Supporting Information for

Characterization of Inhalation Exposure to Gaseous Elemental Mercury During Artisanal Gold Mining and E-Waste Recycling Through Combined Stationary and Personal Passive Sampling

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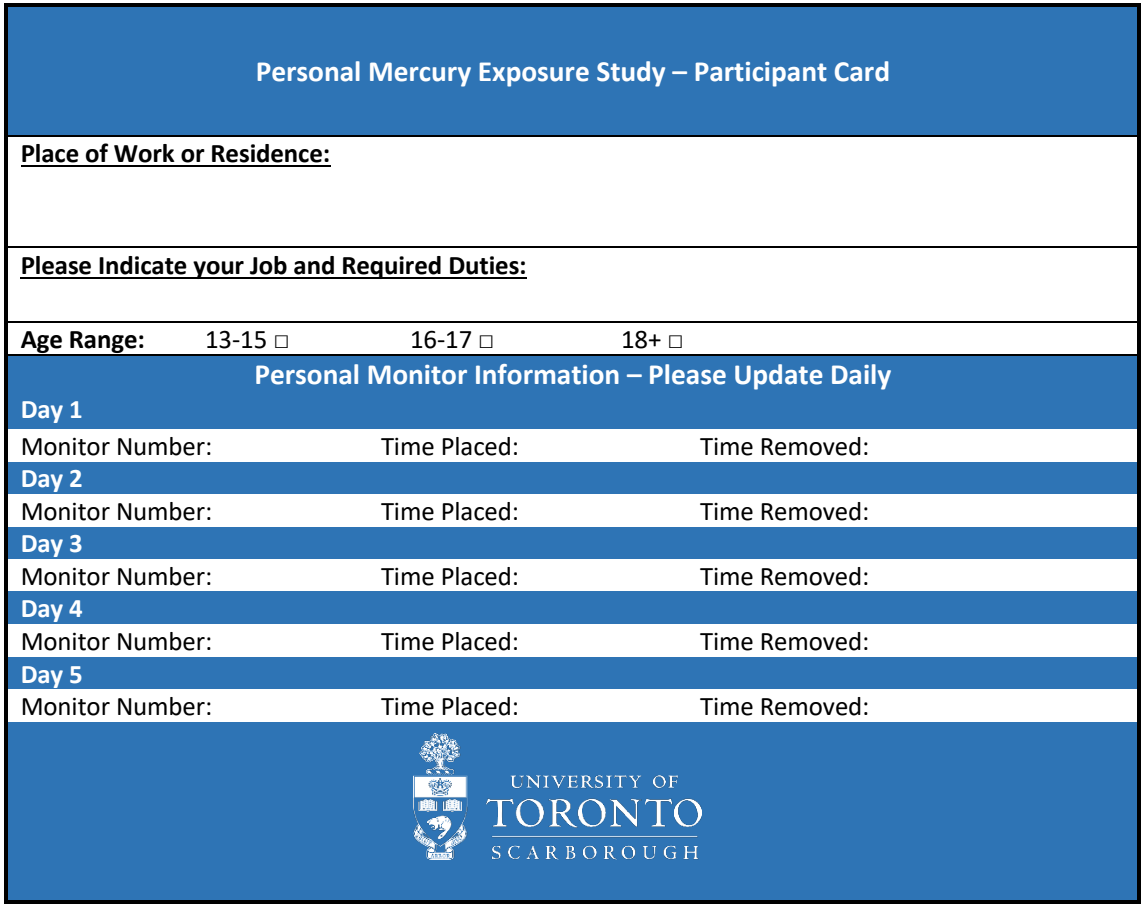
Table of Content

Figure S1 Pictures of the ASGM activities in community 1 in Ghana

Figure S2 Pictures of the ASGM activities in community 2 in Ghana.

Figure S3 Pictures of the waste recycling facility in Norway



Personal Mercury Exposure Study – Participant Card

Place of Work or Residence:

Please Indicate your Job and Required Duties:

Age Range: 13-15 □ 16-17 □ 18+ □

Personal Monitor Information – Please Update Daily

Day 1		
Monitor Number:	Time Placed:	Time Removed:
Day 2		
Monitor Number:	Time Placed:	Time Removed:
Day 3		
Monitor Number:	Time Placed:	Time Removed:
Day 4		
Monitor Number:	Time Placed:	Time Removed:
Day 5		
Monitor Number:	Time Placed:	Time Removed:

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Figure S4 Participant card used to collect all information during personal exposure measurements in Ghana and Norway.

Section S1: Instrument Calibration and Sample Analysis

To determine the amount of total mercury adsorbed to the HGR-AC in a PAS or a pumped sampling tube, we applied thermal decomposition, amalgamation and atomic absorption spectroscopy (US EPA Method 7473) using an AMA-254 trace mercury analyzer (Leco Instruments Ltd, ON, CA) or a MA-3000 Direct thermal decomposition mercury analyzer (Nippon Instruments Corporation, TYO, JP) with oxygen as the carrier gas, (see Tables S1 and S2 for method parameters). Calibration standards with Hg concentrations of 0.1, 1, and 10 mg L^{-1} were prepared by diluting a 1000 mg L^{-1} stock solution of 1000 ± 5 mg L^{-1} Hg in 10 % w/w HCl (Inorganic Ventures, Virginia USA) in 1 % w/w metal grade concentrated nitric acid (Millipore Sigma, MA, USA). New Hg standards were prepared every 30 days.

Table S1 Method details for the analysis of PASs for GEM using the AMA-254 analyzer

Method Step	Time (s)	Duty Cycle (%)
Drying Time	30	9
Decomposition Time	330	100
Cuvette Clear Time	45	-
Dosing Delay Time	20	-
Boat Cooling Time	20	-
Total Time:	445	

Table S2 Method details for the analysis of PASs for GEM using the MA-3000 analyzer

Method Step	Time (s)	Temperature	Duty Cycle Range (%)
Drying Time	30	150	10
1st Decomposition	150	240	10-50
2nd Decomposition	120	650	100
Total Time:	300		

Instrument calibration was completed by the addition of liquid Hg standards to clean, unexposed HGR-AC sorbent, covered with a thin layer (~0.2 g) of sodium carbonate (Na_2CO_3). Given the large range of mercury concentrations that may be encountered in the context of personal exposure monitoring along with the uncertainty in potential exposure, instrument calibration was intensive covering a large range to ensure accurate results were obtained. Calibration curves were prepared to maximize the number of analyzed samples falling near the middle of each curve. Both low and high cell calibrations curves contained a minimum of 5 points and were fitted with linear curves. Typical calibration curves for the low cell consisted of 0, 1, 2.5, 5, 10 and 15 ng of Hg, while the high cell curves consisted of 15, 20, 25, 50, 100, 150, 250 and 500 ng of Hg.

For analysis, the sorbent is removed from the holder, analytically weighed, and then transferred into clean sample boats for analysis. Before analysis, samples were ranked from lowest – highest expected Hg content and then ran in this order. Although not a fool-proof method, this reduces the chance of a potential memory effect of a highly contaminated sample inadvertently increasing the observed concentration of a less contaminated sample analyzed subsequently. Samples with low expected levels of Hg were run using a dosing feature which allows multiple

samples to undergo thermal decomposition in succession while each quantity of GEM is trapped in the gold amalgamator tube. The sample then passes through the cuvette system and is detected in its entirety. For samples of high expected concentrations, a small (~0.02 g) sub-sample was analyzed to determine the approximate GEM concentration of the sample. For practicality reasons samples that could not be analyzed in whole due to exceptionally large concentrations were well mixed via manual shaking and three sub-samples of each were analyzed. The mass of Hg detected in the sub-samples was then mass adjusted according to the following equation:

$$mHg_{total} = \sum mHg_{detected} \times \frac{m_{sample}}{\sum m_{analyzed}}$$

Where, $mHg_{detected}$ is the summation of the quantity of blank-corrected Hg detected in all analyzed sub-samples, m_{sample} is the mass of HGR-AC for the entire sample (g), and $m_{analyzed}$ is the summation of the mass of HGR-AC analyzed for all sub-samples (g).

During thermal decomposition of the HGR-AC, SO_2 is released resulting in pre-mature poisoning of the catalyst tube. To minimize the effect and further improve analysis economy catalyst tubes were modified by addition of ~5 g Na_2CO_3 plug and a thin layer of Na_2CO_3 (approximately 0.2 g) was added directly on top of each sample, standard, and reference material before analysis. Anhydrous $NaCO_3$ was purchased commercially (VWR International LLC. ON, CA) and baked overnight at 450 °C before use. The addition of the Na_2CO_3 aids to increase the lifetime of the catalyst.[74]

To maintain effective quality assurance and quality control, analytical and field blanks as well as continuing calibration verification (CCV) and reference standards were utilized. Clean HGR-AC was used as the analytical blank and was analyzed to confirm instrument baseline levels and performance. Samples were blank corrected by multiplying the mean field blank Hg concentration (ng $g_{HGR\text{-}AC}^{-1}$) by the mass of HGR-AC (g) in a given sample and subtracting this value from the mass of Hg (ng) found in that sample. A high sulfur, bituminous coal standard reference material, NIST 2685c (National Institute of Standards and Technology, Maryland USA) with a concentration of 149.4 ng/g of Hg as well as an in-house prepared powdered HGR-AC sorbent loaded with a Hg concentration of 34.8 ng/$g_{HGR\text{-}AC}$ (loaded carbon) were used as reference standards. Alternating reference standards were analyzed every 5-10 samples. Calibration checks were completed every 5-10 samples by alternating the analysis of 5 and 10 ng of Hg using the 0.1 mg/L calibration standard.

Samples were blank corrected by multiplying the mean field blank Hg concentration (ng $g_{HGR\text{-}AC}^{-1}$) by the mass of HGR-AC (g) in a given sample and subtracting this value from the mass of Hg (ng) found in that sample. The limit of detection (LOD) and limit of quantification (LOQ) in ng of Hg were defined as three and ten times the standard deviation of the field blanks, respectively. The method detection limit (MDL) and method quantification limit (MQL) in ng/m^3 were defined as the LOD and LOQ, respectively, divided by the temperature corrected *SR* for a given experiment multiplied by the average deployment time (days) for that experiment.

Table S3 Summary of data from stationary PASs deployed in ASGM Community 1

Sample Number	Blank Adjusted Sorbed Hg (ng)	Total Deployment (days)	Air Concentration (ng/m3)	Ratio of Air Concentrations to:	
				WHO & ATSDR MRL (200 ng/m3)	ACGIH TLV (25 000 ng/m3)
311	180	2.21	630	3.2	
312	200	2.19	700	3.5	
313	120	2.19	360	1.8	
314	210	2.19	620	3.1	
315	180	2.19	530	2.7	
316	170	2.19	510	2.5	
317	130	2.18	380	1.9	
318	120	2.18	840	4.2	
319	140	2.18	410	2.1	
320	170	2.18	1,550	7.7	0.1
321	300	2.18	900	4.5	
322	1,110	2.18	31,430	157	1.3
323	540	2.19	1,580	7.9	0.1
324	420	2.17	1,240	6.2	
325	490	2.17	1,450	7.2	0.1
326	280	2.16	840	4.2	
327	80	2.18	740	3.7	
328	250	2.16	740	3.7	
329	280	2.16	840	4.2	
330	200	2.15	900	4.5	

Table S4 Summary of data from stationary PASs deployed in ASGM Community 2

Sample Number	Blank Adjusted Sorbed Hg (ng)	Total Deployment (days)	Air Concentration (ng/m3)	Ratio of Air Concentrations to WHO & ATSDR MRL (200 ng/m3)
335	0.2	1.23	<LOD	
338	4.2	1.23	<LOD	
339	5.5	1.22	<LOQ (30)	0.2
340	67.2	1.26	360	1.8
341	30.5	1.26	160	0.8
342	9.0	1.26	<LOQ (50)	0.2
343	3.0	1.25	<LOD	
344	7.0	1.13	<LOQ (40)	0.2
345	8.4	1.12	<LOQ (50)	0.2

Table S5 Summary of data on daily exposure of participants classified by (self-reported) occupation in ASGM Community 1.

Participant Code	Job Description	Age Range	Day	PAS #	Blank Adjusted Sorbed Hg(ng)	Total Deployment (days)	Air Concentration (ng/m3)	Average Air Concentration of Multiday Participants (ng/m3)	Ratio of Air Concentration to:			
									WHO & ASTDR MRL (2000g/m3)	ACGIH TLV (25 000 ng/m3)	NIOSH REL (50 000 ng/m3)	OSHA PEL (100 000 ng/m3)
A	Digging, Washing	18+	1	175	21.0	0.25	1,090		5			
A	Digging, Washing	18+	2	197	205	0.30	9,070	14,600	45			
A	Digging, Washing	18+	3	228	765	0.30	33,770		169	1	1	
B	Student	13-15	1	209	4280	0.27	207,510	132,700	1038	8	4	2
B	Student	13-15	3	220	1400	0.32	57,850		289	2	1	1
C	Digging, Trading	18+	2	205	2530	0.30	113,480	104,300	567	5	2	1
C	Digging, Trading	18+	3	226	2170	0.30	95,060		475	4	2	1
D	Burning, Digging, Washing	18+	3	221	30.9	0.32	1,280		6			
E	Burning, Digging, Washing	18+	1	182	52.7	0.26	2,710	39,600	14			
E	Burning, Digging, Washing	18+	2	201	1700	0.29	76,530		383	3	2	1
F	Digging, Washing	18+	3	232	41.5	0.29	1,900		10			
G	Supervisor	18+	1	173	133	0.27	6,590		33			
G	Supervisor	18+	2	196	41.9	0.29	1,880	4,600	9			
G	Supervisor	18+	3	218	128	0.32	5,230		26			
H	Burning, Crushing, Digging	18+	2	210	193	0.29	8,670	217,800	43			
H	Burning, Crushing, Digging	18+	3	230	9530	0.30	426,850		2134	17	9	4
I	Drilling	18+	1	189	17.3	0.25	910	900	5			

I	Drilling	18+	2	208	19.5	0.29	900		4			
I	Drilling	18+	3	223	9.6	0.32	<LOQ (390)		2			
J	Sieving	18+	1	188	166	0.26	8,470	6,300	42			
J	Sieving	18+	2	202	91.0	0.29	4,100		21			
K	Bar Operator	18+	1	185	36.5	0.25	1,970	6,300	10			
K	Bar Operator	18+	2	198	40.7	0.29	1,850		9			
K	Bar Operator	18+	3	217	370	0.33	15,000		75	1		
L	Burning, Crushing, Digging	18+	1	184	17.0	0.25	910	12,400	5			
L	Burning, Crushing, Digging	18+	2	211	501	0.28	23,880		119	1		
M	Student	13-15	3	231	113	0.30	5,080		25			
N	Sieving	18+	1	190	96.7	0.24	5,250	2,700	26			
N	Sieving	18+	2	194	38.4	0.30	1,700		8			
N	Sieving	18+	3	216	30.1	0.33	1,210		6			
O	Sieving	18+	1	187	84.0	0.25	4,470	4,000	22			
O	Sieving	18+	2	207	106	0.30	4,700		24			
O	Sieving	18+	3	224	66.0	0.32	2,710		14			
Q	Sieving	18+	2	212	128	0.31	5,520	3,800	28			
Q	Sieving	18+	3	215	54.4	0.33	2,170		11			
R	Weaving	18+	1	186	57.3	0.25	3,050	2,300	15			
R	Weaving	18+	2	206	48.1	0.29	2,170		11			
R	Weaving	18+	3	222	42.6	0.33	1,730		9			
S	Burning, Crushing, Digging, Washing	18+	1	174	152	0.26	7,670	4,500	38			
S	Burning, Crushing, Digging, Washing	18+	2	203	27.8	0.29	1,260		6			
T	Sieving	18+	3	234	34.8	0.29	1,570		8			
U	Digging, Washing	18+	1	181	150	0.26	7,660	54,400	38			
U	Digging, Washing	18+	2	200	2,200	0.29	101,200		506	4	2	1
V	Washing	18+	1	179	31.8	0.26	1,620	36,500	8			
V	Washing	18+	2	204	1,600	0.30	71,430		357	3	1	1
W	Burning, Crushing, Digging, Washing	18+	3	233	12,000	0.30	531,350		2657	21	11	5
X	Chop Bar Operator	18+	1	192	1.2	0.25	<LOD					
X	Chop Bar Operator	18+	2	195	5.0	0.30	<LOD		1			

X	Chop Bar Operator	18+	3	219	22.9	0.33	910		5			
Y	Driver	18+	1	176	1,300	0.43	39,700		198	2	1	0
Y	Driver	18+	2	199	238	0.32	9,870	63,200	49			
Y	Driver	18+	3	229	3,260	0.31	139,910		700	6	3	1
Z	Seamstress	18+	1	183	13.3	0.28	<LOQ (620)		3			
Z	Seamstress	18+	2	213	94.4	0.29	4,250	3,000	21			
Z	Seamstress	18+	3	225	45.9	0.33	1,840		9			

Table S6 Summary of data on daily exposure of participants classified by (self-reported) occupation in ASGM Community 2.

Participant Code	Job Description	Day	PAS #	Blank Adjusted Sorbed Hg (ng)	Total Deployment (days)	Air Concentration (ng/m^3)	Average Air Concentration of Multiday Participants (ng/m^3)	Ratio of Air Concentration to WHO & ASTDR MRL (200 ng/m^3)
1	Researcher	1	243	7.4	0.41	<LOQ (240)		
2	Researcher	1	244	5.1	0.40	<LOQ (170)		
2	Researcher	2	267	0.1	0.37	<LOD		
3	Researcher	1	241	19.1	0.41	610	410	3.1
3	Researcher	2	266	5.8	0.38	<LOQ (200)		
4	Guide	1	250	4.9	0.34	<LOQ (190)		
5	Shop Attendant	1	237	1.0	0.35	<LOD		
5	Shop Attendant	2	289	0.6	0.27	<LOD		
6	Food Seller	1	258	4.4	0.30	<LOQ (190)		
7	Food Seller	1	236	3.1	0.35	<LOD		
8	Motorcycle Rider	1	239	8.3	0.30	<LOQ (360)		
9	Cocoa Farmer	1	242	7.6	0.30	<LOQ (330)		
10	Soil Carrier	1	247	1.7	0.34	<LOD		
10	Soil Carrier	2	276	0.0	0.34	<LOD		
11	Soil Carrier	1	248	17.1	0.31	730	650	3.6
11	Soil Carrier	2	275	11.6	0.27	560		2.8
12	Soil Carrier	1	252	5.0	0.28	<LOQ (240)	440	
12	Soil Carrier	2	274	15.9	0.33	640		3.2
13	Soil Carrier	1	245	6.4	0.30	<LOQ (280)		
14	Soil Carrier	1	246	3.8	0.32	<LOQ (160)		
15	Soil Carrier	1	249	2.0	0.32	<LOD		

16	Soil Carrier	1	255	0.2	0.33	<LOD		
17	Soil Carrier, Supervisor	1	254	4.1	0.28	<LOQ (200)		
18	Soil Carrier, Nursing Mother	1	253	20.1	0.37	720		3.6
19	Crushing	1	288	3.4	0.27	<LOQ (170)		
20	Digging	1	287	20.7	0.27	1,010		5.0
21	Crushing	1	286	0.6	0.27	<LOD		
22	Crushing, Digging	2	285	3.5	0.27	<LOQ (170)		
23	Shop Attendant (day 1)	1	238	0.0	0.35	<LOD		
23	Crushing (day 2)	2	284	1.2	0.27	<LOD		
24	Crushing	2	283	3.3	0.27	<LOQ (160)		
25	Digging	2	282	141	0.27	6,830		34.2
26	Crushing, Digging	2	281	0.1	0.27	<LOD		
27	Crushing, Digging	2	279	1.1	0.27	<LOD		
28	Crushing, Digging	2	278	1.0	0.27	<LOD		
29	Crushing, Digging	2	277	45.8	0.27	2,210		11.1
30	Crushing, Digging	1	257	19.8	0.28	920	1180	4.6
30	Crushing, Digging	2	273	30.9	0.28	1,430		7.2
31	Crushing, Digging	1	256	1.6	0.28	<LOD		
31	Crushing, Digging	2	272	37.4	0.28	1,730		8.7
32	Crushing, Digging	2	271	11.6	0.29	530		2.6
33	Crushing, Digging	1	260	129	0.28	6,190	3390	30.9
33	Crushing, Digging	2	270	13.0	0.29	590		3.0
34	Crushing, Digging	1	259	12.2	0.28	580	480	2.9
34	Crushing, Digging	2	269	8.2	0.29	<LOQ (370)		
35	Crushing, Digging	1	251	31.8	0.32	1,320	1780	6.6
35	Crushing, Digging	2	268	51.9	0.31	2,230		11.2
36	Crushing, Digging, Grinding	1	262	8.2	0.23	470		2.4
36	Crushing, Digging, Grinding	2	265	1.0	0.38	<LOD		
37	Crushing, Digging, Grinding	1	263	3.7	0.23	<LOQ (210)	530	
37	Crushing, Digging, Grinding	2	264	24.8	0.38	860		4.3
38	Smelting/Burning	1	240	46.5	0.36	1710		8.5

Table S7 Summary of data from stationary PASs deployed in e-waste facility

Sample Number	Blank Adjusted Sorbed Hg (ng)	Total Deployment (days)	Air Concentration (ng/m3)	Comparison to WHO & ATSDR MRL (200 ng/m3)
1	33.6	4.13	58.9	0.3
2	17.8	4.12	31.2	0.2
3	1.6	4.12	2.8	
4	1.8	4.13	3.1	
5	0.9	4.13	*1.6*	
6	2.2	4.13	3.8	
7	1.7	4.13	3.0	
9	42.9	4.14	75.0	0.4
11	184.8	4.14	322.0	1.6
12	653.8	4.14	1140.0	5.7
13A	0.8	4.07	*1.4*	
13B	1.1	4.07	*1.9*	
14	0.8	4.09	*1.4*	
15	0.6	4.08	*1.1*	
16	0.5	4.07	*0.9*	
17	1.0	4.07	*1.7*	
18A	1.7	4.07	3.0	
18B	1.7	4.07	3.0	
19	0.6	4.07	*1.0*	
20	0.6	3.88	*1.2*	

Table S8 Summary of data on daily exposure of participants classified by (self-reported) occupation in e-waste facility.

Participant Code	Age Range	Job Description	Day Participated - Sample Number	Blank Adjusted Sorbed Hg (ng)	Total Deployment (days)	Air Concentration (ng/m^3)	Average Air Concentration (ng/m^3)	Comparison to WHO & ATSDR MRL (200 ng/m3)
1	40+	Plant Operator – Alternates between operating machines and sorting waste each day	1 - Y11	12.8	0.50	380	2,120	1.9
			2 - Y12	85.6	0.33	3,850		19.2
2	40+	Excavator Operator – Alternates between operating machines and sorting waste each day	1 - Y21	2.7	0.50	80	970	0.4
			2 - Y22	61.1	0.33	2,750		13.7
			3 - Y23	1.8	0.34	80		0.4
3	18-39	General Employee – Sorting	1 - Y31	7.1	0.50	210	700	1.1
			2 - Y32	35.7	0.34	1,590		7.9
			3 - Y33	6.9	0.34	300		1.5
4	40+	General Employee – Sorting	1 - Y41	13.9	0.34	620	930	3.1
			2 - Y42	28.1	0.34	1,250		6.2
5	18-39	General Employee – Sorting	1 - Y51	16.6	0.30	850	2,050	4.2
			2 - Y52	74.5	0.34	3,250		16.3
6	18-39	General Employee – Sorting	1 - Y61	17.3	0.30	880	1,250	4.4
			2 - Y62	35.3	0.35	1,500		7.5
			3 - Y63	31.0	0.34	1,380		6.9
7	18-39	Operations Manager – Drives a truck which transports shredded waste	1 - Y71	2.2	0.42	80	120	0.4
			2 - Y72	1.6	0.35	70		0.3
			3 - Y73	4.8	0.33	220		1.1
8	40+	Accounts Officer – Finances, not involved directly with waste recycling	1 - Y81	0.0	0.32	<LOD		
			2 - Y82	0.0	0.31	<LOD		
			3 - Y83	0.0	0.28	<LOD		