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Assessing releases of mercury from small-scale gold mining sites in Ghana

Martin J. Clifford

Department of Geography, Pearson Hall, University of Delaware, Newark, United States

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ABSTRACT

The small-scale gold mining sector has been and continues to be identified as a major source of mercury contamination. Although many studies have assessed the human and ecological health impacts of mercury emissions in the vicinity of small-scale mining operations, only a handful have surveyed the source of the contamination: the sites themselves. This paper reports findings from an environmental analysis undertaken directly within three small-scale gold mining sites in Ghana. Using targeted soil and water sampling analysed through mass spectrometry, the findings are compared with findings in the literature and safety guidelines to gauge the scale of contamination at surveyed sites. The analysis reveals that there is widespread pollution, often several orders higher than background levels. Expanding upon this, the results are extrapolated to provide estimates for mercury emissions accountable to the artisanal mining sector for Ghana as a whole.

1. Introduction: mercury, artisanal and small-scale gold mining and the Minamata Convention

The artisanal and small-scale mining sector is estimated to employ in excess of 25 million people (Hruschka and Echavarria, 2011) across 50 countries worldwide. Its workforce is engaged in the extraction of a diverse range of minerals. Gold is the most widely sought commodity by artisanal miners owing to its relatively ubiquity and high value-to-weight ratio. An extremely buoyant world gold price, in combination with widespread poverty and wider socio-economic and political instability, has stimulated the sector's rapid growth worldwide. The sector has grown to the extent that it now contributes an estimated 20–30% of total global gold production (Veiga et al., 2006).

Artisanal gold prospectors almost exclusively use elemental mercury (locally referred to as 'med') to extract gold. Although efficient (Teschner et al., 2017), mercury can have numerous wide-ranging deleterious effects on humans, biota and the environment even at levels marginally exceeding naturally occurring 'background' limits (WHO, 2003; Clifford et al., 2010; Clarkson, 2002). It is estimated that between at least 1 and 2 grams of mercury is lost to the environment for every gram of gold that is produced (Veiga and Baker, 2004). With next to no technology in place to recover mercury used in refining gold, the vast percentage is emitted into the environment. The United Nations Environment Programme (UNEP) estimates that ASM now constitutes the largest 'intentional use' of mercury worldwide. It consumes and emits between 640 and 1350 tons of mercury per year, around one third of all anthropogenic emissions (UNEP, 2013).

An extensive body of research spanning some 40 years has drawn attention to how the growth of ASM has been responsible for increased mercury contamination (e.g. Martinelli et al., 1988; Malm et al., 1990; Lacerda et al., 1991; Lin et al., 1997; Marrugo-Negrete et al., 2008; Olivero-Verbal et al., 2016; Gibb and O'Leary, 2014). This body of literature has also helped to raise awareness of the impacts of mercury and legitimise its seriousness as a global environmental concern (see Pacyna et al., 2016; Nriagu 1994; Swain et al., 2007; UNEP, 2008, 2013). Mercury pollution is now on the radar of a number of development organisations, which have committed to remediating environments left contaminated by artisanal and small-scale gold miners. Local interventions made by bilateral donors[1] with the support of small grants from the likes of the United Nations and European Union, would pave the way for the Global Mercury Project, a three year, multi-agency initiative which operated across several countries.[2] The work carried out

[1] Such as the development agencies of Germany in Ghana (see Hilson and Clifford, 2010), Denmark in Tanzania and others (see GEUS, 2008) and Canada in Guyana (see Hilson and Vieira, 2007), for example.

[2] See https://unites.uqam.ca/gmf/intranet/gmp/front_page.htm for more information.

E-mail address: martinjc@udel.edu (M.J. Clifford).

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under the auspices of this project, however, has failed to reduce mercury emissions significantly. The author, like many other researchers, has reflected critically on why, to date, this has proved so elusive (see Clifford, 2010, 2014).

The most recent and certainly most far-reaching effort made to date to address the problem is the Minamata Convention on Mercury, an international agreement, ratified in 2013 by 128 countries, which seeks to stimulate a reduction in global mercury emissions from a wide range of sources. Quite understandably, ASM is highlighted within the Convention as a particular area of concern. Each signatory country with 'more than significant' artisanal gold mining activity is required to formulate and submit a 'national action plan' outlining the steps they propose to take to tackle mercury pollution in the sector. The Convention was adopted in October 2013 and the aforementioned plans were scheduled to be drafted within three years. It is likely that many signatory countries with notable ASM activity will find drafting and implementing such plans extremely challenging because of a lack of vital baseline data, coherent strategies, and resources to tackle mercury pollution in the sector (Sippl, 2015). However, the Minamata Convention has catalysed a renewed wave of research aimed at gathering additional information about mercury pollution in the ASM sector and proposing ways to tackle the problem (see, for example, Porgo and Gokyay 2017; Fritz et al., 2016; Bose-O'Reilly et al., 2016), including Ghana (Basu et al., 2015a, 2015b; Rajaee et al., 2015a). This paper helps to address 'the substantial gaps in data availability' (Rajaee et al., 2015a: 8974) in this area, drawing on experiences from Ghana.

2. The case of Ghana: context, previous work and an estimate of mercury emissions from ASM

Ghana, famous for the abundance of its gold, is home to an estimated 500,000 to 1,000,000 small-scale gold miners. According to the Ghanaian Minerals Commission, the chief government body in the country responsible for policymaking in the mining sector, these operators extracted 39,642,782 oz of gold from 1980 to 2008 and contributed almost of quarter of national production in 2010 (Tetteh, 2010). Following the $Au^{PRODUCED}$:Hg^{LOST} ratio of 1:1 to 1:2 cited above, processing of this gold released an estimated 1123–2246 tons of mercury into the natural environment. The 2,796,834 oz. (79 tons) of gold produced in the year 2008 alone was responsible for the release of an estimated 79–158 tons of mercury. These figures are of serious environmental concern, especially when considering that estimates of 640–1350 tons have been given as the worldwide total of mercury emissions from ASM (UNEP, 2013).

Ghana has been a focal point of research on ASM for many years. It has attracted significant research on mercury in particular, work which has sought to provide an idea of the scale of contamination and impacts of the sector on surrounding communities and natural environments (e.g. Mensah et al., 2012; Ahiamadjie et al., 2011; Babut et al., 2003; Bonzongo et al., 2003; Golow and Adzei 2002; Golow and Mingle 2003; Paruchiri et al., 2010; Rambaud et al., 2000; Rajaee et al., 2015a). Surprisingly, however, studies which have looked specifically at the pollution of soils and waterbodies found within the direct catchment areas of the country's ASM sites are in short supply. Most research carried out on mercury contamination in the country has focused on communities adjacent to those supporting mining activity (e.g. Ahiamadjie et al., 2011; Golow and Adzei 2002; Golow and Mingle 2003; Amonoo-Neizer et al., 1996). Data collected from within the boundaries of sites themselves (e.g. Paruchuri et al., 2010) would certainly yield a more complete picture of the problem. Such findings have long served as important reference points in the ASM-Hg literature.

3. Criteria assessed

Veiga and Baker (2004), who offer a set of *Protocols for Environmental and Health Assessment of Mercury Released by Artisanal and Small-Scale Gold Miners*, list four different ways in which analysis of soil and water may be used for substantiating mercury contamination at artisanal gold mining sites (Table 1): identifying 'hotspots', estimating total mercury releases and assessing water quality against guidelines for drinking and protection of aquatic life. These are discussed further below (with the two water-related methods being placed together) and their implementation elaborated upon in Section 4.

3.1. Identification of mining and environmental 'hotspots'

'Hotspots' are areas which have extremely high mercury concentration. They are defined by Veiga and Baker (2004) as having levels 100 times higher than what could be considered naturally occurring. Their existence is owed largely to current and/or pre-existing artisanal gold mining activity. Identifying terrestrial hotspots at active mine sites is a relatively simple procedure, consisting of sampling locations where miners amalgamate gold, and analysing these for total mercury content. This strategy formed the first strand of the research: soil and water collected from mining sites was analysed and compared with relevant literature to determine the severity of contamination.

3.2. Estimating mercury releases

Estimating emissions of mercury from ASM operations is, as Veiga and Baker (2004: 37) explain, a 'crucial' part of any assessment of the impact small-scale mining has in a locality. Obtaining an estimate involves collating direct and indirect data on issues such as the quantity of mercury being introduced and recovered at each stage of processing (through weighing at each point), purchases of mercury over a period of time, gold production figures, and the mercury content of amalgam and tailings, to

Table 1
Use of soil and water analysis in assessing environmental impacts of mercury use in ASM.

Subject	Purpose	Material Sampled	Technique
Identification of mining & environmental hotspots	Apply remedial procedures depending on bioavailability	Superficial soil and bottom sediments	Hg analysis (semi or quantitative) or panning for visual inspection
Estimate Hg releases	Estimate the relevance of Hg released by ASM in the region	Hg introduced and recovered; Hg lost in amalgam, tailings, etc.	Hg_{lost}: $Au_{produced}$ ratio estimation through Hg balance in ASM operations
Drinking water guidelines	Determine quality to meet guidelines; resolve health issues	Filtered and unfiltered water	Total Hg analysis
Protection of aquatic life guidelines	Determine contamination to meet guidelines	Filtered and unfiltered water	Total Hg analysis

Taken from Veiga and Baker (2004).