BRIEFING NOTE

ASGM on the African Continent

(i) An updated estimate of gold production and mercury emissions
(ii) Which **Mercury Abatement Strategies** are effective?

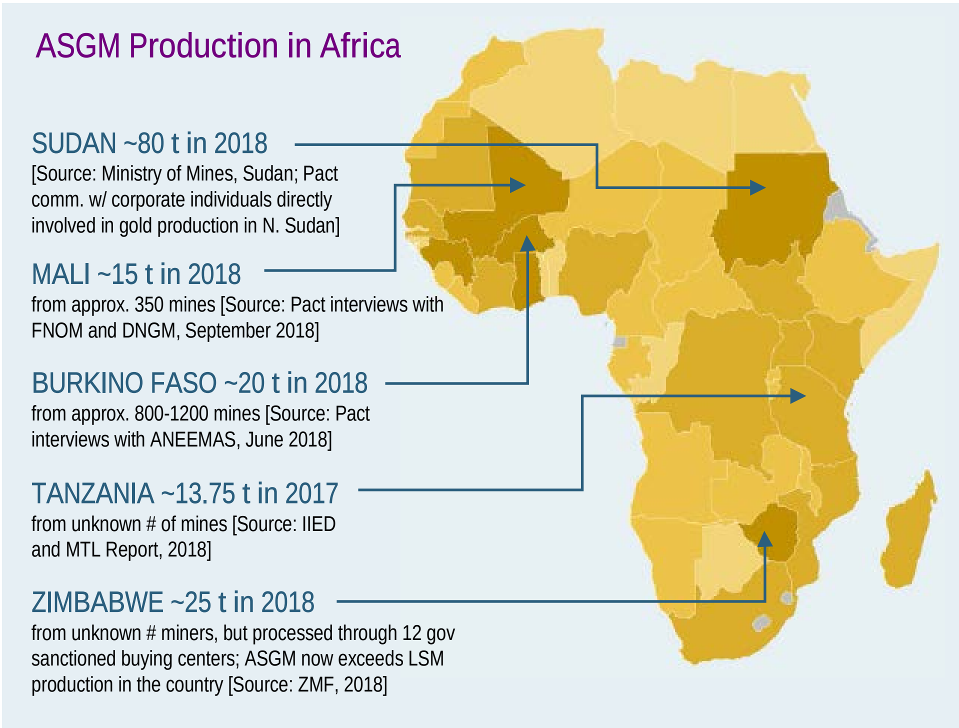
(i) *Regarding 'An Updated estimate of gold production and mercury emissions from the African Continent'*

Despite rises and falls in the price of gold (Au) over the past decade, production by Artisanal and Small-scale Gold Miners (ASGM) in Africa has surged, providing mining populations with rural income diversification, economic resilience, poverty alleviation, and opportunities for SME development. ASGM exists in nearly every country on the continent, and evidence of production increases are not hard to find, despite miners (and trader's) reluctance to share information regarding production and trade quantities. Key enablers for increased production have included an increase in semi-mechanized mines, as well as increase in processing sites using cyanide (Cn) which enable operators to reprocess tailings with little effort, and to exploit lower grade gold deposits. Unfortunately these operations come with grave health and environment risks including mobilizing mercury (Hg) present in tailings from ASGM operations, that are re-processed with Cn.

Following the work of Telmer and Veiga (2009)[1] which highlighted the significance of global mercury emissions from ASGM, Seccatore et al. (2014)[2] indicated that up to 90 tonnes (t)[3] of ASGM gold might be produced in Africa annually. However, many of the individual country estimates used by Seccatore et al. were based on outdated statistics. Since 2014, production estimates have improved as a result of gold supply-chain studies and increased government engagement in the sector: Zimbabwe, Sudan, Tanzania, Mali and Burkina Faso are notable examples. Recent production references from these countries provide a snapshot of the surge in ASGM production over the past decade, as shown in the figure below.

The intention of this briefing note is not to provide an authoritative estimate of ASGM production, but rather to contextualize the sector in 2018. Minamata Initial Assessment Reports may provide data to improve estimates provided here.

≥15 t
≥ 5 t
≥ 1 t
Evidence of ASGM
No evidence of ASGM



Several organizations have undertaken supply chain analysis of ASGM production and trade networks[4] which have indicated Dubai as a destination point for a large portion of African ASGM gold. Recently however, buyers in Turkey, Italy, Switzerland, India, China and elsewhere are increasingly competing for this gold supply.

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[1] Telmer and Veiga, 2009. "World Emissions of Mercury from Artisanal and Small-Scale Gold Mining" in Mercury Fate and Transport. Springer.
[2] Seccatore et. al., 2014. "An estimation of the artisanal small-scale production of gold in the world". Science of Tot Env 496 (2014) 662–667.
[3] A tonne is equal to 1000 kg, also known as a Megagram (Mg). In Nov. 2018 the international value of 1 t of gold is ~39 M USD.
[4] Alliance for Responsible Mining (ARM). 2018 "Supply Chains of Artisanal Gold in West Africa"; Levin Sources. 2017. "Follow the Money: Financial Flows linked to Artisanal and Small-Scale Gold Mining in Sierra Leone"; McQuilken. 2018. "Small scale mining and production networks in sub-saharan Africa" (PhD Thesis).

UAE import statistics[5] indicate >500 t of gold was imported from African sources in 2016, with an international value of over 19 B USD dollars. While this staggering import figure clearly indicates the economic significance of Au production in Africa, it remains unclear how much of this is from large scale mining, versus ASGM, or recycled & other trade.

DELVE
a global platform for ARTISANAL & SMALL SCALE mining data

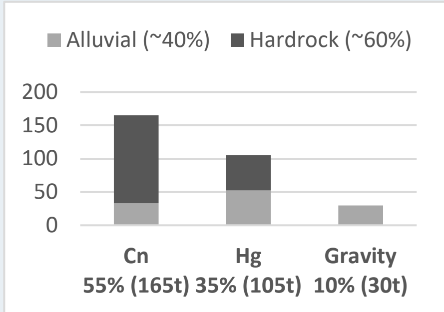
BOX 1: The lack of reliable data in ASGM is a huge challenge which is being addressed by the Delve Platform: a collaborative data sharing network.

Despite large uncertainties in production which remain, an updated conceptual model of 2018 ASGM production on the African continent is presented here. The model is based on production estimates from: 19 high-producing countries for which multiple citations (2015 or younger) have been used to triangulate a 2018 production estimate[6]; and an additional 26 countries for which evidence for ASGM exists, and estimates are based on conservative increase factors to previously published production estimates[1], or given baseline estimates of 0.1 t. The model indicates 2018 ASGM production on the African continent of 250-350 t/a (median estimate 300 t). For reference, the large-scale mining sector in Africa produced roughly 600 t in 2017 (19% of official global production[7]).

ASGM population estimates (past and present) continue to vary widely, and a tendency exists to over-estimate the workforce responsible for gold production. For example, the previous synthesis of African ASGM population estimates[1] sums to 9.7 million workers. Even considering the drastic expansion in Au production over the past decade, a cursory economic analysis reveals this figure to be an over-estimate. We postulate an ASGM workforce (all actors involved in production through to export) ranging between 5 and 7 million workers (median estimate 6 M), also noting that a high proportion of the miners in this workforce also find employment in alternative livelihoods such as farming, especially during the wet season and at harvest time. With production of ~300 t of gold in 2018, the *averaged net income* earned per workforce individual is $1,460 USD per year[8], which amounts to ~$7.30/day[9], but of course production and profits are not distributed equally: many workers make 1-2 dollars/day while mechanized operators and bosses earn much more.

The gold can be grouped in 3 categories based on how it is produced: using cyanide (Cn); using mercury (Hg); or gravity-only (in many alluvial regions, gold grains are sufficiently coarse to enable gravity concentration alone). In several of the largest-producing ASGM countries including Zimbabwe, Tanzania, and Burkina Faso there is evidence that Au production from cyanidation has eclipsed Au production by Hg amalgamation, while in other ASGM countries including Mali, DRC, and Sierra Leone cyanidation has not (yet) been widely adopted. Based on the strong trends in mechanization and Cn use observed by Pact, we postulate that ~55% of current ASGM production in Africa results from cyanide leaching (165 t), while ~35% is from Hg amalgamation (105 t), and ~10% is produced by gravity-only (30 t). These proportions are based on a 'best-guess' assessment, drawing from observations in multiple ASGM regions, and discussions with numerous traders and gov officials working in ASGM. It may be that the Cn:Hg:Gravity proportions (Africa-wide) are closer to ~30% Cn (90 t), ~50% Hg (150 t), and ~20% gravity (60 t). This distribution is used in the present model to provide a hypothetical upper-limit (estimate) of Hg consumption.

BOX 2. ASGM PRODUCTION (t) in 2018



Box 3. Mechanization in ASGM

Several countries in Africa have seen a strong trend towards semi-mechanization and proliferation of cyanide (vat-leach) operators. Pact photos at right, from Nigeria and Burkina Faso, in 2018.



Four (4) methods for estimating Hg consumption in ASGM are described in the UNEP ASGM Assessment Toolkit[10]. Due to reasons including variability in Hg behaviors, secrecy of Hg trade, and uncertainty in ASGM populations, deriving Hg consumption estimates based on gold production (which can be constrained more readily) is the preferable method for deriving national and continental level estimations.

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[5] UN Comtrade database, UAE official 2017 reported import of 'Gold, unwrought or in semi-manufactured or powder forms'
[6] All references used are 2015 or younger. Ghana, Sudan, Zimbabwe, DRC, Burkina Faso, Madagascar, Mozambique, Tanzania, Mali, Central African Rep., Sierra Leone, Nigeria, Uganda, Ethiopia, Kenya, Liberia, Senegal, Burundi, Ivory Coast, and Niger. (Pact has Journal Publication of this data in press)
[7] World Gold Council production statistics for 2017, from https://www.gold.org/goldhub
[8] Based on Nov 2018 international gold price at ~$39,000/kg, and assuming the total costs of production and trade amount to 25% of the international product value (ie. the ASGM workforce, after production costs, earns 75% of gold value, at international price)
[9] Based on a 200 work days per year, for the average ASGM worker
[10] Artisanal Gold Council (AGC) and United Nations Environment Program (UNEP) ASGM Baseline Toolkit, 2017

Based on observations of mercury amalgamation by Pact during 2018 in Nigeria, Kenya, Zimbabwe, Mali, Burkina Faso, DRC, and Ghana, most Au production networks (that Pact has visited) practice 'concentrate amalgamation'. While there are locations where 'whole-ore amalgamation' (WOA) is used, this practice is much less common. Measurements made by Pact using portable weigh scales, during 'concentrate amalgamation' indicated consumption ratios between 0.8Hg:1Au and 1.2Hg:1Au, with an average of 1Hg:1Au (consumption ratio is the mass ratio of Hg consumed to Au produced, as per the methods prescribed in UNEP Mercury Assessment Toolkit). Pact observed WOA operations in Shurugwi, Zimbabwe in Aug. 2018 and measured consumption ratios of 3Hg:1Au, however other ASGM hotspots where Pact is active in Zimbabwe (Kwekwe, Zvishavane, Gwanda, and West Nicholson) practice 'concentrate amalgamation' and Cn leaching. These Hg:Au ratios are in general agreement with preliminary results from MIA Hg Assessments[11] in DRC, Eritrea, and Sierra Lione[12].

Thus, we postulate here that an average Hg consumption ratio of 1.5Hg:1Au, can be used to estimate mercury consumption by Hg amalgamation, Africa-wide. This ratio is derived based on concentrate amalgamation (average 1Hg:1Au) methods (which are more common, based on Pact's research) producing 3 times more gold than WOA methods (average 3Hg:1Au), Africa wide. Note that the ASGM mercury consumption estimate of Seccatore et al. (2014) used an Africa-wide mercury-to-gold ratio of 8.5 to 1. This extremely high Hg consumption ratio was derived based on observations at WOA sites in Burkina Faso with enormous Hg consumption (70Hg:1Au), however metadata on these measurements was not provided.

On this basis, we postulate that approximately 158 t of mercury will have been consumed Africa-wide in 2018 (105 t x 1.5). This 'best-guess' estimate can be considered conservative (ie. a minimum estimate). To derive a hypothetical upper-limit estimate, we suppose the Cn:Hg:Gravity proportions (Africa-wide) are ~30% Cn (90 t), ~50% Hg (150 t), and ~20% gravity (60 t), and that the averaged Hg:Au ratio could be as high as 2 parts Hg to each part Au (when averaged Africa-wide between WOA and concentrate amalgamation). On this basis the hypothetical upper range estimate for mercury consumption is 300 t (150 t x's 2). This estimate (range) is lower than the UN's Hg estimate of ASGM in Africa. UNEP's 2017 'Global mercury supply, trade and demand'[13] postulated Hg consumption in African ASGM in 2015 of 196-535 t, with a mean estimate of 366 t. Thus, the Africa-wide ASGM model presented here provides a more constrained estimate, that is roughly 80% of the UNEP estimate at the minimum (158 t *conservative estimate* verses UNEP *minimum-threshold estimate* of 196 t), and 55% of the UNEP estimate at the upper bound (300 t verses UNEP estimate of 535 t). This difference is not a result of ASGM Hg consumption decreasing since 2015 but instead is due to different methods of deriving ASGM Hg estimates. The estimated 158 t of mercury has an (official) international value of 11.7 M USD (Nov. '18 price of $75/kg) but the Hg value on the ground at mine level, which arrives through illegal channels which supply ASGM, can be up to 3 x's higher[14].

What is the fate of this mercury? Based on ASGM studies in peer-reviewed literature[15] approximately 55% (87-165 t) will have been deposited to land sources as tailings, and to the landscape and water bodies nearby amalgamation activities; while 45% (71-135 t) will have been released to atmosphere resulting in longer distance transport. Little work has been done to provide human health testing of Hg-affected populations in Africa, and attention to this task is urgently needed.

BOX 4. NITRIC ACID is used extensively in refining ASGM gold produced from <u>both</u> cyanide and mercury. In Harare, Pact learned of dramatic increases in the sale of concentrated nitric acid by a chemical distribution company. On the same trip, we visited gold buying centers where nitric acid effluent from the refining process (with high concentrations of dissolved metals) was being discarded directly into urban drainage systems, without treatment. Sadly, this practice is very common in ASGM. The mismanagement of ASGM waste streams including nitric acid effluent, is an issue with serious environmental and health implications, and potential public health linkages such as cancer, metal poisoning, and threats to municipal water systems. Waste management in ASGM should be a high priority for NAP action plans.

(ii) *Regarding 'Which mercury reduction strategies are effective?'*

The Minamata Convention aims to reduce mercury emissions from ASGM which is the largest anthropogenic 'direct-use' source of Hg emissions to the global environment. The convention provides a call-to-action which has resulted in mining associations eager for viable alternatives to mercury processing which meet the needs of miners. The sobering fact remains that mercury is the most cost-effective method for gold extraction in ASGM: it is cheap; quick and simple; cost-effective relative to the service it provides; provides a method for independent processing; and its' efficacy is difficult-to-beat in terms of Au recovery when compared (on a per-cost basis) with Hg-free processing[16].

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[11] Per comms. Of the author with personnel directly involved in ASGM Hg assessments
[12] Sierra Leone EPA, 2018. 'ASGM Overview of Sierra Leone'. Environment Protection Agency. Freetown, Sierra Leone
[13] UN Environment, 2017. 'Global mercury supply, trade and demand' country estimate for 2015 in Table 21
[14] Price at mine level for Hg in 2018: $8.55/100g (Nigeria in June), $20/100g (DRC in Feb.), $35/100g (Zim. in Aug.) [intern. price Nov 2018 ~$7.50/100g]
[15] Body of research summarized in UNEP Global Mercury Assessment, 2013: Sources, Emissions, Releases and Environmental Transport
[16] Teschner et. al 2017. 'How efficient are they really? A testing method of small-scale gold miners' gravity separation systems. Minerals Engineering.

Two decades of international development efforts and interventions focused on Hg awareness and abatement have shown that Hg use is very difficult to eradicate from ASGM production networks characterized by informality. In this context, a critical assessment of these interventions is necessary in order to avoid pitfalls of the past and draw attention to the most impactful success stories. Primary barriers to mercury reduction usually result from the *cost-of-business* for ASGM groups, and from the gold buying structures (business models, business interests) which provide Hg and cash to miners and processors, for their gold. Individuals that use Hg for processing have few economically viable options to get cash for their gold (which they often require on a daily basis). The cost burden for shifting to Hg-free methods cannot be shouldered by this economically marginalized group. Sourcing models that deliver cash to miners for Au produced without Hg, are needed.

Government task forces across Africa and the world, with the assistance of international agencies and organizations, are presently developing National Action Plans to the Minamata Convention, which will activate strategies for reducing Hg in ASGM production networks. Increasing awareness of health risks and imploring safer Hg use must be prioritized. It will be critical that interventions find *inclusive* ways to engage miners and mine operators, co-ops and associations, chambers of mining, and investors who are directly responsible for the current surge in gold production. Solutions must be inclusive of traders and aggregators as these actors fulfill critical roles in production networks, including financing miner groups and providing goods and services which ASGM communities rely upon. Equipment manufacturers and distributors are another stakeholder group which must be at the table.

There is increasing consensus that behavior changes are more likely to arise from inclusive co-operation and business supports in ASGM supply chains, rather than mercury-bans or policing and enforcement strategies. While it is understandable that countries signatory to the convention are planning to ban the use of mercury in ASGM, it will be critical that NAP strategies (i) advocate and implement SAFER mercury use interventions (ex. ensuring ASGM mercury users understand the inhalation exposure pathway, and take protective measures); and (ii) test, develop, and incentivize alternative options to mercury and make accessible to ASGM workforce.

BOX 5. CYANIDE. Under which conditions is cyanidation preferable to Hg amalgamation? Should NAP strategies advocate cyanidation as a preferred alternative to Hg amalgamation, for small-scale operators and investors moving towards mechanization? In many districts, cyanide operators are processing tailings from ASGM that have previously been processed by Hg amalgamation and this constitutes a worst practice which mobilizes Hg into hydrological systems. How can governments and NAP stakeholders ensure that cyanide is used responsibly? How can the International Cyanide Management Code, and related stakeholders including mining companies contribute? Numerous learnings on this subject are available from South American case studies where small-scale cyanide operations are further developed, as compared to ASGM production networks in Africa and Asia. Key learnings on this subject will be consolidated in Pact's forthcoming report, described below.

Solutions for mercury reduction are emerging. Premium gold market solutions such as FairMined™ and Fairtrade have shown promise, but the level of engagement required to meet OECD's seminal due-diligence guidelines[17] and the costs of segregated supply chains (for traders and refiners) are major challenges which impede scale-up. •The AGC has developed and is piloting a '2kg business model' for site-level engagement and investment with ASGM producers in Burkina Faso, which uses a 'hub-and-spoke' processing model, has shown very promising outcomes. •Pact's recent work in Nigeria has included prototyping of Hg-free production with locally fabricated forges for 'direct-smelting', and the prototype is progressing to a second stage in early 2019 with a business model that provides access to shaking tables for improving concentration. Gold traders are pre-financing miners for the purchase of mineral concentrates on a weekly basis, and those concentrates are then processed at aggregation point (gold buying center) where Hg-free technology will be employed. •The CRAFT Standard[18] conceived by ARM holds potential as an inclusive standard for engaging ASGMs on the road towards responsible and formalized (legal export) production. Pact is presently developing a CRAFT 'scheme' with support from ARM to pilot the tool in African ASGM production networks. In spring 2019 Pact will publish a report expanding which will highlight key learnings from case-studies on mercury abatement initiatives in South America, Africa and Asia. The report represents the culmination of a Pact-led research study undertaken in 2018 to consolidate mercury interventions with supporting contextual data regarding whether mercury reduction was achieved and sustained afterwards. It will include a discussion of ASGM sourcing models: a key thematic area for pilot projects aiming to ensure that Hg-free processing facilities are accessible and incentivized.

Pact is soliciting reviewers of a first draft, scheduled for release in January 2019. Interested parties are requested to contact the author, and Pact's Gold Program Officer Daniel Stapper, by email to dstapper@pactworld.org

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[17] OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas, Supplement on Gold, Second Edition (2012). www.oecd.org/fr/daf/inv/mne/mining.htm

[18] CRAFT Code v1 was published in August 2018. Refer to http://www.responsiblemines.org/en/our-work/standards-and-certification/craft/