Umezaki M, 2 Oct 2012

Environmental Research 111 (2011) 463–467

Multiple metals exposure in a small-scale artisanal gold mining community

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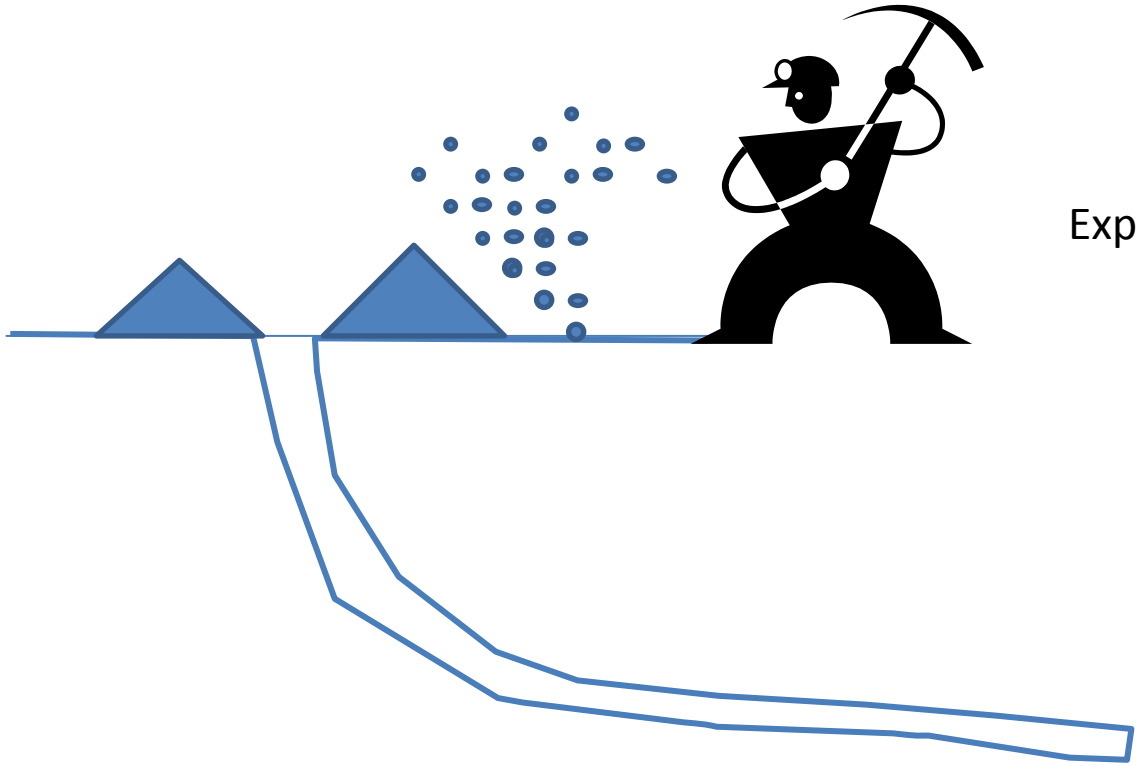
ABSTRACT.
Urinary metals were characterized in 57 male residents of a small-scale gold mining community in Ghana. Chromium and arsenic exceeded health guideline values for 52% and 34%, respectively, of all participants. About 10–40% of the participants had urinary levels of aluminum, copper, manganese, nickel, selenium, and zinc that fell outside the U.S. reference range. Exposures appear ubiquitous across the community as none of the elements were associated with occupation, age, and diet.

Health concerns in small-scale gold mining (SSGM) communities

- Dust, noise, lack of protective gear, mercury vapor



Exposure to toxic elements?

Miners
Non-miners

Exposure to toxic elements in SSGM

- SSGM in Brazil: blood Pb of 57% > CDC guideline (10 µg/dL)
- SSGM in Nigeria: all children > CDC guideline
- SSGM in Ghana: Urinary As – elevated

Objectives

- to characterize exposures to several elements (Al, As, Cd, Co, Cr, Cu, Mn, Ni, Pb, Se, Zn) in the urine of male residents of a small-scale gold mining community.

- Association with occupation, diet, health, and lifestyle?

Participants and samples

- Summer 2009
- a mining community in the Talensi-Nabdam District in the Upper East region of Ghana.
- 57 males (self-selection)
- 20-50 ml urine (-20 ℃)

Metals analysis

- Al, As, Cd, Co, Cr, Cu, Mn, Ni, Pb, Se, Zn
- ICP-MS
- Quality control: INSPQ; QMEQAS09 urine (ref)
- Analytical detection limit: 3 SD of blank

Reference range for urinary elements

- non-exposed U.S. populations (Paschal etal.,1998; Komaromy-Hiller etal.,2000).

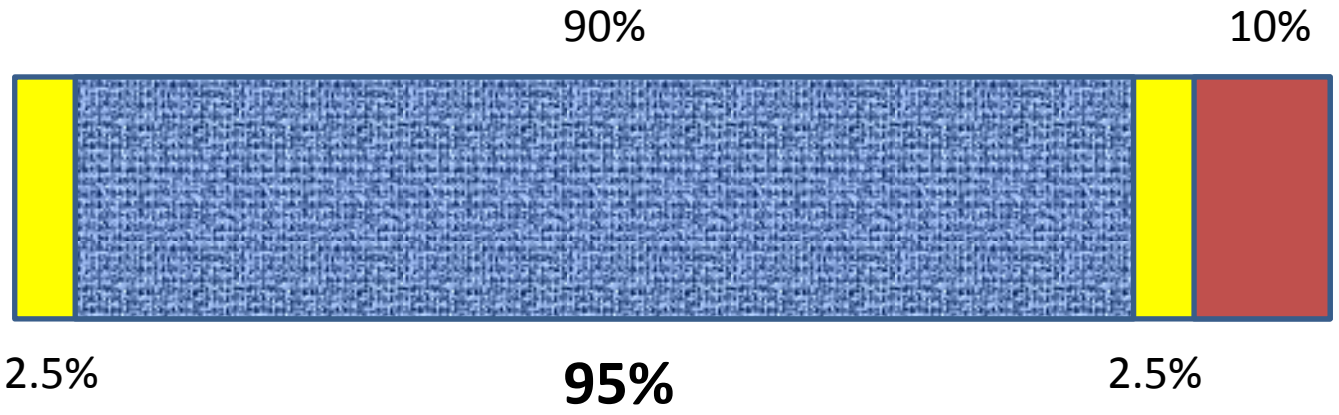


Table 1

Means and selected percentile of urinary elements (μg/L) for the entire population. For each element the corresponding reference range (in μg/L) for the U.S. population is provided based on the work of Komaromy-Hiller et al. (2000) and Paschal et al. (1998) using the superscripted letters A and B, respectively. For added comparison, range of urinary elements is also reported from a small study of four individuals from Accra, Ghana based on the work of Asante et al. (2007).

	Geometric mean	Mean	Percentile						U.S. ref. range	Ghana ref. range
			Min	25	50	75	90	Max		
Al	16.91	21.62	4.4	10.84	17.46	27.34	40.87	109.65	0–34.0[A]	
As	94.33	114.52	11.75	73.19	100.21	135.32	223.97	354.81	0–52.2[A]	120–280
Cd	0.38	0.45	0.10	0.25	0.36	0.6	0.88	1.32	0–1.0[A]	0.3–0.4
Co	1.79	2.32	0.31	1.05	2.01	3.37	4.56	7.41	0–8.3[B]	1.6–2.2
Cr	24.17	26.58	5.73	18.69	24.65	32.23	44.15	58.59	0–3.5[A]	22–31
Cu	37.33	40.85	12.02	28.85	37.41	51.14	66.13	79.43	1.0–55.0[A]	536–708
Mn	1.16	2.01	0.33	0.6	0.91	1.73	4.29	14.45	0–3.3[B]	3.1–4.9
Ni	5.36	6.51	1.35	3.85	5.41	7.95	11.5	25.71	0–12.0[A]	
Pb	1.12	1.34	0.18	0.73	1.31	1.9	2.41	2.75	0–6.4[B]	1.0–3.1
Se	31.29	39.4	5.75	19.38	31.47	53.63	77.29	123.03	25.0–182.0[A]	47–77
Zn	437.21	601.27	87.10	207.97	476.19	892.73	1222.88	2089.30	8.0–766.8[A]	333–697

Elements that exceeded US ref range

- Cr (100%); 34% >30µg/g Cr (protect workers)
- As (87%); 52% >100 µg/L (health concern)
- Zn (40%)
- Al, Cu, Mn, Ni (10-20%)

- Se (38%) < US ref range

Table 2

Urinary elements stratified according to several variables with mean concentrations (μg/L) provided. No statistically significant differences were found for any of the variables below.

		Al	As	Cd	Co	Cr	Cu	Mn	Ni	Pb	Se	Zn
Age	19–29	17.58	104.86	0.45	1.92	26.31	37.90	2.74	4.96	1.34	555.99	31.79
	30–39	25.45	120.95	0.50	2.91	29.55	48.46	1.22	9.55	1.64	758.45	44.36
	40–49	22.70	101.25	0.32	2.16	22.43	38.53	1.94	5.22	1.18	570.00	36.36
	50–60	18.55	130.32	0.54	1.99	27.55	35.04	2.53	4.84	1.09	459.20	42.12
# Years worked	0–3	17.06	115.89	0.43	2.13	29.12	42.39	3.41	5.92	1.40	629.85	40.91
	4–10	26.68	97.58	0.43	2.13	26.77	47.67	2.01	7.87	1.54	646.77	43.55
	11–34	21.56	122.31	0.47	2.51	25.21	36.68	1.30	6.10	1.20	562.86	36.63
Education level	None	22.49	109.45	0.40	1.82	37.48	36.08	1.37	5.90	1.29	40.85	479.07
	Primary	12.16	66.07	0.31	1.64	30.69	32.89	1.58	4.27	0.75	22.34	314.05
	Secondary	18.00	96.54	0.42	1.96	31.89	42.04	1.03	5.93	1.19	29.30	532.48
	> Secondary	4.68	46.77	0.13	0.48	20.42	35.48	0.33	3.16	0.63	14.45	120.23
Mining concession site	World Bank	16.36	108.08	0.56	2.16	35.58	35.28	0.96	7.08	1.31	47.59	559.11
	Obuasi	19.13	96.36	0.37	1.78	34.69	38.02	1.40	5.64	1.19	32.07	447.94
	Kejitia	15.14	71.73	0.27	1.48	27.82	36.07	0.81	3.64	0.69	20.89	355.98
Fish consumption frequency	Never	9.05	77.03	0.28	0.94	33.11	34.67	0.88	4.20	0.81	24.55	208.93
	< 1x per week	20.54	92.84	0.38	1.64	34.91	36.80	1.47	6.01	1.25	36.23	493.80
	> 1x per week	16.81	99.37	0.39	2.20	32.56	38.58	1.03	5.08	1.01	28.21	436.52

Association with individual characteristics

- Age
- Number of years worked
- Education level
- Freq fish consumption
- Occupational groups (miners, non-miners)

→ NO

Table 3

Correlation matrix among urinary elements. Cells with an asterisk indicate elements that are significantly ($p < 0.05$) correlated. Mercury data were obtained from the study of Paruchuri et al. (2010).

	Al	As	Cd	Co	Cr	Cu	Hg	Mn	Ni	Pb	Se
As	0.32*										
Cd	0.38*	0.57*									
Co	0.24	0.26	0.37*								
Cr	0.35*	0.70*	0.69*	0.41*							
Cu	0.14	0.44*	0.41*	0.26*	0.64*						
Hg	0.00	0.15	−0.16	0.08	−0.08	−0.12					
Mn	0.35*	0.00	−0.05	−0.02	0.01	−0.03	−0.08				
Ni	0.40*	0.43*	0.60*	0.62*	0.68*	0.57*	−0.16	−0.02			
Pb	0.52*	0.51*	0.57*	0.38*	0.61*	0.45*	−0.05	0.05	0.64*		
Se	0.42*	0.67*	0.68*	0.25	0.79*	0.48*	−0.05	−0.02	0.58*	0.67*	
Zn	0.51*	0.46*	0.56*	0.51*	0.61*	0.45*	0.15	0.09	0.64*	0.73*	0.67*

%variation explained =68.2%

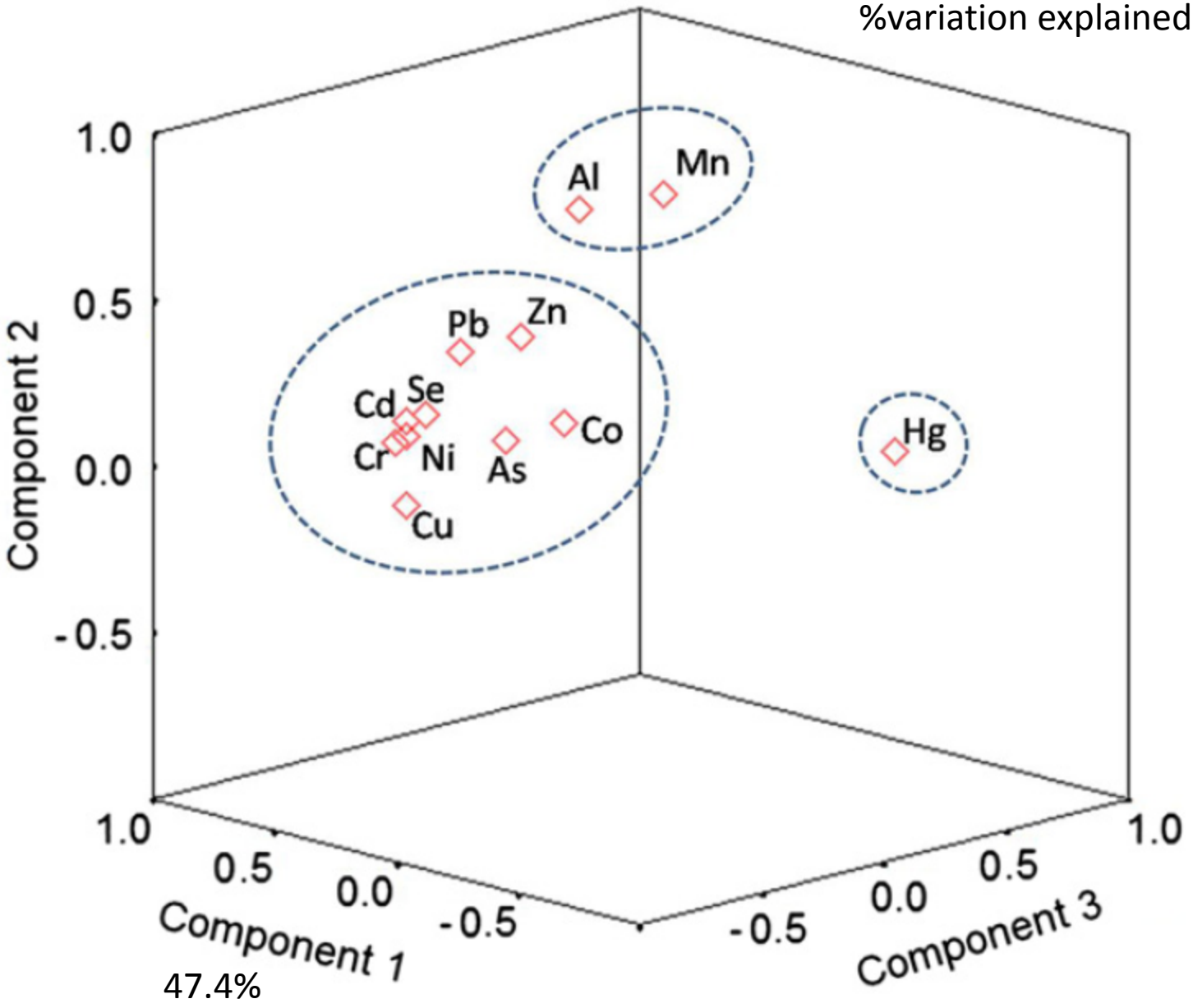


Fig. 1. Principal component analysis of urinary elements. Three grouping are apparent: (a) mercury; (b) aluminum and manganese; and (c) all other elements.

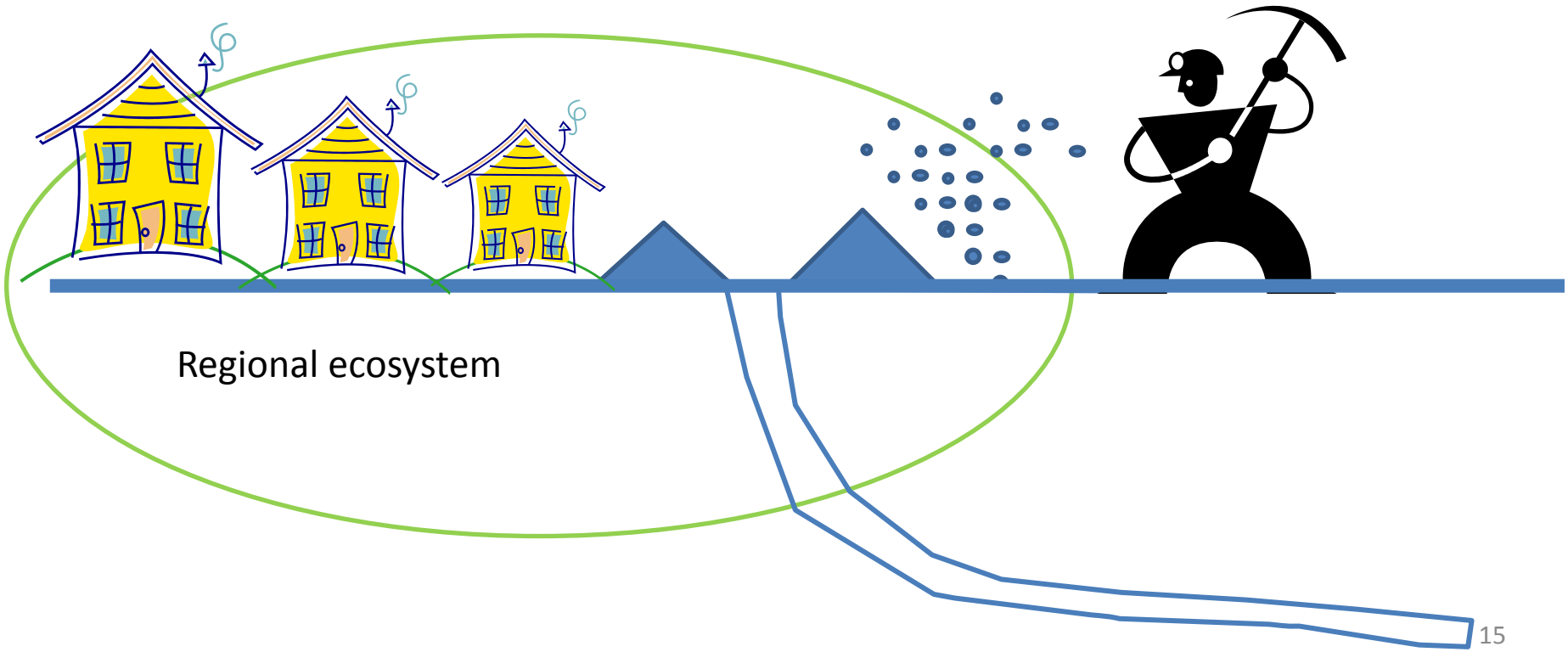
Discussion

Mercury exposure in the target region (Paruchuri et al., 2010) :

5%: high level of U_Hg >50µg/L (WHO guideline）

The highest levels in the mining sector

(←→ findings of the current study)



Discussion

Elevated U_Al

～self reported neurological and visual problems?

Low U_Se

～mercury toxicity↑　？

Elevated As and Cr

～carcinogens (ATSDR, 2007, 2008); different toxicity by chemical forms

Discussion

SSGM communities

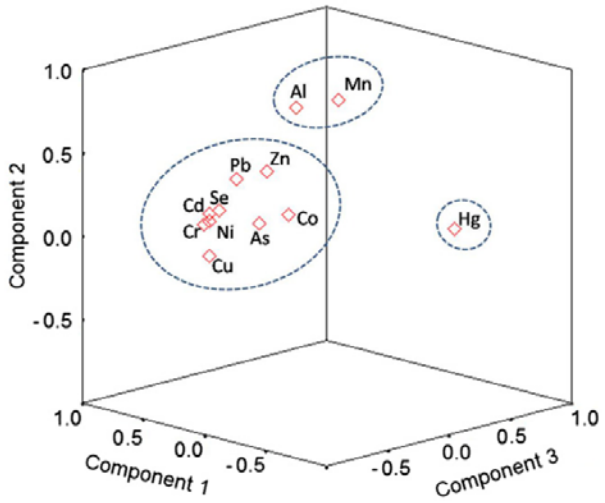


Fig. 1. Principal component analysis of urinary elements. Three grouping are apparent: (a) mercury; (b) aluminum and manganese; and (c) all other elements.

Hg exposure: preventable by occupational and environmental routes

The other elements: methods for prevention unknown

Action for 100 million people depends on SSGM