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Assessing and mitigating human health risks in mercury mining communities: A case study in the Kyrgyz Republic

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Mercury Mining in Batken

- 1940s mercury mining and smelting; one of largest Hg producers globally
- Aidarken:
 - Active mine and smelter
 - One of the last Hg smelters
 - Investigations by Kyrgyz researchers and UN
- Chauvay
 - Facilities abandoned/salvaged post-USSR
 - No previous studies
- Residential areas adjacent to / on mine and processing wastes



Partnerships and Goals

- Doctors Without Borders (MSF), Kyrgyz Ministry of Health (MOH), TerraGraphics International Foundation (TIFO)
- Local stakeholder committee formed to engage in every project activity
- Developed and implemented investigation *to better understand risks and inform a health intervention*



2019 Environmental Sampling

- Soil, drinking water, irrigation water, and locally grown fruit and vegetables (from homes) were collected from residential and public areas
- >600 samples collected
- Sample collection methods blended US and Kyrgyz protocols
- Soil screening with handheld x-ray fluorescent spectrometer (XRF) and Lumex vapor mercury detector to reduce analytical costs
- Samples analysis:
 - MOH district Sanitary Epidemiological Service (SES)
 - Jožef Stefan Institute (JSI) in Slovenia

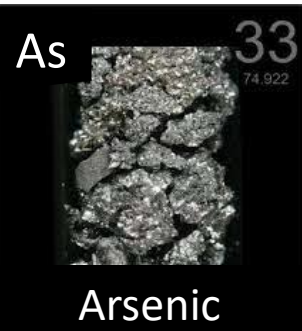


Hg 80
200.59



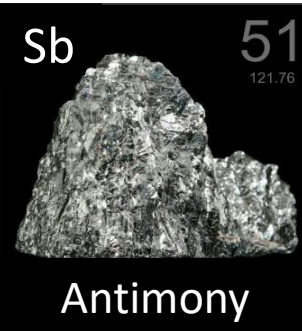
Mercury

As 33
74.922

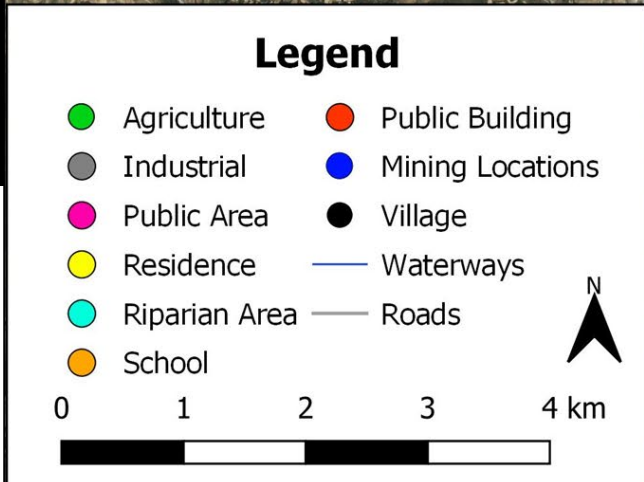
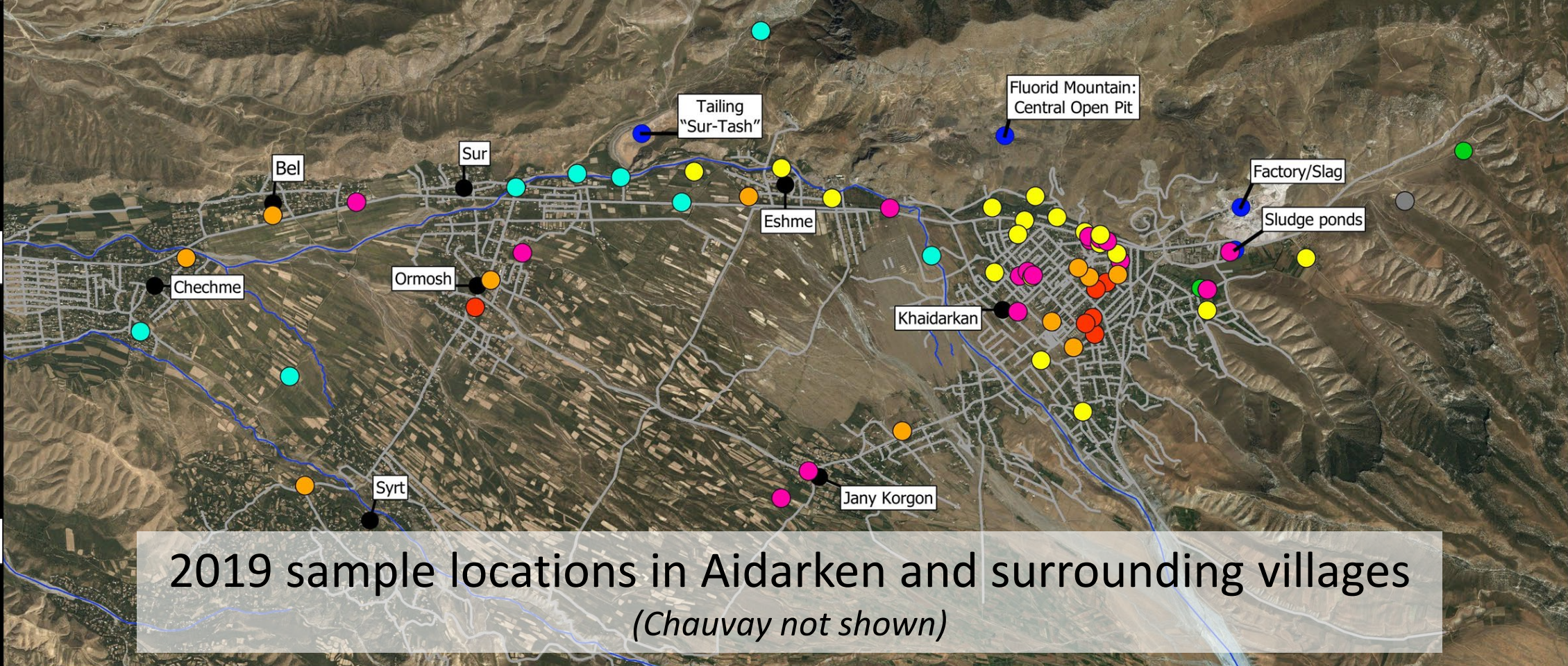


Arsenic

Sb 51
121.76



Antimony



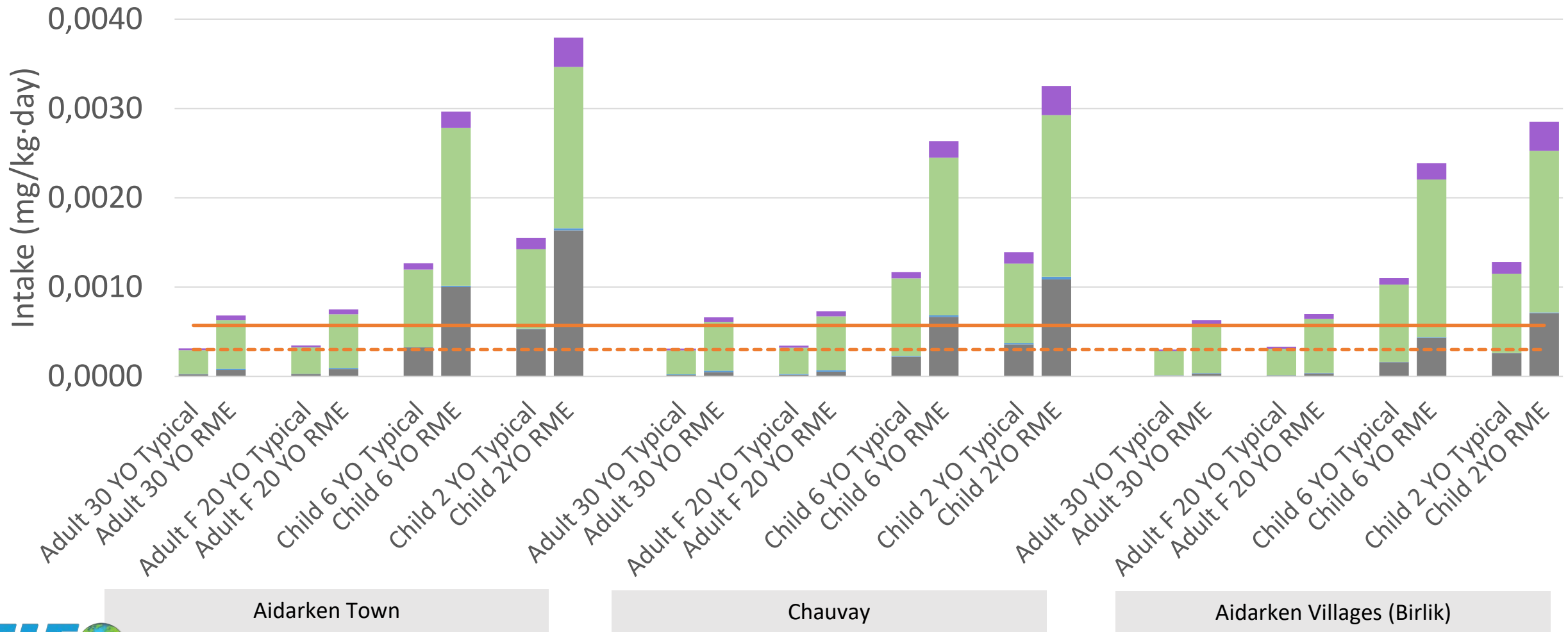
HHRA Methods Summary

- 4 population groups
 - 30-year-old adult
 - 20-year-old female adult
 - 6-year-old child
 - 2-year-old child
- 3 communities
 - Aidarken town (active mine/smelter)
 - Chauvay village (abandoned mine/smelter)
 - Rural villages outside Aidarken (Birlik)
- Modified exposure factors
 - Body weights, soil ingestion rates, vegetable and fruit ingestion rates
- Typical (arithmetic average) and Reasonable Maximum Exposure (RME) concentrations
- Ingestion only



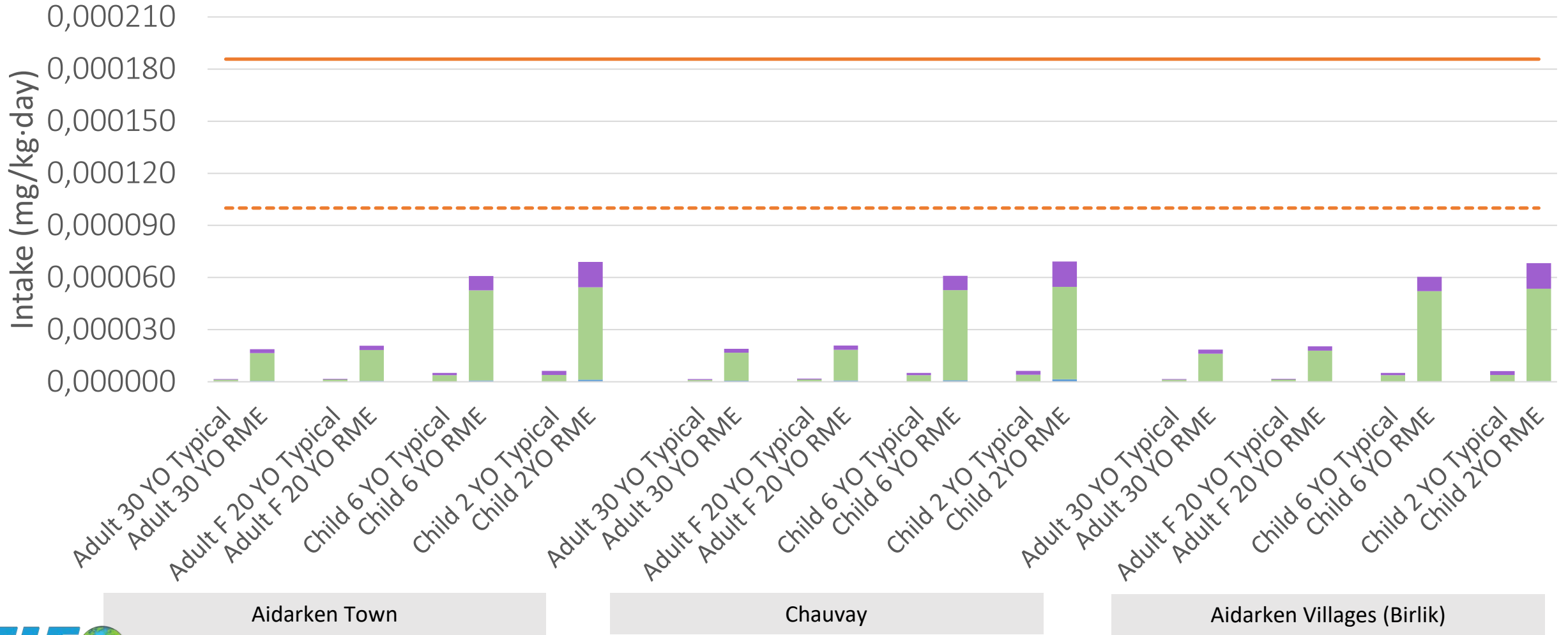
Intakes: Mercury (Hg)

Soil	Vegetable
Water	Fruit
<u>TDI (WHO)</u>	<u>RfD (US)</u>



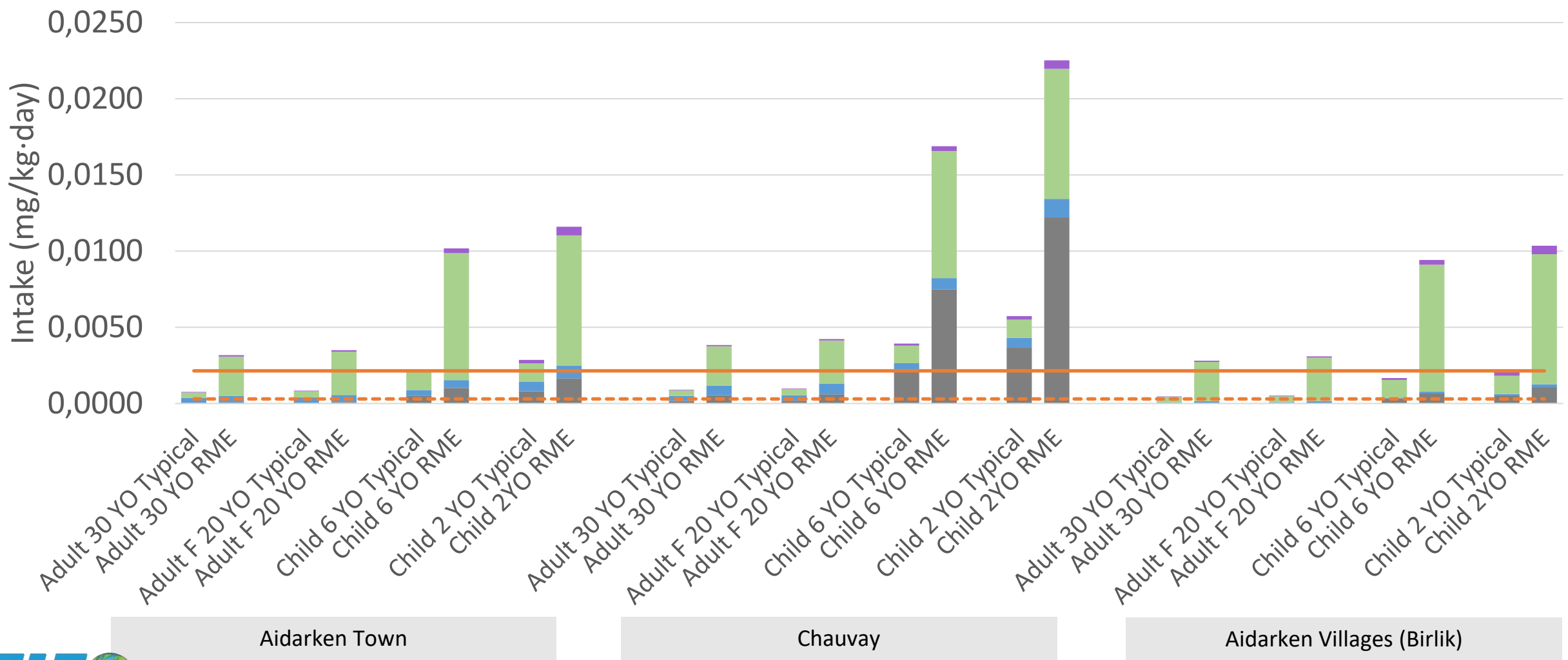
Intakes: Methyl Mercury (MeHg)

Soil	Vegetable
Water	Fruit
<u>TDI (WHO)</u>	<u>RfD (US)</u>



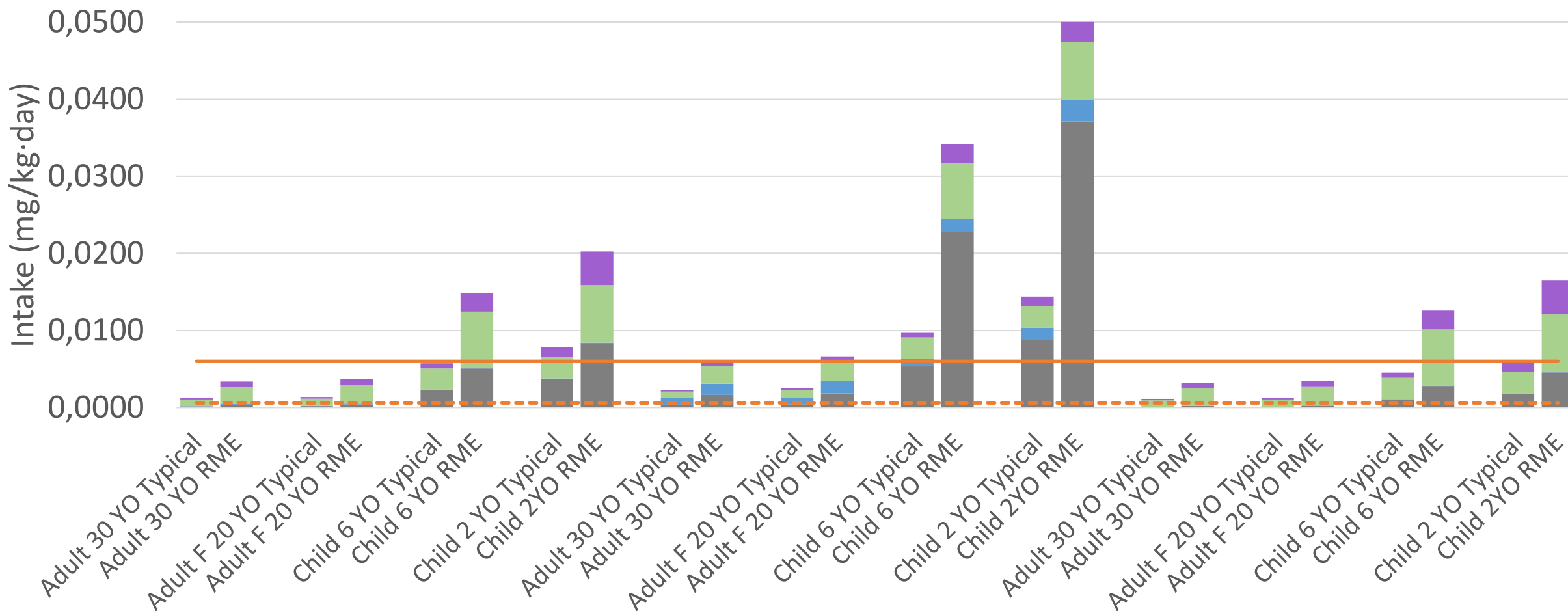
Intakes: Arsenic (As)

Soil	Vegetable
Water	Fruit
<u>TDI (WHO)</u>	<u>RfD (US)</u>



Intakes: Antimony (Sb)

Soil	Vegetable
Water	Fruit
<u>TDI (WHO)</u>	<u>RfD (US)</u>



Summary of Hazard Indices (Hg + As + Sb)

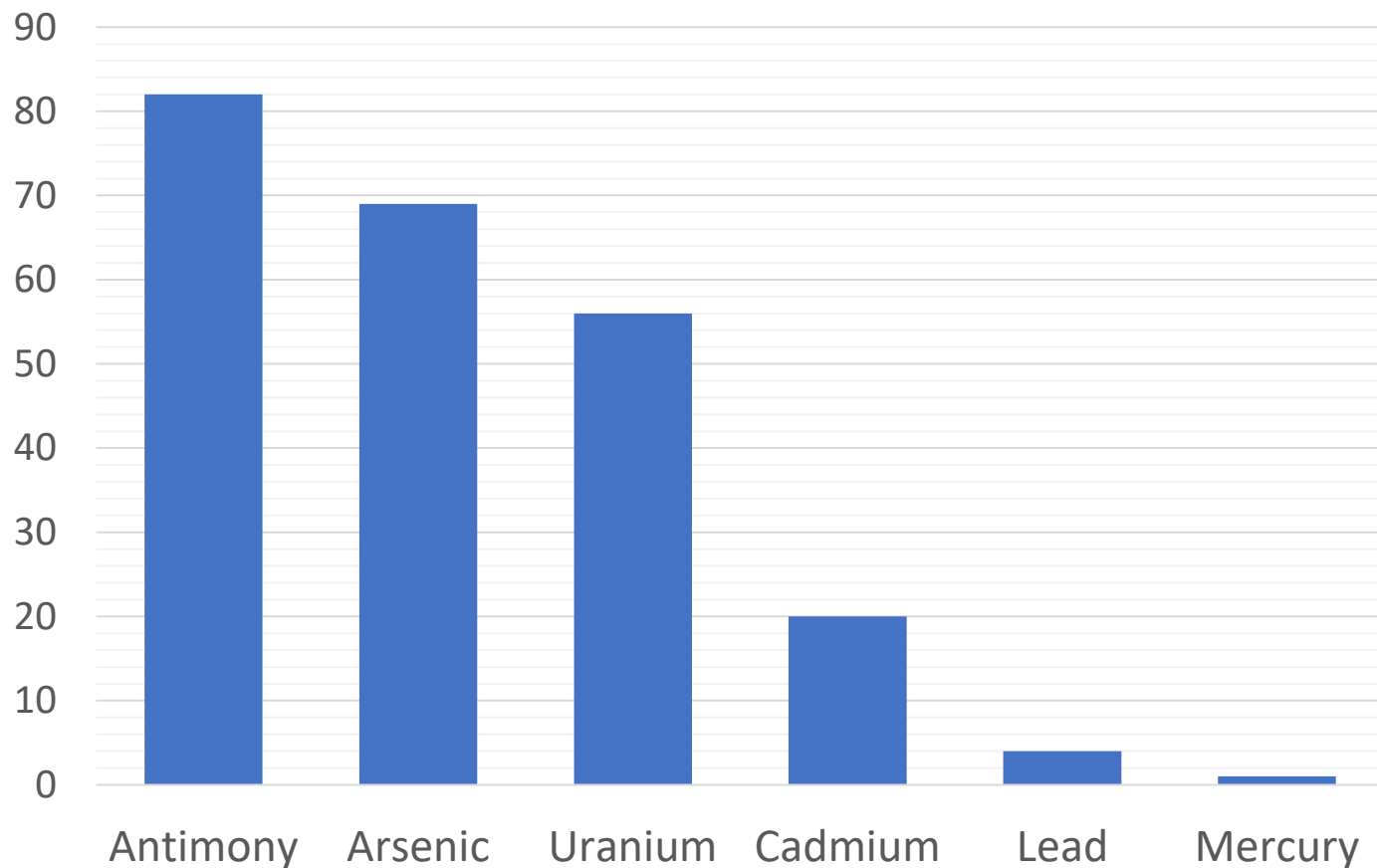
Hazard Indices across metals for all media, based on the WHO Tolerable Daily Intake (TDI) health-based criteria. These have been calculated for four risk populations and both a typical (average) and a reasonable maximum exposure (RME) concentration.

		Typical					RME				
		Soil HI	Veg HI	Fruit HI	Water HI	Total HI	Soil HI	Veg HI	Fruit HI	Water HI	Total HI
Aidarken	Adult Age 30 Years	0.1	0.6	0.1	0.1	0.9	0.2	2.1	0.2	0.2	2.7
	Adult F. Age 20 Years	0.1	0.8	0.1	0.2	1.2	0.2	2.8	0.3	0.3	3.6
	Child Age 6 Years	1.2	2.1	0.3	0.2	3.8	3.1	6.9	1.0	0.3	11.2
	Child Age 2 Years	1.9	2.6	0.6	0.3	5.4	5.0	8.7	1.6	0.5	15.9
Chauvay	Adult Age 30 Years	0.1	0.6	0.1	0.2	1.1	0.5	2.1	0.2	0.5	3.2
	Adult F. Age 20 Years	0.2	0.8	0.1	0.3	1.4	0.7	2.8	0.3	0.6	4.3
	Child Age 6 Years	2.3	2.1	0.3	0.4	5.1	8.5	6.9	1.0	0.7	17.0
	Child Age 2 Years	3.8	2.6	0.6	0.6	7.6	13.8	8.7	1.6	1.1	25.3
Villages (Birlik)	Adult Age 30 Years	0.0	0.6	0.1	0.0	0.8	0.1	2.1	0.2	0.0	2.4
	Adult F. Age 20 Years	0.0	0.8	0.1	0.0	1.0	0.1	2.8	0.3	0.1	3.2
	Child Age 6 Years	0.6	2.1	0.3	0.0	3.0	1.5	6.9	1.0	0.1	9.5
	Child Age 2 Years	1.0	2.6	0.6	0.1	4.2	2.5	8.7	1.6	0.1	13.0

Biomonitoring

- 255 participants; blood and urine
- Adult females (15-59 years) and children (5-14 years)
- Results in children higher than in adults (not shown)
- 82% above reference levels for Sb
 - 18% above clinical action level for Sb (not shown)
- 69% above reference levels for As

PRELIMINARY RESULTS: Percent of 255 study participants > reference level for each heavy metal



Limitations

- Focused on ingestion risks; *inhalation risks likely significant, especially for arsenic*
- Lumex vapor Hg results were all low, but mercury vapor exposures could be significant depending on smelter operations
- Analyses were limited to residential and public areas and exclude active mining sites; no occupational risks were assessed
- Food sample results from Aidarken were applied to all communities; this may result in an over- or under-estimation of risk in Chauvay, and likely an over-estimation of risk in Birlik
- No food samples from markets (i.e., rice); no consumer product samples

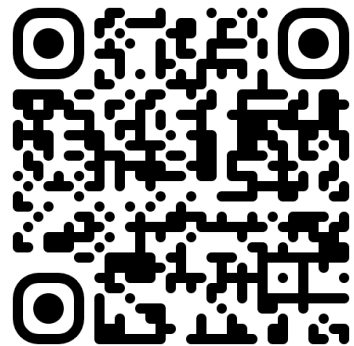
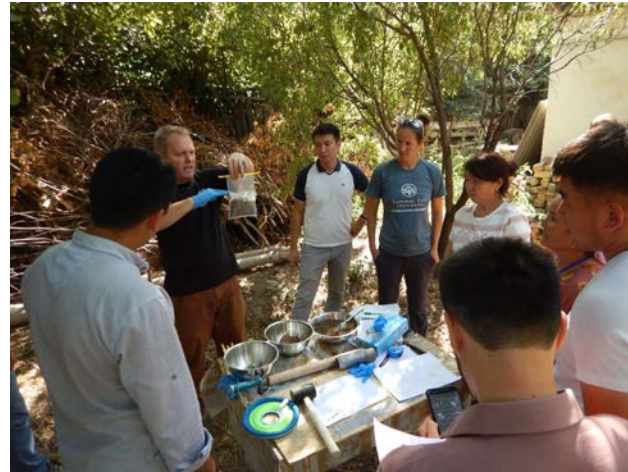


Interventions

- Advocacy for:
 - Remediation
 - Broad health intervention programming
 - Additional investigations
- Health promotion
- Limited remediation at three schools
- Building local lab capacity
- Health worker training

Rakhmat Spacibo Thank You

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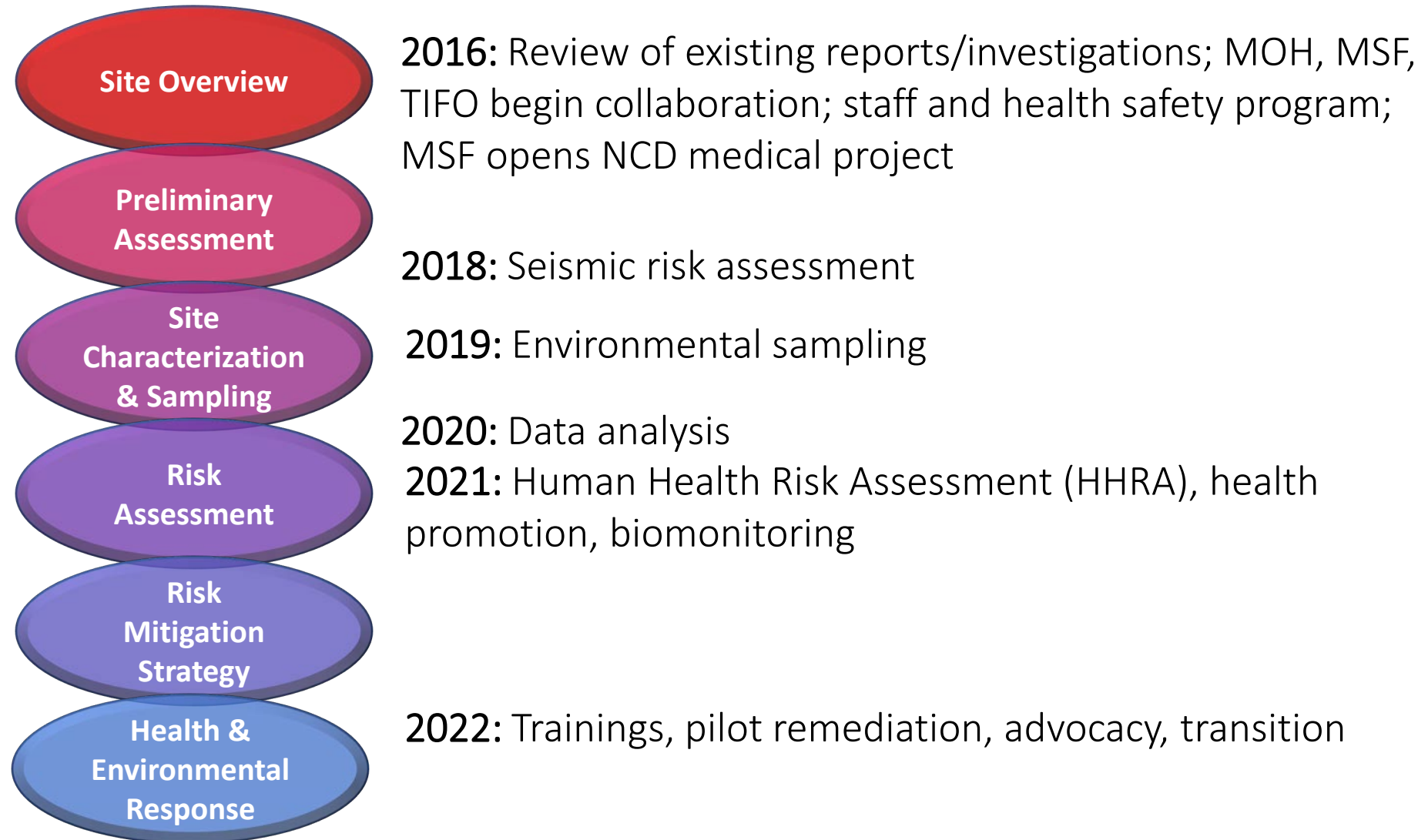
TERRAGRAPHICS INTERNATIONAL FOUNDATION



MEDECINS SANS FRONTIERES
DOCTORS WITHOUT BORDERS

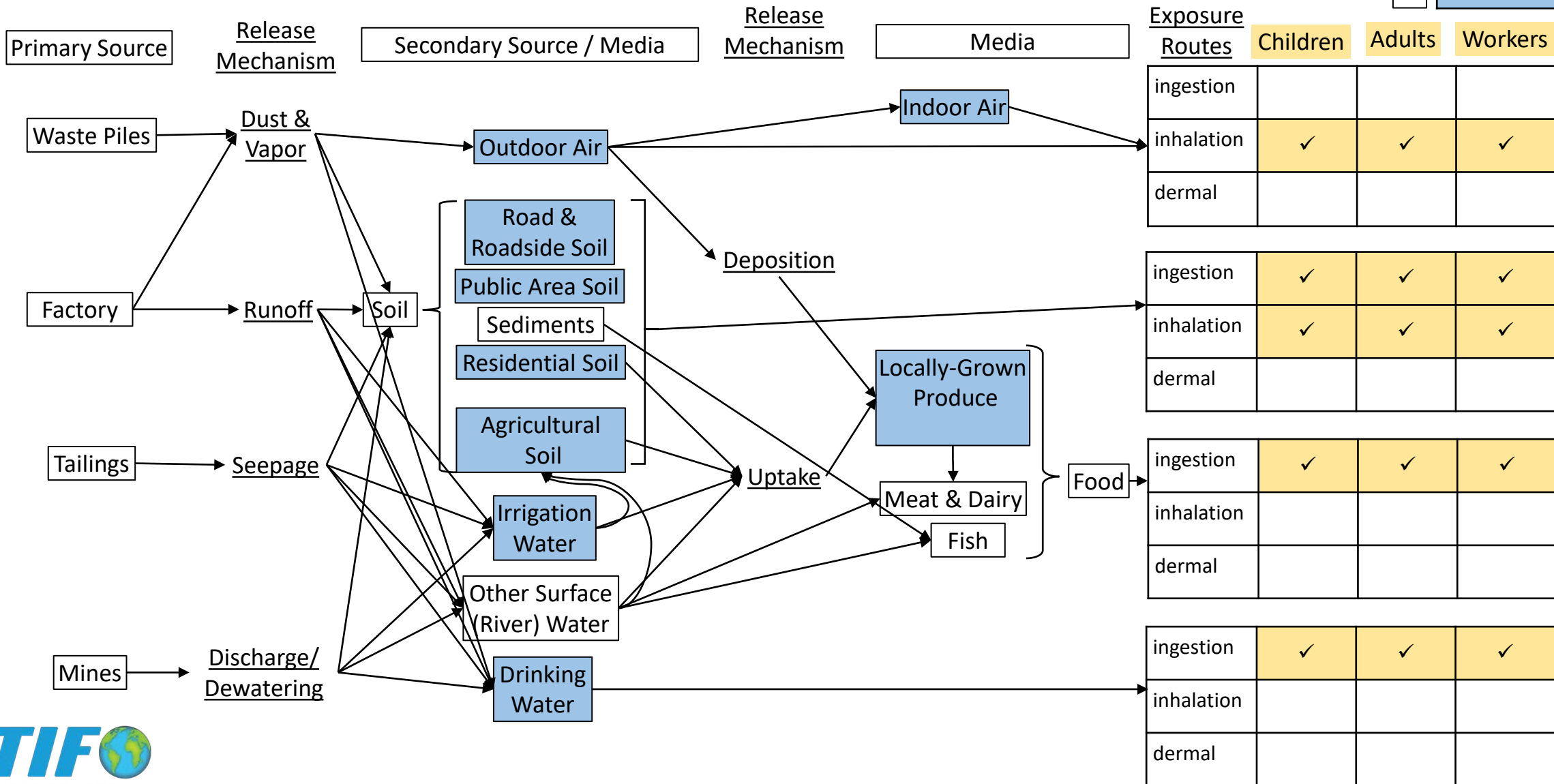


Kyrgyzstan EH Project Timeline

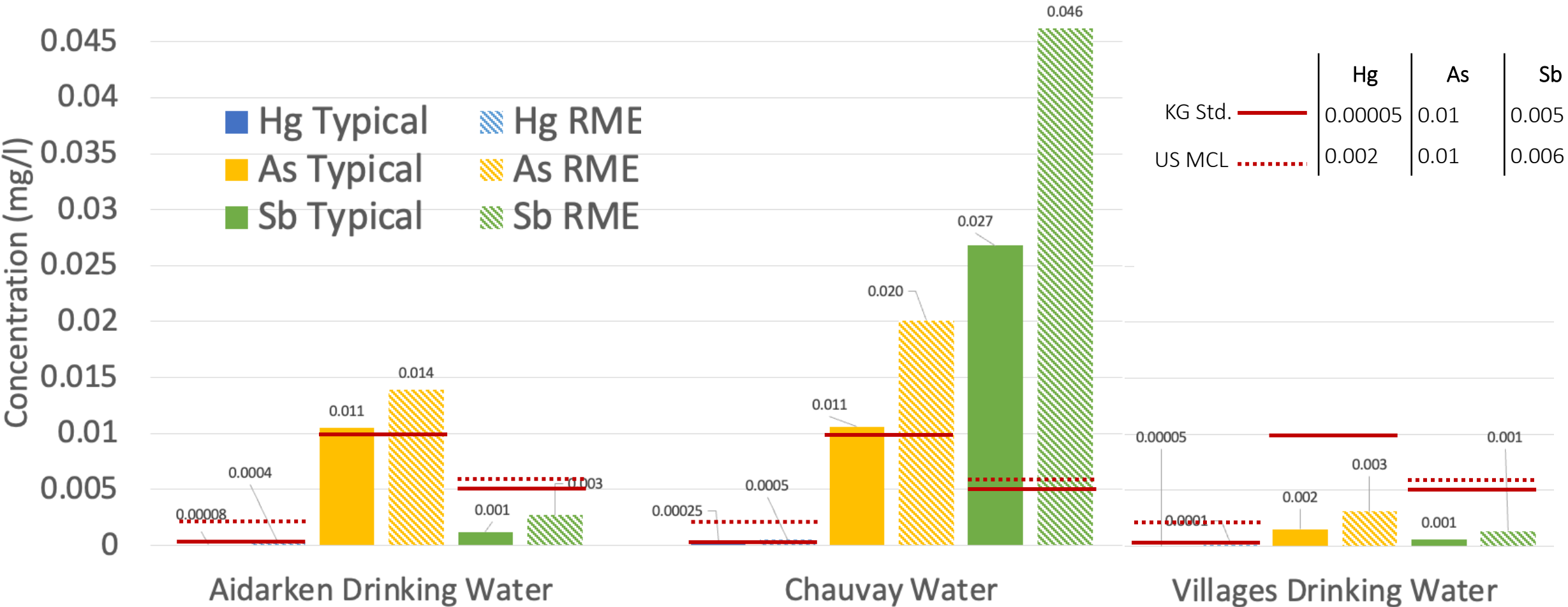


Conceptual Site Model (pre-risk assessment)

Legend	Complete Pathway	✓
	Incomplete Pathway	✓
	Unknown	✓
	Primary Data Needs	



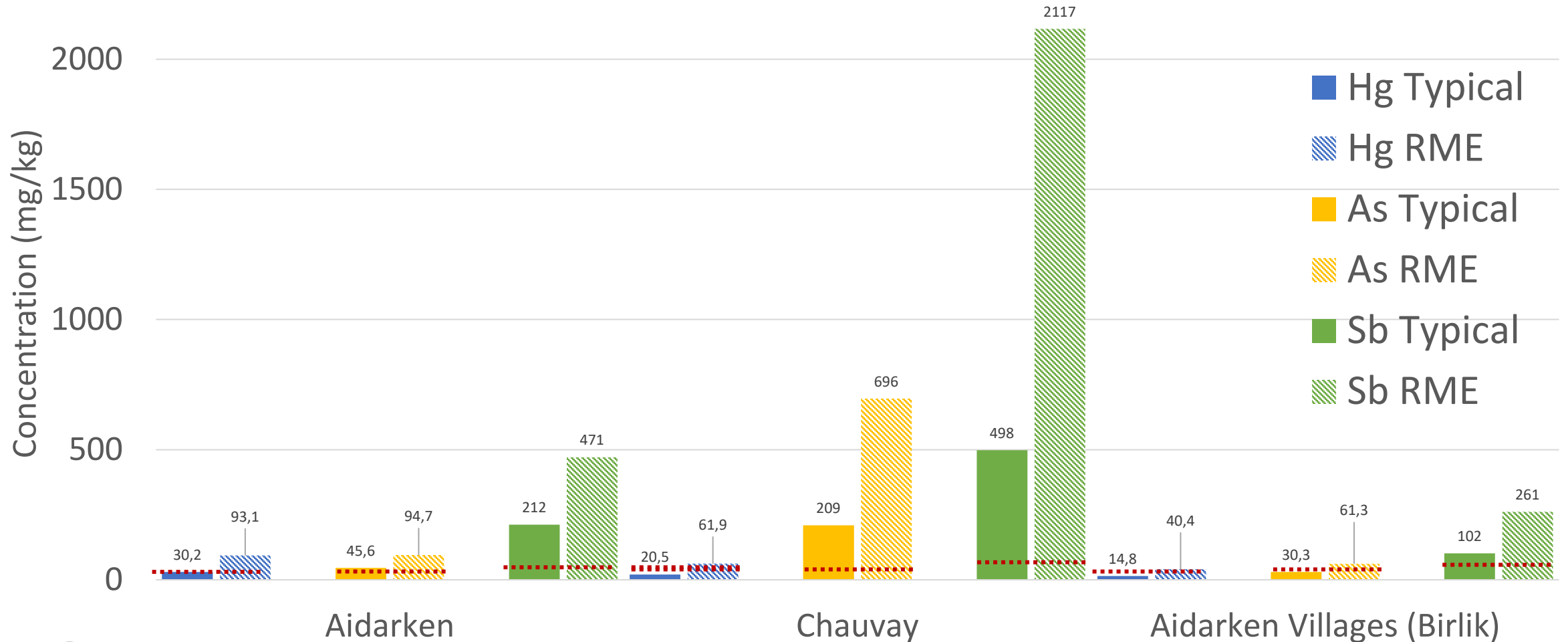
Results: Drinking water concentrations



*Reasonable Maximum Exposures (RME) are 95th percentile values.

Results: Soil concentrations

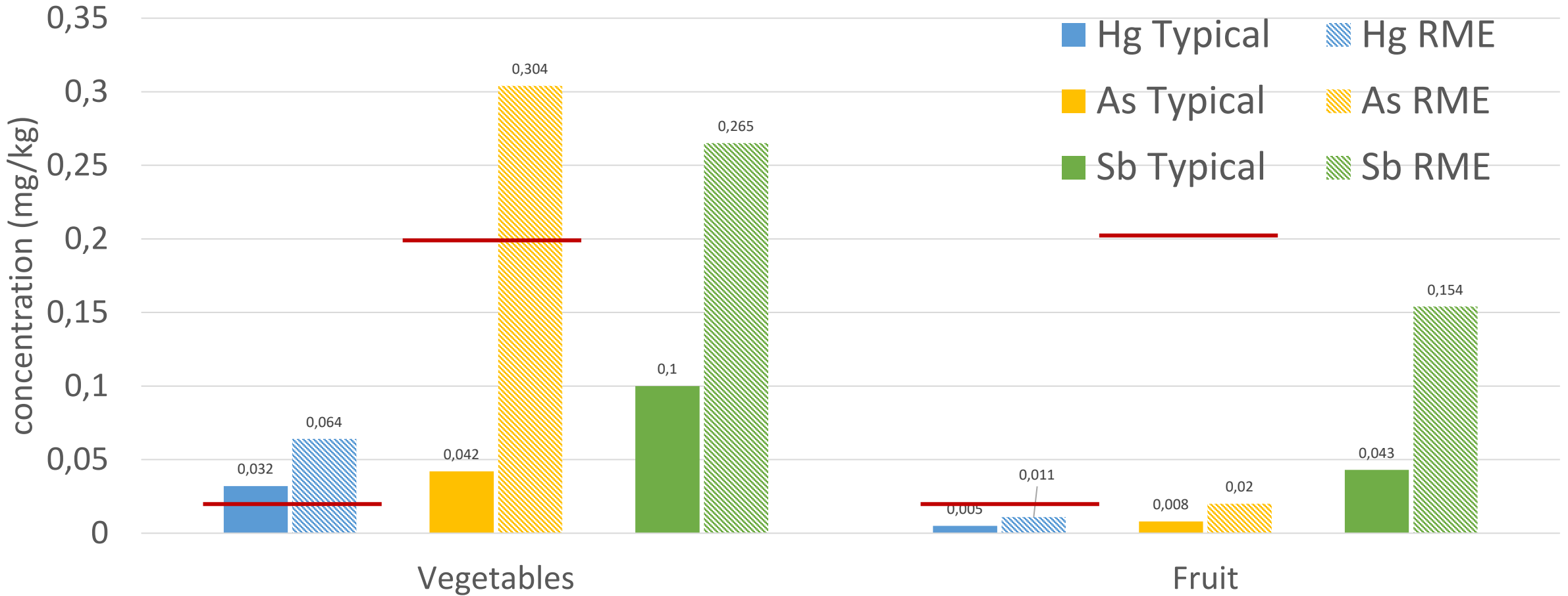
	Hg	As	Sb
KG Std.	2.1	2	4.5
US MCL	23	35	31



*Reasonable Maximum Exposures (RME) are 95th percentile values.

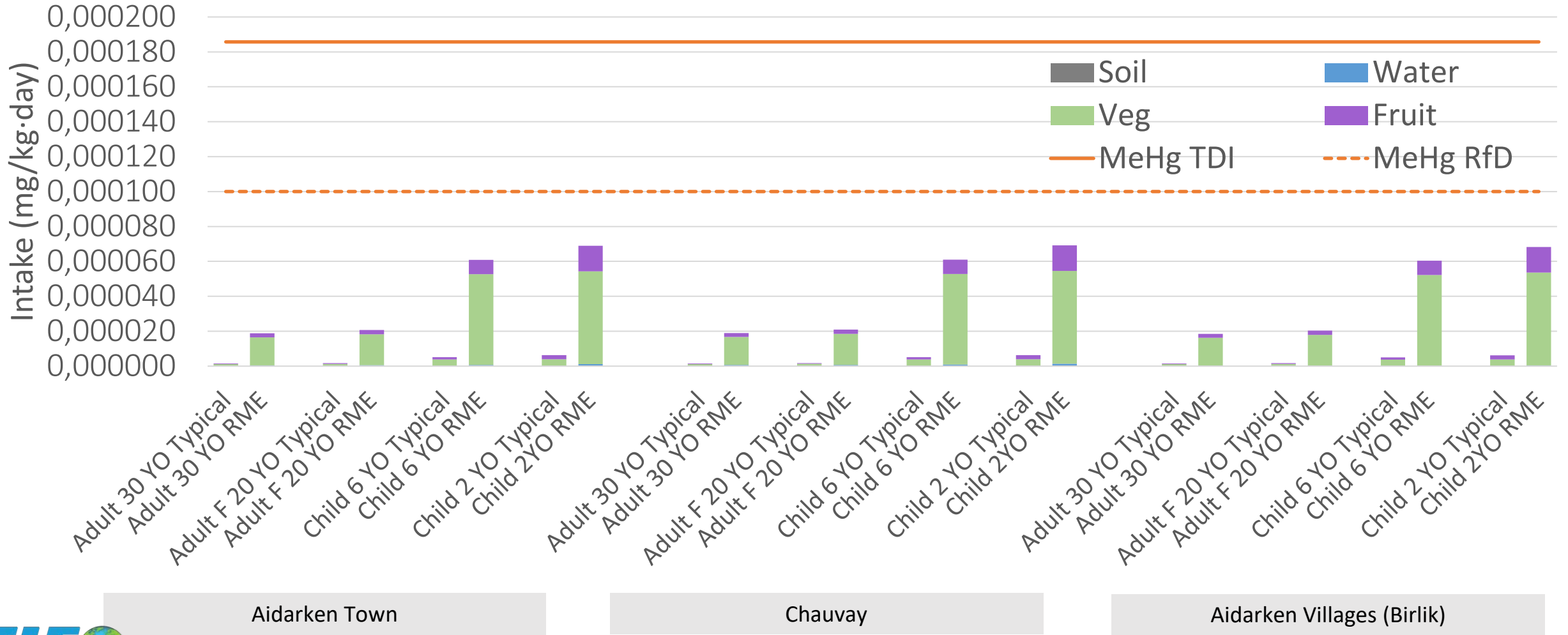
Results: Food concentrations

	Hg	As	Sb
KG Std.	0.02	0.2	n/a



**Reasonable Maximum Exposures (RME) are 95th percentile values.*

Intakes: Methyl Mercury (MeHg)



Exposure Factors for each population sub-group

Table 1. Exposure factors (EFs) proposed for calculating contaminant intakes. Values in red text indicate culturally specific exposure factor estimates based on Kyrgyz standard EF values and/or literature review.

Exposure Factor	Adult Age 30 Years	Child Age 6 Years	Adult Female Age 20 years	Child Age 2 Years
Age (yr)	30	6	20	2
Body weight (kg)	80	18.6	60	11.4
Duration-Food, Soil, Water (yr)	1	1	1	1
Frequency- Soil, Water (day/yr)	365	365	365	365
Frequency- Food (day/yr)	365	365	365	365
Frequency- Air (day/yr)	260	260	260	260
Ingestion Rate-Soil (mg/day)	50	200	50	200
Ingestion Rate-Water (L/day)	2	0.69	2	0.69
Ingestion Rate-Fruit (g/day)	280	314	280	325
Ingestion Rate- Vegetable (g/day)	542	259	542	201
Average Time- Food, Water, Soil (days)	365	365	365	365

Health Criteria (RfD, TDI)

Table 2. Health criteria used in comparison to the contaminant EDIs.

Criteria	Units	Arsenic	Methylmercury ²	Total Mercury ²	Antimony
PTWI ¹	µg/kg*week	15	1.3	4	NA
TDI	µg/kg*day	2.1	0.2	0.6	6.0
TDI ³	mg/kg*day	0.0021	0.000186	0.00057	0.006
RfD ⁴	mg/kg*day	0.0003	0.0001	0.0003	0.0004

¹ Provisional Tolerable Weekly Intake (PTWI) is the WHO health-based criteria for minimal risk. Available at <https://apps.who.int/iris/handle/10665/40675>

² EFSA 2012. Scientific Opinion on the risk for public health related to the presence of mercury and methylmercury in food. European Food Safety Authority, Parma, Italy

³ Tolerable Daily Intake (TDI) is derived from the PTWI by dividing by 7 days/1 week.

⁴ Reference Dose (RfD) is the USEPA health-based criteria for minimal risk. Available at <https://www.epa.gov/iris>.

Risk Characterization

Intake (I): How much are people exposed and taking in the element/chemical

$$I = \frac{(C \times CR \times EFD)}{BW \times AT}$$

I- Intake ($\frac{mg}{kg-day}$)

C- Concentration ($\frac{mg}{kg}$)

CR- Contact Rate ($\frac{g}{day}$)

EFD-Exposure, frequency, and duration
($\frac{day}{yr}$) \times (yr)

BW- Body Weight (kg)

AT- Average Time Exposed (yr)

Risk Characterization

Hazard Quotient (HQ): The ratio of potential exposure to level of adverse health effects - unitless

$$HQ = \frac{Intake}{RfD}$$

HQ > 1 = Adverse health effects

HQ < 1 = No adverse health effects

RfD- Reference Dose, given by the EPA $\left(\frac{mg}{kg-day}\right)$

Cancer Risk (CR): Probability of developing cancer - unitless

$$CR = I \times SF$$

SF- Slope Factor, given by EPA, for carcinogens
 $\left(\frac{mg}{kg-day}\right)^{-1}$

Level of Concern	Risk Scale	HQ	HI
Serious Concern	5	>5	>10
Concern	4	3-<5	>5-10
Some Concern	3	1.5-<3	>3-5
Minimal Concern	2	.5-<1.5	1-<3
Negligible Concern	1	<.5	<1

Cancer Risk

- Lifetime cancer risks for Typical and RME scenarios for each community
- Total cancer risk ranges from 10^{-3} in the Birlik Typical Scenario to 10^{-2} in Chauvai RME scenario
- All communities exceed the recommended US health criteria of 10^{-4} to 10^{-7} (1 in 10,000 to 1 in 10,000,000) range of probability of excess cancers *from oral exposure alone*

Table 1-2. Lifetime cancer risks associated with oral arsenic exposures.

Exposure Source	Aidarken		Chauvai		Birlik	
	Typical	RME	Typical	RME	Typical	RME
Soil	2.1E-04	4.4E-04	9.8E-04	3.3E-03	1.4E-04	2.9E-04
Water	6.3E-04	8.3E-04	6.4E-04	1.2E-03	9.2E-05	1.9E-04
Veg Food	7.5E-04	5.4E-03	7.5E-04	5.4E-03	7.5E-04	5.4E-03
Fruit Food	6.1E-05	1.4E-04	6.1E-05	1.4E-04	6.1E-05	1.4E-04
Total	1.7E-03	6.8E-03	2.4E-03	1.0E-02	1.0E-03	6.0E-03

AVOID



PRACTICE

