memorandum

Division of Health and Environment

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To Jane Houlihan, HBBF

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Subject Analysis of Drinking Water Lead and its Association with Select Levels of IQ Loss for Children Under the Age of Seven

Introduction

At the request of HBBF, Abt Associates conducted an analysis to determine the levels of lead in drinking water that would be associated with various thresholds of IQ loss for children under the age of seven. Specifically, we explored what lead concentration of drinking water is enough to cause a 0.25 point IQ loss, a 0.5 point IQ loss, a 0.75 point IQ loss, a 1 point IQ loss, and a 2 point IQ loss. Additionally, we calculated how much IQ loss would be anticipated if children were to consume drinking water at 5 µg/L, 10 µg/L, or 15 µg/L. The population of interest for this analysis is children who are exclusively formula-fed using powder-based products that are reconstituted with drinking water during infancy. Therefore, in this analysis we assumed higher-than-average drinking water consumption during the first year of life, based on data for exclusively formula- fed infants. From ages 1 to 7 years, we assumed average drinking water consumption for children in the analysis. In all scenarios, drinking water lead concentrations were assumed to stay constant throughout childhood.

Methods

Blood Lead Levels

Baseline Lead Exposure Scenario

Abt developed estimates for baseline lead exposures using EPA's Integrated Exposure Uptake and Biokinetic Model (IEUBK). The baseline scenario represents what blood lead levels would be if no additional lead was coming from drinking water. For this baseline scenario, the inputs to IEUBK based on information contained in Exhibit 14 through Exhibit 20 in EPA's *Proposed Modeling Approaches for a Health-Based Benchmark for Lead in Drinking Water Report* (2017) were used with the exception of the drinking water intake rate for 0 to 1 year old infants (as described in the subsequent subsection). The inputs for each year of age are summarized below in Table 1. Additional information about the sources of these suggested inputs can be found in the EPA (2017) report. We used these inputs in IEUBK to estimate an average blood lead level for children for the first 7 years of life, and used this average blood lead level as our baseline lead exposure scenario.

Table 1. Summary of Inputs for IEUBK Estimation of Baseline Lifetime Average Blood Lead Levels

Variable	Input for IEUBK Analyses Ages 0-1 year	Input for IEUBK Analyses Ages 1-2 years	Input for IEUBK Analyses Ages 2-3 years	Input for IEUBK Analyses Ages 3-4 years	Input for IEUBK Analyses Ages 4-5 years	Input for IEUBK Analyses Ages 5-6 years	Input for IEUBK Analyses Ages 6-7 years
Time Spent Outdoors (h/day)	1.03	1.03	1.63	1.74	1.85	1.81	1.65
Inhalation Rate (m^3/day)	5.4	8.00	8.9	10.1	10.1	10.1	12.0
Soil/Dust Ingestion (g/day)	0.027	0.027	0.026	0.029	0.032	0.034	0.029
Mean Drinking Water Rate (L/day)	0.84**	0.151	0.176	0.193	0.197	0.213	0.228
Air Lead (µg/m^3)	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Soil Lead (mg/kg)	160	160	160	160	160	160	160
Dust Lead (mg/kg)	104	104	104	104	104	104	104
Diet Lead (µg/day)	0.65	2.00	2.85	2.98	3.00	3.31	3.29
Maternal (µg/dl)	0.61	0.61	0.61	0.61	0.61	0.61	0.61
Geometric Standard Deviation	1.60	1.60	1.60	1.60	1.60	1.60	1.60

* Values in the table are from Exhibit 14 through Exhibit 20 in EPA's *Proposed Modeling Approaches for a Health-Based Benchmark for Lead in Drinking Water Report* (2017) except where indicated.

** This value is not from EPA (2017), but instead was calculated from estimated drinking water intake as a function of estimated formula consumption and energy requirements from the first year of life, as described in the subsequent section of this report.

Infant (0-1 year old) Drinking Water Intake Rates

We considered two options for drinking water ingestion rate, particularly for ages 0 to 1 year. The first drinking water ingestion rate we considered for ages 0 to 1 year was the rate listed in Appendix A of EPA's *Proposed Modeling Approaches for a Health-Based Benchmark for Lead in Drinking Water Report* (2017), which specifically addresses the drinking water intake for formula-fed infants.

As such, this drinking water ingestion rate, 0.64 μg/day, is slightly higher than the drinking water ingestion rate in Exhibit 14 of the aforementioned EPA report, which included both formula-fed and non-formula-fed infants. This formula-fed only group includes only children that reported consuming formula that was re-constituted or diluted with community water. We do not have further information regarding if the child was fed exclusively through powder-based formula.

The second option for the drinking water ingestion rate for ages 0 to 1 year involved calculating an estimated drinking water ingestion rate using information on estimated energy requirements of children and formula feeding guidelines. For this alternate estimate, we started by estimating the amount of formula kids age 0 to 12 months are drinking in order to estimate drinking water intake rates. We used the USDA *Infant Nutrition and Feeding Guide* (2019) to estimate energy requirements in kilocalories for each of the first six months of life. The *Infant Nutrition and Feeding Guide* lists the following calculations for estimating energy requirements:

Table 2. Estimated Energy Requirements as Adapted from USDA (2019)

Age	Calculation
0-3 months	(89 * weight [kg] – 100) + 175 Kcal
4-6 months	(89 * weight [kg] – 100) + 56 Kcal

Abt used 50th percentile bodyweight from CDC growth charts (CDC, 2001) for each month of the first year of life to calculate estimated energy requirements for each month of life using the table above. We compared the CDC growth chart bodyweight figures to summary bodyweight figures in NHANES 2015-2016 to verify the accuracy of these figures as representations of bodyweight, since these growth charts were developed in the early 2000s (CDC, 2017; CDC, 2017b). Generally speaking, the NHANES bodyweights were slightly higher than the figures in the CDC growth charts, but not significantly so. Thus, we used the average weight between the two genders from the CDC growth charts to estimate energy requirements. Table 3 below presents the average between the male and female 50th percentile bodyweight from CDC growth charts for each month of the first year of life.

Table 3. 50th Percentile Bodyweight from CDC Growth Chart: Average Weight Between Males and Females

Age	50th Percentile Bodyweight (kg)
Birth to < 1 month	3.9
1 to < 2 months	4.7
2 to < 3 months	5.45
3 to < 4 months	6.15
4 to < 5 months	6.7
5 to < 6 months	7.3

Using the figures for bodyweight presented in Table 3 in the equations presented in Table 2 yielded the energy requirements presented in Table 4.

Table 4. Estimated Energy Requirements for each Month of Age in the First Six Months of Life

Age	Energy Requirement (Kcal)
Birth to < 1 month	422.1
1 to < 2 months	493.3
2 to < 3 months	560.1
3 to < 4 months	622.4
4 to < 5 months	552.3
5 to < 6 months	605.7

Once we obtained these energy requirements for each month of life, we then calculated the amount of formula needed to fulfill that energy requirement. Similac, a major brand of powder-based formulas, specify an approximate caloric density of 20 Kcal per 30 mL of water (Abbott Nutrition, 2016; Abbott Nutrition, 2020). From this caloric density, we calculated the approximate daily intake of water for the first six months of age in the first year of life by using the following equation:

$$WaterIntake(mL) = RequiredEnergy(Kcal) * \frac{30\ mL\ (Water)}{20\ Kcal\ (Formula)}$$

Since we know that children approximately age six months and older are starting to supplement their formula intake with solid food, we cannot assume that their entire diet is coming from formula. Thus, we assumed each child's formula intake to be roughly equivalent to the formula feeding guidelines published by Stanford Children's Health (Stanford Children's Health, 2020). Stanford Children's Health recommends the following feeding guidelines:

Table 5. Feeding Guidelines for Children Ages 6 Months to 12 Months USDA (2019)

Age	Breastfeeding or Formula Intake Guideline	Breastfeeding or Formula Intake Guideline Midpoint
6 months	28 to 32 ounces per day	30 ounces per day
7-9 months	30 to 32 ounces per day	31 ounces per day
10-12 months	24 to 30 ounces per day	27 ounces per day

We assumed the midpoint of the recommended formula intake for each of these age groups in order to calculate the drinking water intake for the final six months of the first year of the child's life. We then converted each drinking water intake rate from Table 5 to liters for the purposes of this analysis by dividing each figure by 33.814. The calculated drinking water intake rate based on either required energy intake rate for the first six months of life, or the recommended formula intake for the next six months of life, is presented below in Table 6. The average drinking water intake rate based on these calculated figures for each month of the first year of life is also presented below in Table 6.

Table 6. Calculated Drinking Water Intake Rate For Powder-Based Formula Fed Infants

<table>
<tr><th>Age</th><th>Calculated Drinking Water Intake Rate (L/day)</th><th>Average Drinking Water Intake Rate (L/day)</th></tr>
<tr><td>Birth to < 1 month</td><td>0.633</td><td rowspan="12">0.843</td></tr>
<tr><td>1 to < 2 months</td><td>0.740</td></tr>
<tr><td>2 to < 3 months</td><td>0.840</td></tr>
<tr><td>3 to < 4 months</td><td>0.934</td></tr>
<tr><td>4 to < 5 months</td><td>0.828</td></tr>
<tr><td>5 to < 6 months</td><td>0.909</td></tr>
<tr><td>6 to < 7 months</td><td>0.887</td></tr>
<tr><td>7 to < 8 months</td><td>0.917</td></tr>
<tr><td>8 to < 9 months</td><td>0.917</td></tr>
<tr><td>9 to < 10 months</td><td>0.917</td></tr>
<tr><td>10 to < 11 months</td><td>0.798</td></tr>
<tr><td>11 to < 12 months</td><td>0.798</td></tr>
</table>

We opted to use the calculated average drinking water intake rate of 0.843 L/day that is presented above in Table 6 as opposed to the drinking water intake rate for formula-fed infants of 0.64 L/day from Appendix A of EPA (2017) as we felt this calculated figure was a more accurate representation of drinking water intake specifically for exclusively power-based formula-fed infants, as the figure from EPA (2017) could also include other types of formula-fed infants in their calculation.

Additional Drinking Water Lead Scenario

Once the baseline blood lead scenario was developed, we then moved on to developing each of our analysis scenarios. For each IQ loss scenario, hypothetical lead in drinking water concentrations were added to IEUBK in the drinking water exposures tab. Average blood lead levels were then estimated using the lifetime (over age 0 to 7 years) blood lead to IQ concentration-response functions described in the next section. In all analyses, we assumed that children were exposed to a constant concentration of lead in their drinking water for the entirety of their childhood .

IQ Loss

Abt used the information above to identify lifetime average blood lead levels over age 0-7 years that correspond to drinking water concentrations that cause a 0.25 point IQ loss, a 0.5 point IQ loss, a 0.75 point IQ loss, a 1 point IQ loss, and a 2 point IQ loss. The relationship between blood lead levels and IQ loss was defined by three separate functions:

1. A linear function that assumes a 1 µg/dL increase in blood lead level is equivalent to a 1 IQ point loss, which was introduced by CalEPA in their 2007 *Child-Specific Benchmark Change in Blood Lead Concentration for School Site Risk Assessment*.

$$IQ\ Loss = \beta \times (PbB_2 - PbB_1)$$

Where:

β	=	Beta estimate from CalEPA (2007), or 1
PbB_1	=	Baseline average blood lead level without water lead
PbB_2	=	Average blood lead level including water lead

2. A non-linear function introduced in Lanphear et al. (2019) based on lifetime blood lead averages:

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

Where:

β	=	Beta estimate from Lanphear et al. (2019), or -3.25
PbB_1	=	Baseline average blood lead level without water lead
PbB_2	=	Average blood lead level including water lead

3. A non-linear function introduced in Crump et al. (2013) based on lifetime blood lead averages:

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

Where:

β	=	Beta estimate from Crump et al. (2013) independent analysis, or -3.25
PbB_1	=	Baseline average blood lead level without water lead
PbB_2	=	Average blood lead level including water lead

The Lanphear et al. (2019) function has previously been used by EPA NAAQS only when blood leads are above the lowest lifetime average blood lead observed in the Lanphear et al. (2019) analysis, or 1.47 µg/dL. This is because at very low blood lead levels, the slope of the logarithmic function becomes quite steep, leading to an unrealistically strong relationship between blood lead levels and IQ. Though the Crump et al. (2013) function is also a logarithmic function, it mitigates this issue by adding 1 to the blood lead average. One mitigation to this issue with the Lanphear et al. (2019) function is to use a low-dose linearization function to estimate IQ changes at blood leads lower than this lowest observed blood lead of 1.47 µg/dL. This means that the original logarithmic function (equation 2) would be used when both the baseline and the water lead inclusive blood leads are greater than or equal to 1.47 µg/dL, a derived linear function would be used when both the baseline and the water lead inclusive blood leads are below 1.47 µg/dL, and a hybrid function that combines the logarithmic and linear functions would be used when the baseline blood lead is below 1.47 µg/dL but the water lead inclusive blood lead is greater than or equal to 1.47 µg/dL. This low-dose linearization function was used in the EPA quantitative risk assessment in support of the 2007 review of the NAAQS for lead (EPA, 2007). This fourth function is described by the equations below:

4. When PbB_2 is greater than or equal to 1.47 µg/dL but PbB_1 is less than 1.47 µg/dL,

$$IQ\ loss = (\beta_1 \times \ln\left(\frac{cut\ point}{PbB_2}\right)) + (\beta_2 \times (cut\ point - PbB_1))$$

When both PbB_2 and PbB_1 are less than 1.47 µg/dL,

$$IQ\ loss = (\beta_2 \times PbB_2) - (\beta_2 \times PbB_1)$$

Where:

β_1	=	Beta estimate from Lanphear et al. (2019), or -3.25
β_2	=	Linear slope for low-dose region below 1.47 µg/dL, or 2.1
Cut point	=	Lowest observed blood lead from Lanphear et al. (2019), or 1.47 µg/dL
PbB_2	=	Average blood lead level including additional water lead
PbB_1	=	Baseline average blood lead level

In the case where there are estimated blood lead levels less than 1.47 µg/dL in our analysis, we will present results for Lanphear et al. (2019) both with and without the low-dose linearization function.

For each IQ loss function presented above, we used each equation to solve for PbB_2, since all of the other parameters in the equations are known quantities. IQ loss is determined by the *a priori* thresholds determined by the research question, β is a constant that was derived from each function's publication, and PbB_1 was calculated previously based on the IEUBK inputs from Table 1. Once we solved for PbB_2 in each IQ loss scenario, we used that blood lead level as a target blood lead level in IEUBK, and iteratively determined the water lead concentration based on the additional µg/L of lead in drinking water throughout the childhood that is necessary to reach that lifetime average blood lead level.

For the case of estimating IQ loss based on a lead in drinking water concentration of 5 µg/L, 10 µg/L, or 15 µg/L, we input these levels as the drinking water concentration for the entire childhood assuming the baseline inputs for other exposures in Table 1. We then calculated a lifetime average blood lead level to represent PbB_2 in each equation above, and calculate IQ loss based on the functions.

Results

Baseline Blood Lead Estimation

Using the baseline inputs into IEUBK presented in Table 1, we estimated a baseline lifetime average blood lead level of 0.850 µg/dL. Since this baseline blood lead is assumed for all kids in each of our

IQ loss scenarios, and this blood lead falls below 1.47 µg/dL, we additionally applied the low-dose linear function when using the Lanphear et al. (2019) function. This linearized function is used instead of the logarithmic function in all IQ loss scenarios until a blood lead level of 1.47 µg/dL is reached, at which point any additional blood lead is subject to the logarithmic function. Both the CalEPA (2007) function and the Crump et al. (2013) function are used as is.

IQ Loss Scenarios

Table 7 presents results from all of the *a priori* lifetime IQ loss scenarios using the CalEPA (2007) function. Table 8 presents results from all of the *a priori* lifetime IQ loss scenarios using the Lanphear et al. (2019) function without the low-dose linearization. Table 9 presents results from all of the *a priori* lifetime IQ loss scenarios using the Lanphear et al. (2019) function with the low-dose linearization. Table 10 presents results from all of the *a priori* lifetime IQ loss scenarios using the Crump (2013) function.

Table 7. IQ Loss Scenarios Based on CalEPA (2007) Function

Additional Lifetime IQ Loss	Lifetime Average Blood Lead Level that Results in Specified Additional IQ Loss (µg/dL)	Minimum Water Lead Concentration Consumed to Reach Associated Lifetime Average Blood Lead Level (µg/L)
0.25 points	1.10	4.1
0.5 points	1.35	8.4
0.75 points	1.60	12.8
1 point	1.85	17.3
2 points	2.85	36.8
0.30 points	1.15	***5***
0.59 points	1.44	***10***
0.87 points	1.72	***15***

Numbers in ***bold italics*** are *a priori* figures determined by the research question.

Table 8. IQ Loss Scenarios Based on Lanphear et al. (2019) Function without Low-Dose Linearization

Additional Lifetime IQ Loss	Lifetime Average Blood Lead Level that Results in Specified Additional IQ Loss (µg/dL)	Minimum Water Lead Concentration Consumed to Reach Associated Lifetime Average Blood Lead Level (µg/L)
0.25 points	0.92	1.1
0.5 points	0.99	2.4
0.75 points	1.07	3.6
1 point	1.16	5.1
2 points	1.57	12.3
0.99 points	1.15	***5***
1.72 points	1.44	***10***
2.30 points	1.72	***15***

Numbers in ***bold italics*** are *a priori* figures determined by the research question.

Table 9. IQ Loss Scenarios Based on Lanphear et al. (2019) Function with Low-Dose Linearization

Additional Lifetime IQ Loss	Lifetime Average Blood Lead Level that Results in Specified Additional IQ Loss (µg/dL)	Minimum Water Lead Concentration Consumed to Reach Associated Lifetime Average Blood Lead Level (µg/L)
0.25 points	0.97	2.0
0.5 points	1.09	3.9
0.75 points	1.21	6.0
1 point	1.33	8.0
2 points	1.83	16.8
0.63 points	1.15	***5***
1.24 points	1.44	***10***
1.82 points	1.72	***15***

Numbers in ***bold italics*** are *a priori* figures determined by the research question.

Table 10. IQ Loss Scenarios Based on Crump et al. (2013) Function

Additional Lifetime IQ Loss	Lifetime Average Blood Lead Level that Results in Specified Additional IQ Loss (µg/dL)	Minimum Water Lead Concentration Consumed to Reach Associated Lifetime Average Blood Lead Level (µg/L)
0.25 points	1.00	2.5
0.5 points	1.16	5.2
0.75 points	1.33	8.0
1 point	1.52	11.4
2 points	2.42	28.1
0.49 points	1.15	***5***
0.90 points	1.44	***10***
1.26 points	1.72	***15***

Numbers in ***bold italics*** are *a priori* figures determined by the research question.

The linear CalEPA (2007) IQ loss function was the least sensitive of the functions to changes in lifetime average blood lead, with a 1 point IQ loss requiring a water lead concentration of 17.6 µg/L, while Lanphear et al. (2019) function without the low-dose linearization was the most sensitive function, which only required a water lead concentration of 5.1 µg/L to cause a 1 point IQ loss. However, given the low baseline blood lead in this analysis, the Lanphear et al. (2019) function with the low-dose linearization is more appropriate to apply. That said, this function was still more sensitive to changes in lifetime average blood lead levels than both the Crump et al. (2013) and the CalEPA (2007) functions, with an 8.0 µg/L water lead concentration causing a 1 point loss in IQ.

This analysis shows that the exclusively powder-based formula-fed infant can be quite sensitive to the presence of lead in drinking water, and the sensitivity varies depending on the choice of IQ loss function applied. However, when using the most sensitive function relating changes in lifetime average blood lead to IQ loss, a 1 point IQ loss can be attained with less than 10 µg/L of lead in drinking water. Water lead concentrations at these levels are often observable in today's drinking water.

Discussion and Limitations

In any analysis predicting IQ loss, there are sources of uncertainty. The following subsections outline uncertainties in this analysis, specifically related to lead in formula, the choice of the IQ function, blood lead modeling, and exposure assumptions.

Lead in Formula

An additional exploration of the contribution of dietary lead from powdered formula was performed to investigate whether the dietary lead intake rate from EPA (2017) was sufficient to account for any lead reported to be present in the powder. The FDA Total Diet Study (TDS) contains information on lead in infant formula, but unfortunately the data are limited to only ready-to-feed formula rather than the power-based formula we are assuming for this analysis, as this is what is consumed by the majority of U.S. infants. Nonetheless, it is important to note that the TDS data from 2014 to 2017 tested lead concentrations in both soy-based and milk-based ready-to-feed infant formula, and show that there is no lead present in soy-based formula, and minimal lead present in some samples of milk-based formula (1 µg/kg and below). However, HBBF's 2019 *What's in my baby food?* analysis presented lead testing results for 13 different types of power-based infant formula of varying brands, purchased in varying parts of the United States (Health Babies Bright Futures, 2019). In the HBBF testing, 5 of the 13 measurements had values above the limit of detection but below the limit of quantification, meaning the exact estimates may have a larger level uncertainty regarding their precision, but all of the 13 measurements were above the limit of detection. The average value of lead in the powder-based infant formula that was tested in HBBF's report was approximately 2.9 ppb, or 2.9 µg/kg.

According to Abbott Nutrition, the manufacturers of Similac formula, each scoop of formula contains approximately 9 grams of powder (Abbott Nutrition, 2016). This means that each scoop of powder-based formula would contain approximately 0.03 µg of lead. Given these results, we explored substituting the appropriate amount of lead from the powder-based formula as the dietary lead intake rate for the first year of life based on the amount of drinking water consumed. Since we know from manufacturer's instructions that each scoop is mixed with 60 mL of drinking water, we used the following formula to calculate the amount of additional dietary lead coming from the formula:

$$DailyFormulaLead\ (\mu g) = \ 0.03\ \mu g\ lead/scoop * \left(\frac{DrinkingWaterIntakeRate\ (mL)}{60\ mL\ water/scoop}\right)$$

If we are assuming that the whole diet is comprised of formula in the first six months of life, then any assumed dietary lead intake must be coming from reconstituted formula. Our assumed baseline dietary lead intake for the first year of life from EPA (2017) is 0.65 µg/day, which is applicable to even those children assumed to only be consuming formula. Our exploration showed that our calculated daily lead intake from formula fell within the bounds of the EPA (2017) dietary intake figure, and thus we did not include use this exploration to define dietary lead intake for the first year of life.

Choice of IQ Function

There is inherent uncertainty in choosing one particular IQ loss function over another, which creates a scenario where we are unable to conclude that one set of results is more appropriate than another. In addition, all of these IQ loss functions were estimated using blood lead levels that were higher than the blood lead levels used as the baseline for this current analysis, which could affect our ability to generalize these IQ loss functions to this particular analysis. While the low-dose linearization equation for the Lanphear et al. (2019) attempts to solve this problem, a better solution would be an IQ loss function that is estimated using blood lead levels that are more representative of the low baseline levels in this analysis. However, there is a widely accepted assumption that there is no threshold for the adverse effect of lead.

Blood Lead Modeling

The IEUBK model was calibrated using blood leads higher than those relevant to this current analysis, which could affect its ability to predict lifetime average blood lead levels using the relatively low exposure inputs for this analysis. The IEUBK model was also not validated on many children below 6 months of age, and as changes to exposure inputs for this age group are the focus of this analysis, there may be some uncertainty about the validity of the developed lifetime average blood lead predictions.

Exposure Assumptions

Assumptions made for amount of infant formula consumed by children ages 6 months to 1 year of age could be strengthened by using actual consumption data from children, as opposed to using the feeding guidelines that were assumed as representative of this consumption in this analysis. We also do not quantify additional consumption of drinking water for children in the first year of life outside of their consumption of infant formula, so it is possible that our drinking water intake rates could be an underestimate if children are drinking additional tap water. At the same time, however, the relatively higher drinking water intake rate assumed, which was estimated using recommended caloric intake as opposed to the suggested formula-fed infant drinking water intake rate from the EPA *Proposed Modeling Approaches for a Health-Based Benchmark for Lead in Drinking Water Report*, could suggest slightly higher than average drinking water intake rates.

Next Steps

Abt recommends next steps of further exploring other relevant exposure scenarios, such as using 95th percentile inputs for bodyweight, which would increase the number of required calories, and thus increase the drinking water intake rate required to reach the higher number of calories from infant formula. Additional analyses could include an inquiry into differences in the required drinking water intake rate for the *a priori* IQ loss scenarios for representative children of different demographic groups, such as by race, gender, or socioeconomic status. Although because of the non-linear (log-scale) nature of the Lanphear et al. (2019) and the Crump et al. (2013) functions, children with higher baseline levels of lead exposure will likely require less exposure from drinking water in order to reach each IQ loss threshold. This is because the slope relating changes in lifetime average blood leads to changes in IQ is steepest at levels closest to zero, and gradually declines as you move to higher blood lead levels. This means that at higher baseline blood lead levels, it takes more additional blood lead to result in the same level of IQ loss than it would at lower baseline blood lead levels.

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