.056	0.071	0.071	100
rice infant cereal, instant, prepared with whc	26	0.038	0.027	0.044	0.000	0.000	0.053	0.087	0.087	73.077
chicken, fried, fast-food	13	0.025	0.009	0.026	0.000	0.022	0.029	0.038	0.038	92.308
carrots, strained/junior	26	0.024	0.089	0.000	0.000	0.000	0.000	0.233	0.400	7.6923
chicken, fried (breast, leg, and thigh) homer	26	0.024	0.024	0.017	0.000	0.000	0.033	0.072	0.086	73.077
chicken, fried (breast, leg, and thigh), fast-fc	26	0.024	0.020	0.023	0.000	0.014	0.032	0.055	0.083	76.923
granola cereal	39	0.023	0.013	0.022	0.000	0.016	0.029	0.050	0.054	87.179
oat ring cereal	39	0.020	0.013	0.020	0.000	0.013	0.028	0.042	0.045	79.487

Method

1) Collect and process available As residue and food consumption data
   - Continuing survey of food intake by individuals (CSFII) 1994-96/98 by USDA
   - Recipe files from OPP
   - Total diet survey (TDS) by FDA
2) Apply EPA/ORD's Stochastic Human Exposure and Dose Simulation (SHEDS) dietary module using As data
   - Process As residue data
   - Match CSFII data with residues by food items
   - Match CSFII data with residues by food commodities
   - Process measurements below limit of detection (LOD)
   - Apply Processing factors
   - Calculate food residue intake
3) Conduct variability and uncertainty runs with SHEDS
   - Randomly draw subjects from CSFII
   - Randomly draw As residue
   - Repeat runs for stability
   - Bootstrap various portions of CSFII
   - Bootstrap various portion of residues

Table 2 Contribution of Major food categories to As dietary exposure
(from top 50 food items)

	As intake (ug/day)				percent of	Percentage			
	seafood and fish	rice	other	total	total As intake	seafood and fish	rice	other	rice intake (g/day)
All Population									
all CSFII	5.4	1.1	0.3	6.8	61%	79.3%	16.7%	4.0%	15.0
White	5.2	0.6	0.3	6.2	88%	84.7%	10.0%	5.4%	7.9
Asia	18.3	10.4	0.6	29.3	61%	62.3%	35.5%	2.2%	144.4
Puerto Rican	11.6	5.2	0.6	17.3	97%	66.7%	29.9%	3.4%	74.1
95th percentile and above									
all CSFII	112.4	5.2	1.0	118.6	76%	94.8%	4.4%	0.8%	71.1
White	128.2	0.8	1.6	130.6	95%	98.2%	0.6%	1.2%	11.0
Asia	110.3	32.8	4.2	147.3	80%	74.9%	22.3%	2.8%	447.9
Puerto Rican	104.2	11.6	2.8	118.6	100%	87.8%	9.8%	2.3%	164.6

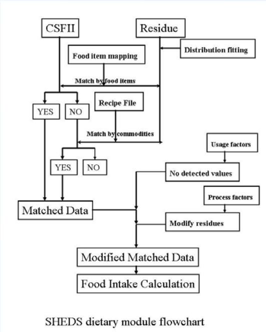


Figure 1.

Figure 3. Uncertainty of daily dietary exposure of As with 1/8 for As residue and 1/30 CSFII bootstrap

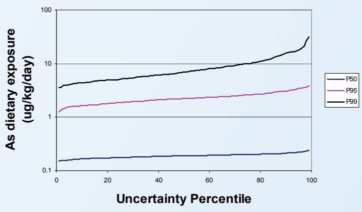
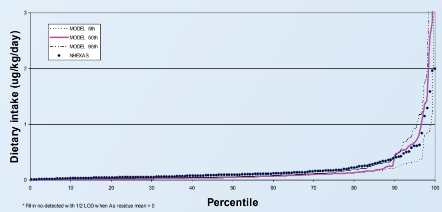


Figure 2. Dietary Model evaluation*



* Fill in no-detected with 1/2 LOD when As residue mean > 0

Table 3 As dietary intake from SHEDS evaluated with NHEXAS duplicate data

lable	n	mean	std	p50	p5	p25	p75	p95
NHEXAS	156	0.185	0.300	0.095	0.019	0.049	0.174	0.612
Fill in no-detects with zero								
MODEL 5th by Mean	154	0.080	0.305	0.000	0.000	0.000	0.031	0.272
MODEL 50th by Mean	154	0.152	0.406	0.009	0.000	0.000	0.066	0.631
MODEL 95th by Mean	154	0.260	1.168	0.007	0.000	0.000	0.055	1.313
Fill in no-detects with 1/2 LOD when As residue mean > 0								
MODEL 5th by Mean	154	0.128	0.399	0.051	0.004	0.023	0.110	0.324
MODEL 50th by Mean	154	0.192	0.561	0.052	0.004	0.024	0.115	0.723
MODEL 95th by Mean	154	0.300	1.293	0.062	0.009	0.029	0.128	0.951

Table 4 Uncertainty Analyses on CSFII and As residue data

	Uncertainty Ratio (95th vs 5 th)		
Bootstrap	50th	95th	99th
CSFII 1/20 bootstrap	1.19	1.93	3.28
As 1/4 and CSFII 1/10 bootstrap	1.20	1.66	2.43
As 1/4 and CSFII 1/20 bootstrap	1.24	2.03	3.40
CSFII 1/8 bootstrap	1.14	1.51	2.14
As 1/8 bootstrap	1.20	1.31	1.73
As 1/8 and CSFII 1/10 bootstrap	1.26	1.69	2.52
As 1/8 and CSFII 1/20 bootstrap	1.30	1.99	3.87
As 1/8 and CSFII 1/30 bootstrap	1.39	2.22	4.47

Results

- Seafood has 100% detection rate with high As residue concentrations; Rice also has high As residues (see Table 1)
- Asian has higher As intake from dietary than other races (Table 2)
- Seafood is dominant contributor; for Asian, rice accounts for 22% high percentile and 35% for whole (Table 2)
- 200 repeated runs with SHEDS dietary matched with region, race, age, and gender show good fit with NHEXAS data (Figure 2 and Table 3)
- Model uncertainty ranged from 1.5 to 5 times for 50th, 95th and 99th by using ratio of 95th to 5th percentiles. The higher percentile, the higher uncertainty and uncertainty is more sensitive to CSFII (Figure 3 and Table 4)

Conclusions

- Seafood and rice are major sources of dietary exposure to As
- SHEDS dietary model performs well in evaluation of model against duplicate dietary survey
- Uncertainty analyses indicated dietary survey data has more uncertainty

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