Results of Lifetime IQ Decrement Analysis from Dietary Exposures to Lead and Inorganic Arsenic for Children 0 to <2 years of Age

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Introduction

Abt Associates conducted an analysis to determine the impact of childhood lead and arsenic consumption through food on subsequent lifetime IQ loss. This analysis had a specific focus on children under the age of two. In order to carry out this analysis, Abt combined data from the following sources:

- **The National Health and Nutrition Examination Survey (NHANES)**, run by the CDC's National Center for Health Statistics (NCHS). NHANES was designed to collect information on the health and nutritional status of the U.S. civilian, non-institutionalized population through in-home interviews and physical examinations.

- **What We Eat in America (WWEIA)** data, which are 24-hour food recall data collected as part of NHANES, and serve as the dietary intake measurement component of the survey. Dietary data are collected for up to two days for each respondent.

- FDA's **Total Diet Study (TDS)**, an ongoing FDA program that collects information on levels of various contaminants, including lead and arsenic, that occur in food and beverages commonly consumed by the U.S. population. To estimate the levels of contaminants in these food products, the FDA buys these foods as a consumer would, prepares them as directed, and then analyzes the prepared foods for levels of the contaminants of interest. This process yields nationally representative estimates of contaminant levels in approximately 280 kinds of foods and beverages.

This memorandum outlines the methods used to estimate childhood lead and arsenic consumption, as well as subsequent lifetime IQ loss, and then presents results tables for children 0 to <2 years of age. A discussion of the limitations is also included, along with a few next steps for this research endeavor.

Methods

Lead/ Inorganic Arsenic Daily Intake Estimation Analysis Overview

Abt used TDS cycles from 2014 to 2016 to maximize samples of lead and arsenic contamination from food. These years of data were chosen as they represent the latest TDS data that utilizes FDA's most recent contaminant detection methods. TDS cycles prior to 2014 used a different method of contaminant detection that resulted in a much higher limit of detection (LOD) than the cycles from 2014 to 2016. During the development of this analysis, Abt also gained access to the 2017 TDS data, but were unable to include these data in this analysis due to time constraints.

Abt used a method performed by Xue et al. (2010) for summarizing values of TDS data that fall below the LOD. The Xue et al. (2010) method assigns half the LOD to sample values that fall below the LOD if there was at least one detection among the many samples taken of each particular food; otherwise a value of 0 is assigned.

Abt used WWEIA and NHANES data cycles from 2009 to 2014 to increase the number of children under age two with consumption data, while also keeping consumption information relatively representative of current food consumption patterns.

Abt mapped mean values for each TDS food with each food consumed in the WWEIA dataset using a mapped file[1] that specifically maps data from the 2003 to 2014 WWEIA to 2014 to 2016 TDS data. Although Abt used this file as the basis for mapping the TDS contamination information to the WWEIA consumption information, Abt made a few slight changes to the mapping file; these changes are outlined in Appendix A.

The TDS only collects data for total arsenic in food, as opposed to inorganic arsenic. Inorganic arsenic is the form in which studies relating arsenic exposure to IQ loss are based, and from which concentration-response functions have been developed. Therefore it was necessary to implement a strategy of scaling the total arsenic being consumed by children to account for the fact that a portion of the arsenic was not inorganic arsenic. In the absence of more specific information, Abt assumed in general that 70% of total arsenic consumed in food was comprised of inorganic arsenic, as was done by the European Food Safety Authority in their 2014 report entitled "Dietary exposure to inorganic arsenic in the European population" (EFSA, 2014). Most of the exceptions to the application of this rule came from information about the arsenic makeup of particular foods specified in Cubadda et al. (2017). Using this information, Abt assumed:

- 95% of total arsenic is inorganic in beverages, and 100% of total arsenic is inorganic in bottled water.
- 80% of total arsenic is inorganic in fruit.
- 60% of total arsenic is inorganic in rice.
- 95% of total arsenic is inorganic in wheat.
- 5% of total arsenic is inorganic in fish and shellfish, including New England clam chowder and tuna casserole.
- 90% of total arsenic is inorganic in vegetables.

In addition, Abt assumed the following inorganic arsenic compositions based on independent testing from data provided by HBBF, from laboratory results presented in HBBF (2017):

- 61% of total arsenic is inorganic in infant rice cereal.
- 53% of total arsenic is inorganic in infant multi-grain and non-rice cereals.

Abt also assumed the following inorganic arsenic compositions based on testing performed by FDA, from analysis of data from FDA (2014) provided by EDF (2018):

- 73% of total arsenic is inorganic in grape juice.
- 59% of total arsenic is inorganic in oat ring cereal.

[1] Provided by FDA to Abt via personal correspondence

- 56% of total arsenic is inorganic in teething biscuits.

All other foods not specifically mentioned were assumed to have 70% of total arsenic as inorganic arsenic, per EFSA (2014).

Abt included all children younger than age seven with two days of dietary data from WWEIA in the analysis. Average daily lead and arsenic consumption values for each child were calculated by averaging the two days of lead/arsenic consumption available for each child.

IQ Loss Estimation Analysis Overview

IQ Loss Due to Lead

Abt used the following steps to estimate IQ loss from lead intake:

1. Calculated background concurrent childhood lead uptake without food for each year of age from zero to less than seven. This background concurrent childhood lead uptake was estimated by estimating the sum of U.S. Environmental Protection Agency's (EPA's) default lead levels for air, drinking water, and soil/dust lead exposure, as outlined in the agency's User's Guide for the Integrated Exposure Uptake Biokinetic model for Lead in Children (IEUBK), excluding the contribution from food (EPA, 2007). These estimates were input into approximation equations for EPA's IEUBK model that were derived by Zartarian et al. (2017) to convert this background lead uptake to blood lead level (without food intake).

2. Estimated the lead consumption from WWEIA's contribution to the child's blood lead level by converting average daily lead consumption from the WWEIA data to lead uptake (assuming 50% lead uptake from dietary ingestion), and used the same estimation equations of EPA's IEUBK model described in Step 1 to convert the background lead uptake without food estimated above plus the additional lead uptake from food to a blood lead level (with food intake).

3. Assumed each child's average daily lead intake from food was equal to their estimated survey-specific average daily lead intake for the entire year of their age in the WWEIA data, and equal to the population-wide mean daily lead intake from food for every other year of life. For example, the estimated mean lead intake for a child when they were one year old (assuming they are not one year old in the WWEIA data) is represented by calculating the mean lead intake of all one-year-olds in the dataset.

4. Calculated lifetime blood lead without food by taking the average of the background concurrent blood lead levels for each year of life as estimated by the Zartarian et al. (2017) IEUBK estimation equations (in Step 1). Calculated lifetime blood lead with food by taking the average of the mean value of blood leads with all other sources of lead including food in the data (from Step 2) for each year of life, except for the year of each child's age in the WWEIA data, which is represented by their personal blood lead level with the added contribution from food (as described above).

5. Used information from Crump et al. (2013) to develop a concentration-response function in order to estimate the lifetime IQ loss due to the difference in lifetime blood lead level based on the contribution of lead in food. The following equation was used::

$$IQ\ Loss = \beta \times \ln\left(\frac{PbB_1 + 1}{PbB_2 + 1}\right)$$

where:

Beta = -3.25

PbB_1 = Background lifetime blood lead level without food

PbB_2 = Lifetime blood lead level including food contribution

IQ Loss Due to Inorganic Arsenic

Abt used the following steps to estimate IQ loss as a result of inorganic arsenic intake:

1. Assumed each child's average daily inorganic arsenic intake from food was equal to their estimated survey-specific average daily inorganic arsenic intake for the entire year of their age in the WWEIA data, and equal to the population-wide mean daily inorganic arsenic intake from food for every other year of life. For example, the mean inorganic arsenic intake for a child when they were one year old (assuming they are not one year old in the WWEIA data) is represented by calculating the mean inorganic arsenic intake of all one-year-olds in the dataset.

2. Calculated lifetime inorganic arsenic consumption from food by taking the average of the mean inorganic arsenic consumption figures from the dataset for each year of life, except for the year of each child's age in the WWEIA data, which is represented by their personal mean daily inorganic arsenic intake (as described above).

3. Used a concentration-response function based on a study by Wasserman et al. (2004), as described in Abt (2017), to estimate lifetime IQ loss based on arsenic drinking water concentration:

$$IQ\ Loss = \beta \times \Delta AsDW$$

where:

Beta = 0.44

$\Delta AsDW$ = Change in arsenic drinking water concentration

4. Converted lifetime inorganic arsenic consumption from food (from Step 2) to an approximate drinking water concentration by assuming that each child in the WWEIA data consumes 1 liter of water per day, as was done by CalEPA when deriving a chronic Reference Exposure Level for inorganic arsenic consumption in 2008 (CalEPA, 2008). This was necessary to match the average daily inorganic arsenic intake estimated in Step 2 to the concentration-response function in Step 3. Since Abt assumes each child consumes 1 liter of water per day, Abt is able to input the lifetime daily inorganic arsenic intakes estimated in Step 2 into the concentration-response function in Step 3 with

the magnitude unchanged. For example, if a child has a lifetime average daily inorganic arsenic intake of 2 µg/day, since their average daily water consumption is 1 L/day, their corresponding arsenic drinking water concentration would be 2 µg/L.

Because the Wasserman et al. (2004) concentration-response function for IQ loss is linear, the approximate equivalent drinking water concentration calculated in Step 4 represents the change in arsenic drinking water concentration used in the equation in Step 3. In other words, the IQ loss for a population with any background level of arsenic exposure using the Wasserman et al. (2004) function will always be equal to the change in arsenic concentration from the calculation in Step 4 multiplied by the beta. This differs from the lead analysis, where the background exposure from other sources matters due to the log transformation of lead in the concentration-response function.

Total IQ Loss Due to Lead and Arsenic Combined

Once each person's lifetime IQ loss was estimated for both lead and arsenic separately, total lifetime IQ loss from food from lead and arsenic combined was estimated as the sum of the lifetime IQ loss due to lead consumption from food with the lifetime IQ loss due to inorganic arsenic consumption from food.

Estimating Population Total IQ Loss Due to Each Individual Food in TDS

Total IQ loss was estimated for each food from the TDS based on lead consumption alone, arsenic consumption alone, and lead consumption and arsenic consumption combined. It was necessary to calculate the lifetime IQ loss for each instance that a food was consumed individually, since the method for calculating lead uptake is specific to age. Thus, an instance of food consumption of the same food in the same amount could be responsible for two different magnitudes of IQ loss due to lead if the two children who consumed the food were of different ages.

Lifetime IQ loss from lead was calculated for each instance of food consumption using the IQ Loss equation as above. However, PbB_2 was assumed equal to background lifetime blood lead level without food plus the additional blood lead from the consumption of that one food for the current year of their life. All other years of blood lead averaged into the lifetime blood lead equation for PbB_2 are assumed equal to the background concentration without food. Each of these incremental IQ losses due to each instance of a particular food being consumed were multiplied by their respective survey weight, and summed to estimate the total IQ loss attributable to each food across the population of children.

Lifetime IQ loss from arsenic was calculated using the concentration response function above for each food consumption instance, but was then multiplied by the appropriate NHANES survey weight, and summed to estimate the total IQ loss attributable to each food across the population of children. These two IQ losses for each food were then added together to estimate the total IQ loss from each food due to both lead and arsenic combined.

In the results, total IQ loss attributable to each food figures are presented as proportions of total IQ loss from each specific food, since the method for calculating total IQ loss from the individual foods differs slightly from the methods used to calculate IQ loss at the person level.

Estimating Population-wide Total Lifetime IQ Loss Due to Lead, Arsenic, and Lead and Arsenic Combined

Total IQ loss due to lead, arsenic, and lead and arsenic combined were calculated by multiplying each child's estimated lifetime IQ loss from each of these sources by the corresponding survey weight, and summed together for all children aged zero to less than two in the survey data.

Results

Exhibit 1 through Exhibit 7 below summarize key results from this analysis. The results for each subgroup are lifetime consumption / IQ loss, and are focused on the group of children in the WWEIA data that correspond to each subgroup participating in the NHANES survey. For example, when results are presented for one-year-olds, these results correspond to the children in NHANES who were one year old at the time of the study, but the results presented are all based on their hypothetical lifetime consumption of lead/arsenic.

Exhibit 1 shows average daily lead consumption percentiles for the key age groups of interest of those children younger than 1, children age 1 to <2, and the combined group of children age 0 to <2. Exhibit 2 shows average daily inorganic arsenic consumption percentiles for the same age groups as Exhibit 1. Exhibit 3 shows distributional information for total lifetime IQ points lost due to lead, arsenic, and lead and arsenic combined. Exhibit 4 shows the estimated total number of lifetime IQ points lost from lead, arsenic, and lead and arsenic combined for the population of children age 0 to <2. Exhibit 5 shows the top 15 food categories in TDS contributing to IQ loss from consumption of lead, as well as the proportion of total lead consumption represented by each TDS food category and the estimated number of children that consumed each food in the weighted WWEIA data. This effect can be driven by either high levels of lead in the food from the TDS, high consumption of the food by children in the WWEIA data, or a combination of both. Exhibit 6 shows the top 15 food categories in TDS contributing to IQ loss from consumption of inorganic arsenic. Exhibit 7 shows the top 15 food categories in TDS contributing to IQ loss from consumption of both lead and inorganic arsenic combined. Note that with few exceptions, each TDS food is mapped to multiple WWEIA foods that represent the foods that were actually consumed by children. For some TDS foods listed below, mapped WWEIA foods include a range of foods that are similar to the TDS food, but are not exactly the food listed. See HBBF's report at www.healthybabyfood.org for a presentation of results listed according to the WWEIA foods consumed by children.

Exhibit 1. Average Daily Lead Consumption (µg/day) for Children Age 0 to <2 years, Percentiles by Age

Percentile	Lead (µg/day)
Ages 0 to <1 year old	
50th Percentile	0.83
90th Percentile	1.70
95th Percentile	2.04
97.5th Percentile	2.26

Percentile	Lead (µg/day)
99th Percentile	2.89
Ages 1 to <2 years old	
50th Percentile	1.09
90th Percentile	1.97
95th Percentile	2.37
97.5th Percentile	2.88
99th Percentile	3.56
Ages 0 to <2 years old (combined)	
50th Percentile	0.94
90th Percentile	1.89
95th Percentile	2.19
97.5th Percentile	2.64
99th Percentile	3.28

Exhibit 2. Average Daily Inorganic Arsenic Consumption (µg/day) for Children Age 0 to <2 years, Percentiles by Age

Percentile	Inorganic Arsenic (µg/day)
Ages 0 to <1 year old	
50th Percentile	0.34
90th Percentile	1.73
95th Percentile	2.11
97.5th Percentile	2.91
99th Percentile	3.84
Ages 1 to <2year old	
50th Percentile	2.52
90th Percentile	4.40
95th Percentile	5.63
97.5th Percentile	7.21
99th Percentile	8.65
Ages 0 to <2 years old (combined)	
50th Percentile	1.45
90th Percentile	3.58
95th Percentile	4.61
97.5th Percentile	5.90
99th Percentile	7.80

Exhibit 3. Lifetime Intelligence Quotient (IQ) Point Loss Attributable to Lead and Inorganic Arsenic for Children Age 0 to <2 years, Percentiles by Age

Percentile	IQ Points from Lead	IQ Points from Inorganic Arsenic	IQ Points from Lead and Inorganic Arsenic (combined)
Ages 0 to <1 years old			
50th Percentile	0.21	1.28	1.49
90th Percentile	0.24	1.37	1.59
95th Percentile	0.25	1.39	1.63
97.5th Percentile	0.25	1.44	1.68
99th Percentile	0.27	1.50	1.74
Ages 1 to <2 years old			
50th Percentile	0.21	1.29	1.50
90th Percentile	0.23	1.40	1.64
95th Percentile	0.24	1.48	1.71
97.5th Percentile	0.25	1.58	1.79
99th Percentile	0.27	1.67	1.88
Ages 0 to <2 years old (combined)			
50th Percentile	0.21	1.28	1.49
90th Percentile	0.23	1.38	1.60
95th Percentile	0.24	1.44	1.67
97.5th Percentile	0.25	1.51	1.72
99th Percentile	0.27	1.62	1.85

Exhibit 4. Estimated Population Total of Lifetime IQ Points Lost for Children Age 0 to <2 years

Contaminant	Total Number of Lifetime IQ Points Lost
Ages 0 to <2 years old	
Lead	1,616,857
Inorganic Arsenic	9,876,615
Lead and Inorganic Arsenic Combined	11,493,472

Exhibit 5. Top 15 Dietary Drivers of IQ Due to Lead for Children Age 0 to <2 years old, by Age in WWEIA data and TDS Food Category

TDS Food	Approximate Number of Children Consuming Food	% of Total IQ Loss from Lead
Ages 0 to <1 years old		
BF, Infant formula, milk-based, iron fortified RTF	2,973,252	49.43%
BF, sweet potatoes	524,022	9.96%
BF, carrots	500,469	5.05%
Yogurt, lowfat, fruit-flavored	330,141	2.90%
BF, teething biscuits	850,329	2.86%
BF, mixed vegetables	368,798	2.10%
BF, applesauce	630,763	1.65%
Sweet potatoes, canned	111,487	1.61%
BF, chicken noodle dinner	188,188	1.23%
BF, turkey and rice	110,329	1.21%

TDS Food	Approximate Number of Children Consuming Food	% of Total IQ Loss from Lead
BF, juice, apple	683,095	1.14%
BF, cereal, rice, dry, prepared w/ water	1,265,995	1.03%
BF, peaches	303,503	0.92%
BF, green beans	299,803	0.91%
BF, squash	311,768	0.86%
Ages 1 to <2 years old		
Yogurt, lowfat, fruit-flavored	1,073,044	7.63%
Fruit juice blend (100% juice), canned/bottled	836,127	6.68%
Apple juice, bottled	1,390,328	4.97%
Macaroni and cheese, prepared from box mix	846,017	3.42%
Grape juice, frozen conc, reconstituted	244,934	3.40%
Bread, white, enriched	1,314,240	2.51%
Pineapple, canned in juice	364,200	2.33%
Grapes (red/green), raw	786,567	2.28%
Taco/tostada w/ beef and cheese, from Mexican carry-out	393,216	2.11%
Apple (red), raw (w/ peel)	1,181,186	2.06%
Oat ring cereal	1,395,463	2.04%
BF, Infant formula, milk-based, iron fortified RTF	281,081	2.01%
BF, teething biscuits	555,163	1.96%
Sweet potatoes, canned	129,979	1.90%
Fruit cocktail, canned in light syrup	308,094	1.84%
Ages 0 to <2 years old		
BF, Infant formula, milk-based, iron fortified RTF	3,254,333	24.29%
BF, sweet potatoes	599,502	5.46%
Yogurt, lowfat, fruit-flavored	1,403,185	5.41%
Fruit juice blend (100% juice), canned/bottled	923,116	3.89%
Apple juice, bottled	1,603,379	2.87%
BF, carrots	601,666	2.72%
BF, teething biscuits	1,405,492	2.39%
Macaroni and cheese, prepared from box mix	1,007,539	2.06%
Grape juice, frozen conc, reconstituted	284,892	2.02%
Sweet potatoes, canned	241,466	1.77%
Bread, white, enriched	1,552,918	1.48%
Pineapple, canned in juice	494,970	1.45%
Grapes (red/green), raw	890,536	1.31%
Oat ring cereal	1,735,095	1.29%
BF, mixed vegetables	445,182	1.26%
BF= Baby Food RTF= Ready-to-Feed		

Exhibit 6. Top 15 Dietary Drivers of IQ Due to Inorganic Arsenic for Children Age 0 to <2 years old, by Age in WWEIA data and TDS Food Category

TDS Food	Approximate Number of Children Consuming Food	% of Total IQ Loss from Inorganic Arsenic
Ages 0 to <1 years old		
BF, cereal, rice, dry, prepared w/ water	1,265,995	15.20%
Fried rice, meatless, from Chinese carry-out	139,998	9.31%
BF, juice, apple	683,095	5.84%
Rice, white, enriched, cooked	143,698	5.73%
BF, juice, grape	112,345	2.90%
BF, teething biscuits	850,329	2.77%
BF, chicken noodle dinner	188,188	2.74%
BF, applesauce	630,763	2.61%
Milk, whole, fluid	196,794	2.30%
BF, sweet potatoes	524,022	2.22%
BF, pears	398,052	2.15%
Apple juice, bottled	213,051	1.90%
BF, peaches	303,503	1.86%
Bottled drinking water (mineral/spring), not carbonated or flavored	1,054,140	1.84%
Fruit juice blend (100% juice), canned/bottled	86,989	1.71%
Ages 1 to <2 years old		
Fried rice, meatless, from Chinese carry-out	674,003	13.50%
Milk, whole, fluid	2,957,815	12.69%
Rice, white, enriched, cooked	869,290	9.62%
Apple juice, bottled	1,390,328	5.73%
Fruit juice blend (100% juice), canned/bottled	836,127	4.73%
Granola bar, w/ raisins	418,598	2.04%
Oat ring cereal	1,395,463	1.84%
Crisped rice cereal	187,983	1.64%
Tuna, canned in water, drained	64,895	1.47%
Bottled drinking water (mineral/spring), not carbonated or flavored	1,646,264	1.38%
Bread, multi-grain	774,243	1.30%
Macaroni and cheese, prepared from box mix	846,017	1.30%
Grape juice, frozen conc, reconstituted	244,934	1.30%
Fruit-flavored cereal, presweetened	628,029	1.25%
Milk, lowfat (2%), fluid	1,027,023	1.23%
Ages 0 to <2 years old		
Fried rice, meatless, from Chinese carry-out	814,001	12.74%
Milk, whole, fluid	3,154,608	10.80%
Rice, white, enriched, cooked	1,012,988	8.91%
Apple juice, bottled	1,603,379	5.03%

TDS Food	Approximate Number of Children Consuming Food	% of Total IQ Loss from Inorganic Arsenic
Fruit juice blend (100% juice), canned/bottled	923,116	4.18%
BF, cereal, rice, dry, prepared w/ water	1,455,906	3.28%
BF, juice, apple	1,055,616	1.78%
Oat ring cereal	1,735,095	1.74%
Granola bar, w/ raisins	423,825	1.68%
Bottled drinking water (mineral/spring), not carbonated or flavored	2,700,404	1.46%
Crisped rice cereal	193,264	1.35%
Tuna, canned in water, drained	72,206	1.31%
Macaroni and cheese, prepared from box mix	1,007,539	1.18%
Grape juice, frozen conc, reconstituted	284,892	1.17%
Bread, multi-grain	886,828	1.14%
BF= Baby Food RTF= Ready-to-Feed		

Exhibit 7. Top 15 Dietary Drivers of IQ Due to Lead and Inorganic Arsenic Combined for Children Age 0 to <2 years old, by Age in WWEIA data and TDS Food Category

TDS Food	Approximate Number of Children Consuming Food	% of Total IQ Loss from Lead and Inorganic Arsenic Combined
Ages 0 to <1 years old		
BF, Infant formula, milk-based, iron fortified RTF	2,973,252	20.65%
BF, cereal, rice, dry, prepared w/ water	1,265,995	9.28%
BF, sweet potatoes	524,022	5.46%
Fried rice, meatless, from Chinese carry-out	139,998	5.42%
BF, juice, apple	683,095	3.88%
Rice, white, enriched, cooked	143,698	3.34%
BF, carrots	500,469	2.81%
BF, teething biscuits	850,329	2.81%
BF, applesauce	630,763	2.21%
BF, chicken noodle dinner	188,188	2.11%
BF, juice, grape	112,345	1.95%
BF, mixed vegetables	368,798	1.72%
BF, peaches	303,503	1.47%
Milk, whole, fluid	196,794	1.34%
Apple juice, bottled	213,051	1.32%
Ages 1 to <2 years old		
Fried rice, meatless, from Chinese carry-out	674,003	11.43%
Milk, whole, fluid	2,957,815	10.75%
Rice, white, enriched, cooked	869,290	8.14%
Apple juice, bottled	1,390,328	5.61%
Fruit juice blend (100% juice), canned/bottled	836,127	5.03%

TDS Food	Approximate Number of Children Consuming Food	% of Total IQ Loss from Lead and Inorganic Arsenic Combined
Granola bar, w/ raisins	418,598	1.88%
Oat ring cereal	1,395,463	1.87%
Macaroni and cheese, prepared from box mix	846,017	1.62%
Grape juice, frozen conc, reconstituted	244,934	1.62%
Crisped rice cereal	187,983	1.40%
Bread, white, enriched	1,314,240	1.37%
Bread, multi-grain	774,243	1.34%
Apple (red), raw (w/ peel)	1,181,186	1.31%
Tuna, canned in water, drained	64,895	1.26%
Grapes (red/green), raw	786,567	1.22%
Ages 0 to <2 years old		
Fried rice, meatless, from Chinese carry-out	814,001	9.96%
Milk, whole, fluid	3,154,608	8.44%
Rice, white, enriched, cooked	1,012,988	6.96%
BF, Infant formula, milk-based, iron fortified RTF	3,254,333	5.30%
Apple juice, bottled	1,603,379	4.56%
Fruit juice blend (100% juice), canned/bottled	923,116	4.12%
BF, cereal, rice, dry, prepared w/ water	1,455,906	2.69%
Oat ring cereal	1,735,095	1.64%
BF, sweet potatoes	599,502	1.57%
BF, juice, apple	1,055,616	1.57%
Granola bar, w/ raisins	423,825	1.43%
Macaroni and cheese, prepared from box mix	1,007,539	1.37%
Grape juice, frozen conc, reconstituted	284,892	1.35%
BF, teething biscuits	1,405,492	1.29%
Bottled drinking water (mineral/spring), not carbonated or flavored	2,700,404	1.19%
BF= Baby Food RTF= Ready-to-Feed		

Limitations

There are limitations associated with the lifetime blood lead and arsenic concentration calculations, most notable of which is that children included in the analysis are only observed at one particular point in time. As such, a degree of generalization is made with respect to the representativeness of each child's WWEIA recorded food consumption for their current year of life, as well as the representativeness of average lead/arsenic population consumption estimates from the WWEIA data being applicable to the years of life that are not observed for each child.

It is also understood that a certain amount of expert judgement was used in developing the TDS/WWEIA mapping file, and thus some of the foods mapped to each other are less than perfect. FDA notes that "each of the 267 TDS Foods represents a large group of similar foods. The concentrations of chemicals in each of the 267 TDS Foods applies to all of the foods in the group the

TDS Food represents (a limitation that should be noted when reporting chemical concentrations estimated via the TDS and the TDS mapping file)."[2] Abt attempted to account for flawed pairings that significantly influenced the study findings by correcting a few of the mapped foods, as described in Appendix A. Even with the changes made to the mapping file, however, it is possible that additional mapping improvements could be made that would also affect the results presented in this memorandum.

A background level of inorganic arsenic without food could not be estimated from the available literature in the same way that one was estimated for lead. Thus, it was necessary to use a linear concentration-response function relating inorganic arsenic to lifetime IQ loss, and Abt was unable to estimate a range of results related to the many concentration-response functions presented in Abt's previous arsenic analysis (Abt, 2017) as many of the additional functions are non-linear and would have differing effect sizes at different background levels of inorganic arsenic. Additionally, there is a great deal of uncertainty in converting inorganic arsenic intakes to inorganic arsenic drinking water concentrations by assuming each child consumes 1 liter of water per day. Abt is also assuming the linear extrapolation of the Wasserman et al. (2004) function is applicable for a different population and lower doses than those included in the original study.

Next Steps

Abt intends explore the application of additional concentration-response functions for the relationship between blood lead levels and lifetime IQ loss beyond the Crump et al. (2013) function. Abt considers results based on the Crump et al. (2013) concentration-response function (Ln+1) as conservative estimates of IQ loss, as typically when presented with IQ estimates based on a range of applicable functions, the Crump et al. (2013) result is usually smaller than other estimates.

Abt also intends to explore the possibility of an extension of this analysis to other heavy metals included in the TDS, such as Cadmium and Mercury.

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Appendix A. Changes to Original TDS/WWEIA Mapping File

In calculations described above, Abt assumed the following mapped foods that differed from the FDA's original mapping file, to provide more representative concentration estimates where inexact FDA matches yielded inappropriate estimates. In these cases, high arsenic levels in clam chowder from the TDS dataset were inconsistent with arsenic levels typical for the mapped foods from WWEIA listed below.

<u>TDS food from FDA mapping file</u>: Clam chowder, New England, canned, cond, prepared w/ whole milk

- **WWEIA mapped foods:** CHICKEN NOODLE SOUP, CREAM OF; CHICKEN SOUP, CREAM OF, PREPARED W/ WATER; CHICKEN/TURKEY SOUP, CM OF, CAN, RED SOD, W/ MILK; CHICKEN SOUP, CREAM OF, NS AS TO MILK OR WATER
- **Revised TDS food:** Assume 50/50 mixture of these 2 TDS foods: TDS food #1: Soup, chicken noodle, canned, cond, prepared w/ water; and TDS food #2: Milk, whole, fluid

- **WWEIA mapped foods:** POTATO SOUP, CREAM OF, W/ MILK; POTATO SOUP, NS AS TO MADE W/MILK OR WATER; POTATO & CHEESE SOUP
- **Revised TDS food:** Assume 50/50 mixture of these 2 TDS foods: TDS food #1: Potato, boiled (w/out peel); and TDS food #2: Milk, whole, fluid

- **WWEIA mapped food:** CORN SOUP, CREAM OF, PREPARED W/ WATER
- **Revised TDS food:** Assume 50/50 mixture of these 2 TDS foods: TDS food #1: Corn, fresh/frozen, boiled); and TDS food #2: Milk, whole, fluid

- **WWEIA mapped foods:** MUSHROOM SOUP, CREAM OF, PREP W/ MILK; MUSHROOM SOUP, CREAM OF, PREPARED W/ WATER; MUSHROOM SOUP, NFS
- **Revised TDS food:** Assume 50/50 mixture of these 2 TDS foods: TDS food #1: Mushrooms, raw; and TDS food #2: Milk, whole, fluid

- **WWEIA mapped food:** CHEDDAR CHEESE SOUP
- **Revised TDS food:** Assume 50/50 mixture of these 2 TDS foods: TDS food #1: Cheese, cheddar, natural (sharp/mild); TDS food #2: Milk, whole, fluid

- **WWEIA mapped food:** WHITE SAUCE, MILK SAUCE
- **Revised TDS food:** Milk, whole, fluid