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Opportunities and risks of small-scale and artisanal gold mining for local communities: Survey evidence from Ghana☆

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ABSTRACT

The surge in artisanal and small-scale gold mining (ASGM) has led to negative environmental outcomes particularly due to the widespread use of mercury. We use a unique sample of 387 mining-site and non-mining site respondents in eight mining districts in Ghana to understand mining communities' views on the local opportunities and risks that ASGM brings – with a particular focus on mercury use and other environmental issues – as well as on the recently lifted nationwide ban on ASGM. We find that local communities have a favorable view overall of the local impact of ASGM, but negative effects are also identified, with environmental problems being prevalent and ASGM seen as the main cause of environmental issues — even by the miners themselves. Mining-site respondents did not support the ban on average, while residents from nearby settlements supported it. Knowledge about mercury use and its dangers was mixed, yet self-declared exposure to mercury was widespread throughout ASGM communities. Our findings suggest that any ASGM policy will have to address not only the negative externalities of the sector on local communities, but also take into account its positive local development contributions.

1. Introduction

The extractives resource industry plays an important role in the economic growth of developing countries. Artisanal and small-scale mining in particular has rapidly expanded, but is also associated with poor environmental practices that threaten livelihoods (IISD, 2014; Maconachie, 2022). Artisanal and small-scale gold mining (ASGM) is illustrative of these dual trends: an estimated 20 million people across 80 countries now work in ASGM – three times as many as 20 years ago – and generate between 31.5 - 37.8 billion USD each year, contributing up to 20 % of the world's gold production (PlanetGOLD, 2022). Residents of countries that have significant amounts of gold deposits often see ASGM as a route out of poverty; at the same time, though, many rural communities have also experienced negative environmental and socio-economic impacts from ASGM activities, e.g., deforestation, land degradation, and social tension due to immigration, farmland encroachment, and conflict with industrial mining.[1]

One of the challenges the sector's growth has brought lies in the widespread use of mercury in the amalgamation process (i.e., the separation of the gold ore from other materials). ASGM is the largest 'intentional' worldwide mercury emitter (UNEP, 2020), and the concentration of mercury in the air in ASGM regions often exceeds typical industrial areas by a factor of 2000 (Gworek et al., 2017). It has been estimated that for every gram of gold produced by ASGM, 1–2 gs of mercury are released into the environment (Telmer and Veiga, 2009). Mercury causes long-term contamination of the water and soil, and

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[1] There is a growing literature on the development prospects of artisanal and small-scale mining in the Global South, e.g. Bonzongo et al. (2004), Pegg (2006), Banchirigah and Hilson (2010), Ayelazuno (2014), Gamu et al. (2015), Hilson et al. (2021), Hilson and Hu (2022), Maconachie (2022), and Radley (2022).

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consequently the degradation of the environment for all wildlife and humans that depend on them (Clifford, 2017); it also has serious health implications for humans, which are currently not yet well understood by many residents in mining areas (Tschakert and Singha, 2007; Gibb and O'Leary, 2014). Mercury pollution is invisible and non-degradable, and it bio-accumulates in the flesh of fish and other animals that eat contaminated food. It can cause irreparable neurological damage known as Minamata Disease, most tragically in unborn babies and newborns via contamination of the placenta and breast milk (Gibb and O'Leary, 2014). However, mercury is relatively cheap to buy and easy to use, and it continues to see widespread application in the sector.

In this paper, we examine Ghanaian mining communities' views on the local opportunities and risks that ASGM brings, with a particular focus on mercury use and other environmental issues and a unique study of the views on a nation-wide ASGM ban that was lifted shortly before the fieldwork. Ghana is currently the largest gold producer in Africa and a top-ten producer worldwide; the country has a long tradition of both industrial and small-scale gold mining, with the latter seeing common use of mercury (Hilson, 2017). In collaboration with local NGO Friends of the Nation, we surveyed over 380 adult respondents from 21 ASGM communities – including mining sites and nearby settlements – in eight mining districts throughout the country.[2] Data were collected between March and May 2019, a few months after the lifting of a temporary nationwide ban on ASGM in December 2018. The main questions we address are: how do local residents, both those involved in ASGM and those that are not, view ASGM and its economic, environmental and health impacts on the local community? How do they view the ban on ASGM and its effects on the local community? And finally, what factors influence the attitudes towards ASGM, knowledge about mercury use, and likely health risks from mercury exposure?

Our main contribution is twofold: first, we have information on local impacts of ASGM from a large sample of randomly chosen respondents from both mining-site and nearby settlements in ASGM districts across the country, which is unusual in the literature. Second, the timing of our survey shortly after the lifting of a nationwide ban on ASGM activities gave us a unique opportunity to explore not only the local views on ASGM but also the experiences of such a radical policy approach among both those working in the sector and those that are not.

We find that local communities generally have a favorable view overall of the impact of ASGM on local communities, particularly of its contribution to non-mining income and the compensation offered for land use. At the same time, there are also critical views – even among ASGM workers – on the negative local impacts, including illegal land appropriation, migration and related social problems, and pollution of the natural environment. Indeed, our survey shows that environmental problems are prevalent in ASGM communities, and that ASGM is seen as the main cause of the environmental problems identified by local communities — even by the miners themselves. Views instead diverged strongly when it came to support for the ASGM ban: mining-site respondents on average did not support the ban, while respondents from nearby communities clearly supported it, despite acknowledging the detrimental economic effects it had on their communities. Knowledge about mercury use and its dangers was mixed, yet self-declared exposure to mercury through direct contact or fumes was worryingly widespread in ASGM communities, as were potential symptoms of mercury poisoning. Our econometric analysis confirms that mining-site respondents have on average a much more positive attitude towards the local impacts of ASGM and were more likely to be against the ban. We also find that more educated respondents and those with farming or fishing in their household are on average more sceptical about the impact of ASGM; the latter also viewed the ban much more positively.

In sum, our results show that ASGM is viewed by local communities as bringing opportunities and risks. Though our survey was not designed to be representative of all ASGM communities in Ghana, the widespread critical views on environmental pressures and the support for the ASGM ban among settlements close to mining sites in different regions of the country implies that there is a need for strong policy intervention to address the negative local impacts. However, any policy will also have to take the substantial positive local development contributions of ASGM into account. The current situation in Ghana suggests that striking a balance in ASGM policy has not yet been achieved. A new intervention to control the ASGM sector should emphasise the environmental and health benefits to the local communities, while fostering alternative sources of livelihood to help cushion the loss of income in case ASGM activities decrease.

Our study contributes to the literature on the environmental impacts – particularly mercury contamination – of small-scale gold mining in Ghana and elsewhere in Africa.[3] Most of these studies rely on small-N samples and qualitative data gathered from interviews (e.g., A. K. Donkor et al., 2009; A. K. Mensah et al., 2015; Clifford, 2017), or on samples drawn from a narrower geographical area and/ or more restricted set of respondents that were either miners or non-miners (e.g., Obeng et al., 2019; Baddianaah et al., 2023). Some other contributions have used quasi-experimental approaches with geocoded third-party data to look at the impacts of small-scale and/or industrial gold mining on socioeconomic outcomes (Bazillier and Girard, 2020), conflict (Patel et al., 2016), or agricultural productivity (Aragon and Rud, 2016) in Ghana or Burkina Faso. Our research uses data from surveys conducted among nearly 390 respondents both from ASGM workers and members of nearby settlements, giving a broad insight into the issues facing small-scale mining communities. Several studies focusing on Ghana have made policy suggestions centering on improvements on the institutional and/or policy side (Hilson, 2002; Bagah et al., 2016, 2017; Hilson and Maconachie, 2020), or on finding alternative, cleaner amalgamation methods to substitute mercury use (Amankwah et al., 2010; Appel et al., 2014).[4] Our policy implications stress the importance of balancing the benefits and drawbacks of ASGM for local communities, which complement other recent suggestions in the literature.

The rest of this paper is organized as follows. Section 2 briefly describes the smallscale gold mining sector in Ghana; Section 3 explains the data collection strategy; Section 4 offers a detailed description of our sample; Section 5 empirically analyzes the factors linked to ASGM attitudes and the risk of mercury poisoning; and Section 6 concludes.

2. Small-scale gold mining in Ghana

Ghana is a relevant case study because it has a long history of ASGM (locally known as "galamsey") and industrial gold mining (Hilson and Potter, 2005), and is currently the biggest gold producer in Africa. In 1989, the government passed the *Small Scale Gold Mining Law* which effectively legalized the widespread ASGM activities, though they were still subject to a licensing scheme (Hilson, 2002). The large and sustained rise in global gold prices in the early 2010s led to a marked increase in ASGM activities, a sector that now accounts for around a third of Ghana's total gold production (Hilson, 2017) and is estimated to employ up to 1 million people directly and many more indirectly (Clifford, 2017).

The growth in the informal gold mining sector has brought several challenges with it. One of these lies in the environmental pressure due to

[2] See Section 3 for details on the survey.

[3] See Ofosu et al. (2020) for a recent review of the research on complementarities and conflicts between ASGM and agriculture, and Gibb and O'Leary (2014) for a review on the evidence on the effects of mercury pollution from ASGM. Bugmann et al. (2022) offer an interesting study of the reasons behind mercury use in ASGM in Burkina Faso.

[4] See Saldarriaga-Isaza et al. (2015) for a field experiment among Colombian small-scale gold miners to try to incentivize the adoption of alternative amalgamation technologies.

the widespread use of mercury during the amalgamation process (A. K. Donkor et al., 2009).[5] In recent years, ASGM activities in Ghana have led to the release into the environment of over 100 tons of mercury per year and the pollution of the air and water, and degradation of the land, both directly and indirectly via the rain that returns evaporated mercury back to the earth's surface. The areas in Ghana that have seen a surge in ASGM activities, such as around the Pra River Basin (which includes parts of Ghana's Eastern, Central, Western, Western North and Ashanti regions), have seen encroachment on cocoa farmland and have been associated with significant levels of mercury contamination as evidenced by samples of water, soil, sediment, and human hair.[6] Contaminated soil can be cleaned, but so far only at a considerable cost. Mercury is both cheap and easy to use.[7] Alternative, cleaner production methods that do not rely on hazardous substances, e.g. direct smelting or the use of borax, already exist, but they are not yet widely used, in part because of a lack of knowledge and experience among informal mine owners (Amankwah et al., 2010; Appel et al., 2014; Saim, 2021).

The importance of ASGM's income generation alongside its negative environmental externalities, particularly mercury pollution, have been acknowledged in the United Nations Environment Programme's Minamata Convention on Mercury. Ghana signed on to the Minamata Convention in 2014 and ratified it in March 2017. Under the Minamata Convention, the Ghanaian government is required to monitor, regulate and phase out the use of mercury in the ASGM sector. At the time of our fieldwork, past efforts to encourage informal small-scale Ghanaian gold miners to seek a license and formalize their activities had not been very successful, due on the miners' side to the bureaucratic hurdles involved and the cost attached to the required investment in environmentally sound production technology, and on the government's side to a lack of resources.[8]

The boom in Ghana's ASGM activities along with the associated environmental pressures and challenges that came with the legalisation process of ASGM led policymakers to act urgently. The incoming government of Ghana implemented a ban on all ASGM activities in January 2017, which was in effect until December 2018. The ban was subsequently lifted for ASGM sites with legal permits, but both legal and illegal ASGM activities resumed soon after.[9] The government continues to grapple with illegal ASGM activities and its environmental fallout and has employed both military and police interventions to enforce regulations, not without controversy (Hilson and Maconachie, 2020; Reuters, 2021).

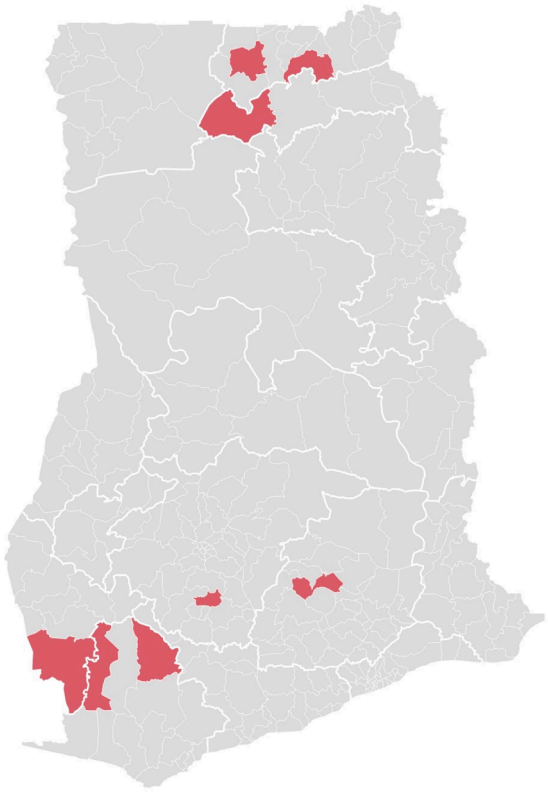

Fig. 1. Map of Ghanaian ASGM districts visited for this study. The map shows region (thick line) and district borders (thin line). Visited districts are shaded in red (see text for district details). Map created with Datawrapper.

3. Data collection strategy

In collaboration with Friends of the Nation (FoN), a Ghanaian socio-environmental advocacy NGO, the research team collected survey data from settlements in Ghana living in small-scale mining districts close to active small-scale mining activities, as well as from workers on nearby small-scale gold mining sites. FoN ran a series of informal information workshops at mining sites they had not previously visited and allowed the research team to accompany them for data collection at and near mining sites. Our sample comprises a total of 387 survey responses, 210 from mining-site interviews and 177 from interviews in nearby

[5] In Ghana, the more visible negative externalities from ASGM activities include water pollution and land degradation. The (illegal) practice of dredging the riverbeds in search of gold has led to silting up and additional pollution of river water (Hilson, 2002; Macdonald et al., 2015; A. K. Mensah et al., 2015). Cocoa farmers and downstream fishermen are among the groups most directly affected by inland ASGM and riverbed dredging, respectively (Aragón and Rud, 2016). Land degradation in ASGM regions is due to soil pollution and open-pit mining. Soil pollution may lead to decreases in the quality and/or quantity of crops being produced. ASGM workers also leave abandoned, open pits that further degrade the land and contribute to soil erosion (S. O. Mensah and Okyere, 2014).

[6] See Clifford (2017), Saim (2021), Yevugah et al. (2021), Ansah et al. (2022), and Coker et al. (2023) and the literature cited therein for details on measured mercury pollution levels in Ghana.

[7] At the time of the fieldwork, one 40-gram unit of mercury cost around USD40 in Ghana. A 40g unit could last between one week and one month, depending on the rock type and the amount of crushing and milling before amalgamation (information from a conversation with Ghanaian NGO Friends of the Nation, September 2018).

[8] In an interview with one District Minerals Commissioner (September 2018), the lack of funds and manpower was described and how this impacts the Minerals Commission's ability to police and enforce the ASGM law. In that particular region, one Commissioner was responsible for nine districts, with the support of only two assistants and one official vehicle.

[9] In practice, not all ASGM activities were in fact suspended during the ban, as a visit by the authors to an active small-scale gold mine in the Western region in September 2018 demonstrated. Nevertheless, some improvements in environmental quality were observed during the ban, most notably a decrease in water turbidity as measured by the Water Bodies Commission (from an interview with Prof Richard Amankwah, University of Mines and Technology, September 2018). Ghana's first full country report under the Minamata Convention lists the efforts undertaken until 2021 to regulate mercury use in ASGM (Environmental Protection Agency, 2021).

settlements. Respondents were randomly chosen, as detailed below. The data were collected between March and May 2019. Fig. 1 shows the map of the eight ASGM districts in six regions visited in Ghana in dark grey.[10]

The survey consisted of the consent statement and the survey questionnaire, which took around 30 min to complete and was done using tablets. The survey questionnaire included questions on socio-economic characteristics, along with a series of questions on knowledge and experiences of pollution related to ASGM activities.[11] The survey was available in English (the official language), Twi and Ewe (the two main local languages), as well as other local languages (with a local translator). 343 respondents (87 %) chose to answer the survey in Twi and 36 (9 %) in English, with the remaining eight surveys in other languages.[12]

The field survey team included a group of Ghanaian enumerators and one Ghanaian

Field Manager.[13] The field team participated in a training session and pilot surveys in September 2018, and another training session in March 2019 prior to the main fieldwork, all led by the authors in collaboration with FoN.

Mining site sample. FoN ran a series of informal information workshops at mining sites they had not previously visited, which took place at the end of the workday upon previous agreement with the local mining site manager. Each FoN workshop lasted around 45 min and focused on health and safety issues related to small-scale mining, including personal safety equipment and the dangers of using mercury in the amalgamation process.

At the end of each workshop, the audience were given a brief explanation of who the research team were and what the survey was about. In order to randomize respondents as much as possible, mining workers who were willing to participate in the survey were given lottery ticket stubs, and corresponding stubs were put in a bag. The appropriate number of stubs (up to 12 per site) were pulled out at random. The participants holding selected lottery numbers were assigned a time slot for their survey. We collected data from 210 adult ASGM workers from 23 different mining sites within eight different districts.[14]

Non-mining site sample. The non-mining site sample, i.e. the sample collected from settlements (towns or villages) close to small-scale mines, includes randomly selected adult household members who lived within a 5 mile radius of an ASGM mining site we visited for the mining-site sample (surveys for the two samples were usually carried out on the same day at different times). The research team administered the survey questionnaire and experiments to 177 adult participants in 21 different mining communities in eight ASGM districts living close to the mining sites visited by the survey team. Local enumerators conducted the interviews on a one-to-one and face-to-face basis, in private. The sample was predominantly made up of households participating in farming activities (see Section 4 below for a more detailed description). Since the sample from non-mining sites were all living in ASGM districts, they were all likely to have been affected by negative environmental externalities stemming from ASGM activities.

Randomization was implemented as follows: upon arrival in a community, the research team went in opposite directions from where the group vehicle was parked and chose the second house on the left. If either no one was available at the second house or an adult member of the household was not available, the research team moved on to the third house from the left, and so on. Upon completion of the survey and experiments, the next respondent was sought from two houses further down the road.

4. A description of ASGM communities in Ghana

Section 4.1 describes the personal and household details of our respondents; Section

4.2 looks at the extent of their knowledge of and their attitudes towards ASGM; and Section 4.3 describes their knowledge of the dangers of mercury use, their exposure and possible health effects. We report sample sizes and average responses for the entire sample, the subsample of ASGM site respondents, and the subsample of respondents from settlements close to ASGM sites.[15] The complete survey questionnaire is available in the Appendix.

4.1. Personal and household details

Personal characteristics. Table 1 presents summary statistics of the personal and household details of our sample. The top panel shows that our sample was mostly male, especially on the mining sites ;[16] our mining site respondents are also younger on average and less educated, though the likelihood that our respondents can read and write in English is very similar across sub-samples. Overall, the average respondent in our sample had lower levels of formal education compared to the national average, but this is in line with the gap in education between the rural and urban areas of Ghana (Anlimachie and Avoada, 2020). Most respondents are Christian, followed by Muslim. Nearly one in ten of our mining site respondents moved to the district in the past two years, and the average time spent in the district is accordingly much lower than in the non-mining sample. This reflects the importance of the ASGM sector as a source of employment and pull-factor for local migration. Only a very small share of our non-mining-site respondents gave ASGM as their main occupation; nearly three-quarters of them were instead farmers, followed by an occupation in an own or a family business such as a trader.

Household characteristics. The bottom panel of Table 1 describes respondents' household (HH) characteristics. When asked to describe their HH's living conditions, the average respondent viewed them as bad (i.e. below 3, the neutral answer); respondents from the non-mining subsample viewed their HH living conditions as slightly worse on average than the ones from the mining sites. As more objective measures of income and wealth, we asked about HH assets such as a car or motorbike and found that around half of the mining site respondents owned at least one of these motor vehicles, while the average ownership among our other respondents was lower. Since owning a motor vehicle is typically a strong indicator of higher income, the reported bad living conditions may be reflecting non-monetary conditions such as the state of the natural environment.

Over one quarter of the HHs from our non-mining-site subsample had a member working in ASGM in the previous two years, with an overall

[10] Districts form Ghana's main subnational administrative level, with regions being the first level (i.e. one level above districts). Visited districts included: Adansi North, Aowin, Atiwa East, Builsa North, Mamprugu-Moagduri, Talensi, Wassa Amenfi East, Wassa Amenfi West. The sample by district and region is listed in the Appendix.

[11] Each individual was told that participation was purely voluntary, and that all data collected would be anonymous. See the Appendix for the consent statement and questionnaire. The mining site and nonmining site surveys also included an experiment as the final survey module; the experiments are not discussed in the present paper and are described in detail in Karapetyan (2022). FoN sought consent from the local traditional authority prior to interviewing members of a community. The full survey and protocol were reviewed and approved by the Ethics Committee of the University of East Anglia.

[12] Three respondents chose to speak to us in Fante, two in Talen, one in Grusi, and two in French.

[13] The Field Manager and two of the three enumerators were female.

[14] In a couple of cases, two mining sites in close proximity to each other were visited, meaning that the total number of mining communities visited (i.e. non-mining sites and corresponding mining sites) is 21.

[15] The small number of 'don't know' answers were treated as missing. Note that all data analyses and estimations were done using Stata 17.

[16] See Adomako and Hausermann (2023), Baddianaah et al. (2022) and P. Donkor et al. (2023) for recent studies of who tends to work on ASGM sites and assume which roles.

Table 1
Personal and household (HH) characteristics of our respondents.

Non-mining	Full sample		Mining sites		sites	
	(1) Obs	(2) Mean	(3) Obs	(4) Mean	(5) Obs	(6) Mean
Respondent characteristics						
Age in years	387	41.041	210	34.448	177	48.864
Female (yes=1)	387	0.160	210	0.086	177	0.249
No formal education (yes=1)	387	0.183	210	0.167	177	0.203
Any primary education (yes=1)	387	0.243	210	0.252	177	0.232
Any secondary education (yes=1)	387	0.519	210	0.514	177	0.525
Any tertiary education (yes=1)	387	0.054	210	0.067	177	0.040
Can read and write in English (yes=1)	387	0.584	210	0.595	177	0.571
Christian (yes=1)	387	0.760	210	0.805	177	0.706
Muslim (yes=1)	387	0.132	210	0.143	177	0.119
Other religion (yes=1)	387	0.109	210	0.052	177	0.175
Recent mover (=1 if less than 2 years in district)	387	0.057	210	0.090	177	0.017
Total years in district	387	18.426	210	9.865	177	28.582
Occupation ASGM (yes=1)	387	0.540	210	0.971	177	0.028
Occupation farmer (yes=1)	387	0.354	210	0.033	177	0.734
Occupation own or family business (yes=1)	387	0.078	210	0.043	177	0.119
HH characteristics						
Living conditions (1=very bad, 5=very good)	387	2.625	210	2.671	177	2.571
HH owns car or motorbike (yes=1)	387	0.463	210	0.510	177	0.407
ASGM in HH in past 2 years (yes=1)	387	0.651	210	0.981	177	0.260
Years working in ASGM (if applicable to HH)	254	7.606	207	7.787	47	6.809
Industrial mining in HH in past 2 years (yes=1)	387	0.013	210	0.019	177	0.006
Farming in HH in past 2 years (yes=1)	387	0.680	210	0.462	177	0.938
Fishing in HH in past 2 years (yes=1)	387	0.013	210	0.019	177	0.006
Farming or fishing in HH in past 2 years (yes=1)	387	0.680	210	0.462	177	0.938
Livestock in HH in past 2 years (yes=1)	387	0.305	210	0.252	177	0.367

Summary statistics for personal characteristics of individual respondents and their households, with information shown for the full sample (columns 1–2), the mining site sample (columns 3–4), and the communities close to mining sites (columns 5–6).

average of over seven-and-a-half years worked in the sector; very few HHs in the whole sample instead had a member employed in industrial mining. Farming is the next most common occupation in HHs across the sample, and many HHs own livestock. Our detailed survey questionnaire shows that the main crop grown by households engaged in farming is cocoa (103 out of 263 responses), followed by maize (56), millet (35) and cassava (33). 142 (54 %) grow the crop for both HH consumption and selling at the market; 111 (42 %) only for selling at the market; and 10 (4 %) only for HH consumption. This suggests that a sizeable share of HHs in mining communities derive income directly or indirectly (through the trade or service sector) from ASGM and also from farming.

After this overview of the individual and HH characteristics of our respondents, we now turn our attention to their knowledge and views on ASGM.

4.2. Knowledge of and attitudes towards ASGM and the ban

Views on ASGM. We asked all respondents a series of questions on their attitudes towards ASGM. Throughout the questionnaire, we sought to formulate questions in terms of agreement to statements that avoided framing or introducing bias as much as possible. Attitude questions had answers given on a 5-point Likert scale from strongly disagree (1) to strongly agree (5).

Table 2
Knowledge of and attitudes towards ASGM and the ban.

Non-mining	Full sample		Mining sites		sites	
	(1) Obs	(2) Mean	(3) Obs	(4) Mean	(5) Obs	(6) Mean
Knowledge and attitudes						
Aware of ASGM in local community (yes=1)	387	0.731	210	0.990	177	0.424
ASGM… (1= strongly disagree to 5=strongly agree) …has provided compensation for land use in local community	290	3.814	206	4.005	84	3.345
…has provided infrastructure in local community	308	3.464	207	3.720	101	2.941
…has provided health care or education services in local community	317	3.760	207	4.043	110	3.227
…has contributed to higher income from non-mining in local community	326	4.166	209	4.359	117	3.821
…has led to illegal land appropriation in local community	296	3.355	205	3.176	91	3.758
…related migration has caused social problems in local community	324	3.562	208	3.404	116	3.845
…has led to pollution of the natural environment in local community	330	3.958	208	3.861	122	4.123
…overall has positive impact on local community	334	3.871	208	4.264	126	3.222
Support for ASGM ban						
The ban… (1= strongly disagree to 5=strongly agree) …improved the quality of drinking and cooking water in local community	328	3.274	192	3.365	136	3.147
…improved the quality of the river and/or sea water in my local community	300	3.407	166	3.428	134	3.381
…improved the quality of the soil for farming in my local community.	253	3.206	122	3.270	131	3.145
…took away a source of livelihood from my HH.	322	4.171	209	4.660	113	3.265
…took away a source of livelihood from my local community.	329	4.316	210	4.61	119	3.798
Overall, I supported the ban on ASGM.	382	3.081	210	2.429	172	3.878

Summary statistics for questions on knowledge of and attitudes towards ASGM sector, with information shown for the full sample (columns 1–2), the mining site sample (columns 3–4), and the communities close to mining sites (columns 5–6).

Table 2 shows that under half of our respondents from non-mining sites say they are aware of ASGM nearby.[17] On the positive side, we see that there is agreement in both our sub-samples that ASGM has provided compensation for land use, health care or education services, and contributed to higher income from non-mining (i.e. positive income spillovers) in the local community. Average agreement on these questions is around 0.5–0.7 points stronger among our mining-site respondents than the non-mining site respondents.

[17] Given the recently ended ASGM ban and the widespread illegal or informal ASGM activities, this is likely to be an understatement.

Interestingly, all respondents also agree that ASGM has led to some negative effects on local communities, including illegal land appropriation, migration and related social problems, and pollution of the natural environment. The non-mining site respondents are around 0.4 points more critical on these aspects than mining-site respondents, but all acknowledge that there are downsides to ASGM for the local communities.

Views diverge only on whether ASGM has provided infrastructure for the local community, with mining-site respondents agreeing quite strongly and non-mining site respondents instead weakly disagreeing. There is average agreement however to the statement that "Overall, artisanal and small-scale gold mining (galamsey) has had a positive effect on the local community", though our mining site respondents unsurprisingly have much more positive views than our non-mining site respondents. We will look in more detail in Section 5 at which respondents were more likely to have positive (negative) views of ASGM's contribution to the local community.

Views on the local natural environment. In our survey, we asked a series of questions about the local natural environment with multiple possible answers to choose from (not shown in detail for space reasons; see the Appendix for the Survey Questionnaire). We avoided framing questions in terms of negative effects of ASGM, asking instead about respondents' satisfaction with various aspects of the natural environment, the main environmental problems they perceived, and their views on the main causes of these problems.

84 % of respondents indicated that they were dissatisfied with the air that they breathe, 91 % were dissatisfied with the water they drink and cook with,[18] 65 % with the soil they grow vegetables and crops in, and 32 % with the river and/or sea water in their local community. Just over half of our respondents (53 %) said they had noticed a decrease in the quality or quantity of the crop their HH grows in the previous two years, with pests being the main culprit (chosen as one cause by 50 respondents), followed by drought (41) and heat (31) and, to a lesser degree, soil pollution (13) and water pollution (9).[19]

We know from the literature that ASGM activities have led to deforestation, land degradation, and water pollution in Ghana (Hilson, 2002; A. K. Mensah et al., 2015; Baddianaah et al., 2023). Air pollution was the main concrete problem with the natural surroundings noticed in the previous two years (indicated by 176 out of 387 respondents), followed by polluted river and/or sea water (175), soil erosion (159), deforestation (155), plant or animal pests (139) and flooding (123).[20] When asked about what they thought the main cause of these environmental problems was, small-scale gold mining was the clear front runner (chosen by 167 respondents, including 124 of our mining-site respondents), followed by climate change (72, including 28 mining-site respondents), poor sanitation (63 overall/ 15 mining-site), normal weather variation (46 overall/ 17 mining-site) and logging (33 overall/ 13 mining-site).[21]

The results from our survey therefore show that environmental problems are prevalent in ASGM communities, and that ASGM is seen as a main cause of environmental degradation by the local communities – even by the miners themselves. This result is in line with the findings in Obeng et al. (2019) and contrasts with those in Baddianaah et al. (2023), where respondents in ASGM areas in the North Western region showed little concern for the negative environmental impacts of ASGM.

Views on the ASGM ban. The bottom panel of Table 2 shows respondents' attitudes towards the temporary ban on ASGM activities throughout the country, lifted just three months before the start of our fieldwork. We asked about respondents' agreement to five statements on particular areas the ban could have affected, as well as a sixth overall support statement.

We see that there is broad agreement that the ban improved the local community's quality of the drinking and cooking water, the river and/or sea water, and the soil for farming. Interestingly, agreement on all these points is slightly stronger among our mining-site respondents; they appear to have felt the benefits for the natural environment more keenly than respondents from nearby settlements. However, mining-site respondents were also very strongly of the view that the ban had taken away a source of livelihood from both their own households and their local communities, compared to the more muted views of respondents from nearby non-mining sites (though the latter still agreed that the ban hadhad negative local economic impacts). The strong feelings regarding the economic impacts probably explain why mining-site respondents on average do not support the ban, while respondents from nearby communities clearly support it, despite also acknowledging the detrimental economic effects. We will explore in more depth in the Section 5 who was more likely to have favorable views on the ban.

4.3. Knowledge of mercury use and exposure to mercury

Knowledge of mercury use and its dangers. Of particular interest is the awareness of the use of mercury in ASGM and its dangers, given the importance of the sector as a source of mercury pollution worldwide and in Ghana. The top panel of Table 3 shows that nearly all of our mining-site respondents had heard or read about mercury pollution in the previous year and knew mercury was used locally in ASGM, compared to over half of our respondents from nearby communities who had heard or read of it and less than a third who said they knew mercury was used in ASGM nearby. We then asked a series of questions about mercury contamination. Again, nearly all mining-site respondents are aware that ASGM can cause mercury contamination, while more than half of non-mining site respondents know this. Knowledge about the long-lasting nature of mercury pollution in the natural environment is similarly high among mining-site respondents, but low – at just under one-third – among our other respondents.

When we ask about specific symptoms of mercury poisoning, however, we begin to see substantial knowledge gaps in both subsamples. More than half of mining-site and less than a fifth of non-mining site respondents know that mercury contamination can cause muscle twitching; just over half (respectively less than one in six) know mercury enters a mother's breastmilk; and under half (respectively just under one in five) know mercury can cause birth defects.

Overall, we see that knowledge and awareness of mercury use and its dangers is substantially higher among mining-site respondents – which can probably be attributed in large part to the FoN workshops (though

[18] 45% of our respondents said that boreholes were their main source of drinking water, followed by sachet water (33.6%) and public standpipes (11.4%). The answers for the main source of cooking water were similarly distributed, though protected dug wells (6%) and a river or pond (3%) were more frequent than relatively expensive purified sachet water (1.3%).

[19] Note that 59% of respondents said later in the survey that the quality of the soil they grow their vegetables and crops in had not changed, while 12% said it had improved and just under 7% that it had worsened, which is in line with the earlier answers on the cause of a decrease in the quantity or quality of crops grown.

[20] Our mining site respondents identified the same top six environmental problems as the respondents from nearby settlements.

[21] Respondents could choose up to two causes, including specifying another cause. Dust from unpaved roads and machinery was a common "other" cause indicated, given by 29 respondents. In another question, 217 respondents (175 from a mining site) also indicated that they or another household member were regularly exposed to dust from mining activities. Adomako and Hausermann (2023) find that women in particular are exposed to dust on ASGM sites.

Table 3
Knowledge of mercury use, exposure and health symptoms.

Non-mining	Full sample		Mining sites		sites	
	(1) Obs	(2) Mean	(3) Obs	(4) Mean	(5) Obs	(6) Mean
Knowledge of mercury use and its dangers						
Heard or read about mercury pollution in past year (yes=1)	387	0.783	210	0.962	177	0.571
Knows mercury is used in ASGM in local community (yes=1)	387	0.651	210	0.952	177	0.294
Knows ASGM can cause mercury contamination (yes=1)	387	0.762	210	0.914	177	0.582
Knows mercury stays in natural enviroment for long time (yes=1)	387	0.641	210	0.905	177	0.328
Knows mercury contamination can cause muscle twitching (yes=1)	387	0.393	210	0.567	177	0.186
Knows mercury enters a mother's breastmilk (yes=1)	387	0.346	210	0.505	177	0.158
Knows mercury can cause birth defects (yes=1)	387	0.351	210	0.486	177	0.192
Exposure to mercury and health symptoms						
Regular exposure to mercury with fumes or direct contact (yes=1)	387	0.470	210	0.700	177	0.198
Potential mercury poisoning symptoms: Someone in HH had … (yes=1) …frequent headaches in past year	387	0.470	210	0.471	177	0.469
…frequent dizziness in past year	387	0.274	210	0.219	177	0.339
…memory loss in past year	387	0.152	210	0.157	177	0.147
…severe mood swings in past year	387	0.062	210	0.048	177	0.079
…hearing loss in past year	387	0.057	210	0.048	177	0.068
…intense coughing and shortness of breath in past year	387	0.173	210	0.186	177	0.158
…muscle weakness in past year	387	0.607	210	0.605	177	0.610
…muscle twitching/ tremors in past year	387	0.090	210	0.110	177	0.068
…uncoordinated walking or movements in past year	387	0.047	210	0.024	177	0.073
…birth defects in child/children born in past year	387	0.005	210	0.000	177	0.011
Sum of potential mercury poisoning health symptoms in HH in past year	387	1.938	210	1.867	177	2.023

Summary statistics for questions on knowledge of mercury use in ASGM, on expsoure to mercury and the frequency of health symptoms potentially related to mercury poisoning, with information shown for the full sample (columns 1–2), the mining site sample (columns 3–4), and the communities close to mining sites (columns 5–6).

our survey did not have the purpose of evaluating these workshops) – but that there is much lower awareness on average in small-scale mining settlements even just a short distance from mining sites.

Exposure to mercury and health symptoms. There are no published health records of mercury exposure and poisoning across different areas of Ghana that we are aware of; we therefore estimate the extent of the problem by recording the frequency of exposure and the experience of health symptoms that could be related to mercury contamination, and show the results in the bottom panel of Table 3. Our survey answers show a worrying level of regular exposure to mercury fumes or direct contact with the metal, not only among our mining-site respondents, but also our non-mining site ones.

We collected information on negative health effects that could be related to mercury exposure by asking whether or not respondents had experienced any of ten different health symptoms over the previous 12 months.[22] The results listed are for dummy variables equal to one if a respondent answered yes to a symptom. The most frequent potential symptoms of either prolonged or acute exposure to mercury were muscle weakness, reported by 60.5 % of our mining-site and 61 % of our non-mining site sample; frequent headaches (47.1 % and 46.9 %, respectively); frequent dizziness (21.9 % and 33.9 %, respectively); intense coughing and shortness of breath (18.6 % and 15.8 %, resp.); memory loss (15.7 % and 14.7 %, resp.); and muscle twitching or tremors (11 % and 6.8 %, resp.). Severe mood swings, hearing loss, uncoordinated walking or movements, and birth defects in children were reported by less than ten percent of our subsamples. The mean number of symptoms experienced was just under two. 128 respondents reported at least three health symptoms (67 of which from mining-site respondents); 25 have five or more symptoms (14 from the mining sites); and 6 report the sample maximum of seven symptoms (two of whom were interviewed on mining sites).

With the obvious caveat that each of these symptoms could be unrelated to mercury poisoning, the overall picture suggests that the population around ASGM mining sites in Ghana is exposed to the health risks from mercury contamination. Given the serious long-term health implications, this issue is worth future investigation. In Section 5 below, we try to shed more light on who among our respondents is most likely to suffer from potential mercury-poisoning symptoms.

5. Estimation results

Our descriptive overview of our sample of respondents from mining sites and nearby settlements in Section 4 shows a lot of commonalities, but also some differences. We now dig a little deeper into what factors are linked to attitudes towards ASGM and the ASGM ban, knowledge of the problem of mercury pollution, and potential incidence of mercury poisoning. To do this, we perform linear OLS estimations with robust standard errors clustered at the site level. A constant term and district dummies are included in all specifications but not shown.

In Table 4 we seek to explain the levels of agreement with the statements that ASGM has a positive overall impact on local communities (columns 1–2) and that the respondents supported the ASGM ban overall (columns 5–6), as well as the awareness of the issue of mercury pollution (columns 3–4). We first run a parsimonious specification with just a mining-site respondent dummy, age (in years), a gender dummy, education level,[23] and district dummies (not shown) before adding more control variables in an extended specification.

Not surprisingly, we see that mining-site respondents' attitudes towards ASGM and awareness of mercury pollution differs markedly from those of our other respondents, *ceteris paribus*: the former are significantly more likely to agree that ASGM has overall positive impacts on the local community (0.4 to just under 1 point on the scale higher agreement levels), and significantly less likely to have supported the ASGM ban (around 0.4 to 0.8 points lower agreement levels). Those who viewed ASGM's impact on the local community more negatively were also significantly more likely on average to support the ASGM ban. Mining-site respondents are around 10–33 % more likely to have heard or read about mercury pollution in the previous year than respondents in nearby settlements, confirming a higher awareness of the issue (possibly due to the FoN workshops).

Other factors are less clearly linked to our dependent variables: older respondents were more likely to support the ASGM ban, but respondent age was not linked to the other dependent variables. More educated respondents are on average less likely to think that ASGM has a positive overall impact on local communities, and are more likely to be aware of

[22] See https://www.epa.gov/mercury/health-effects-exposures-mercury

[23] Education levels go from 0=none to 6=completed tertiary, with an average of 2.62.

Table 4
What factors shape attitudes towards ASGM and knowledge of mercury pollution?.

	Agreement to positive impact of ASGM		Heard or read about mercury pollution		Support for ban on ASGM	
	(1)	(2)	(3)	(4)	(5)	(6)
Mining site respondent (yes=1)	0.959***	0.403**	0.333***	0.103*	−0.837***	−0.395*
	(6.182)	(2.347)	(5.004)	(1.886)	(−5.035)	(−1.861)
Age	−0.00386	−0.00213	−0.00122	−0.00004	0.0157***	0.0129***
	(−0.744)	(−0.456)	(−0.783)	(−0.0404)	(3.245)	(2.822)
Female (yes=1)	0.0703	0.117	−0.113*	−0.0419	−0.219	−0.127
	(0.478)	(0.688)	(−1.766)	(−0.842)	(−1.306)	(−0.773)
Education	−0.0523**	−0.0514**	0.0308**	0.0121	0.0121	0.0177
	(−2.225)	(−2.150)	(2.203)	(1.645)	(0.237)	(0.368)
ASGM in HH in past 2 yrs (yes=1)		0.604***		0.0749		−0.519***
		(4.848)		(1.198)		(−3.240)
Farming or fishing in HH in past		−0.257**		0.0371		0.327**
2 yrs (yes=1)		(−2.208)		(1.572)		(2.025)
ASGM is a main cause of env'tal		0.0651		0.0128		−0.154
problems in community (yes=1)		(0.703)		(0.320)		(−1.002)
Mercury contamination can be caused		0.192*		0.645***		−0.0878
by ASGM (yes=1)		(2.004)		(10.90)		(−0.418)
UC or DA member (yes=1)		−0.254*		0.0408		0.431
		(−1.851)		(1.032)		(1.549)
Traditional authority (yes=1)		−0.348*		−0.0365		0.153
		(−1.756)		(−0.517)		(0.546)
Living conditions (1=very bad,		0.0712**		−0.0195		0.0684
5=very good)		(2.036)		(−1.274)		(1.050)
Lived less than 2 years in district		−0.398		0.0322		−0.318
(yes=1)		(−1.485)		(0.442)		(−0.859)
Christian religion (yes=1)		−0.0401		0.0550		−0.151
		(−0.322)		(1.253)		(−0.743)
Three or more health symptoms				−0.00357		
in HH (yes=1)				(−0.488)		
Agreement to positive impact of ASGM on local					−0.341***	−0.234**
community (1= strongly disagree, 5=strongly agree)					(−4.204)	(−2.599)
District controls	yes	yes	yes	yes	yes	yes
Observations	334	305	387	354	333	304
R-squared	0.389	0.438	0.328	0.681	0.398	0.428

Results for OLS estimations. Dependent variable is respondent's agreement to statement that ASGM has a positive impact on the local community overall (1= strongly disagree, 5=strongly agree) in columns 1–2; a dummy for respondent having heard or read about mercury pollution in previous 12 months in coluns 3–4; and respondent's agreement to statement that they overall support the ban on ASGM (1= strongly disagree, 5=strongly agree) in columns 5–6. All specifications include district dummies and a constant term (not shown). Robust t-statistics in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

mercury pollution, but education is not linked to the support for the ASGM ban. Those with a household member in ASGM are – unsurprisingly – more likely to view ASGM positively and less likely to have supported the ASGM ban. Respondents with a household member in farming or fishing are on average less likely to think that ASGM has positive overall impacts on local communities and more likely to have supported the ban on ASGM, in line with the idea that those most affected by environmental degradation are least supportive of ASGM. The view that ASGM is a main cause of local environmental problems is however not related to any of our dependent variables.

The view that ASGM can cause mercury contamination is weakly linked to more positive attitudes towards ASGM overall, which is puzzling, but also to greater awareness of mercury pollution, which is more in line with expectations. Respondents who are themselves or have a household member who is an elected official (Unit Committee or District Assembly member) or traditional authority (Chief or Queen Mother) are less likely to view ASGM's impact on the local community favorably. Respondents with higher self-declared living conditions are more positive towards the ASGM sector, perhaps because part of their livelihood is derived from it. Recent arrivals and religious belief are not linked to any of our dependent variables.

Finally, in Table 5 we explore what factors might be linked to greater risk of mercury poisoning, as measured by possible health symptoms. In column 1 we look at the sum of the ten health symptoms in the household (see Section 4.3 for details); and columns

2–3 at the likelihood of having three or more and 5 or more symptoms, respectively. The estimation results suggest that socio-economic factors – HH size, education and self-declared living conditions – and the occupation of the respondent's household members are linked to the risk of mercury poisoning. The more educated and better off are less likely to declare several health symptoms in the household, though these factors could of course be linked to generally poorer health among lower-income households. Those in larger households present more symptoms, which could be a mechanical link (i.e. the more people, the more likely someone has a symptom) or again linked to socio-economic effects (lower-income households are more likely to have larger households). Those with someone active in ASGM or farming or fishing are more likely to declare several health symptoms (though mining-site respondents themselves do not declare more symptoms on average).

These results are of course purely exploratory, but they do suggest that risk of mercury contamination and poisoning is more concentrated among some groups in ASGM communities – not only the ASGM workers themselves, but also those perhaps more regularly exposed to environmental degradation caused by ASGM.

6. Conclusions

The surge in artisanal and small-scale gold mining (ASGM) has led to negative environmental and health outcomes, especially due to the widespread use of mercury. The ASGM sector is now the main emitter of mercury worldwide (UNEP, 2020). Ghana is currently Africa's main gold producer and it has a long history of both industrial and small-scale gold mining, with the latter seeing common usage of mercury during the amalgamation process. In this paper, we use a sample of nearly 390 mining-site and non-mining site respondents in eight mining districts across Ghana to examine mining communities' views on the local

Table 5
What factors are linked to risk of mercury poisoning?.

	Sum of health symptoms (1)	At least 3 health symptoms (2)	At least 5 health symptoms (3)
Mining site respondent	−0.414	−0.0816	−0.0783
(yes=1)	(−1.178)	(−0.983)	(−1.129)
Age (years)	0.00154	0.00218	−0.00152
	(0.198)	(0.954)	(−1.192)
Female (yes=1)	−0.136	0.00133	−0.0695**
	(−0.624)	(0.0203)	(−2.601)
HH size (n. of adults)	0.0809*	0.0232**	0.0111*
	(1.826)	(2.532)	(1.714)
Education	−0.103*	−0.0457***	−0.0192**
	(−2.000)	(−2.991)	(−2.456)
Living conditions (1=very bad,	−0.260**	−0.0527*	−0.0329**
5=very good)	(−2.607)	(−1.774)	(−2.688)
Lived less than 2 years in district	−0.381	−0.147*	0.0293
(yes=1)	(−1.038)	(−1.816)	(0.571)
ASGM in HH in past 2 yrs	0.522*	0.222***	0.0703
(yes=1)	(1.916)	(3.194)	(1.516)
Farming or fishing in HH	0.364*	0.122*	0.00826
(yes=1)	(1.924)	(2.007)	(0.304)
Mercury used in ASGM in area	0.232	−0.000204	0.0369
(yes=1)	(0.850)	(−0.00237)	(0.786)
Respondent exposed to mercury	0.213	0.0835	0.00889
(fumes or directly; yes=1)	(0.895)	(1.282)	(0.208)
District controls	yes	yes	yes
Observations	387	387	387
R-squared	0.163	0.159	0.114

Results for OLS estimations. Dependent variable is sum of ten health symptoms potentially linked to mercury poisoning (column 1); a dummy for having at least three health symptoms potentially linked to mercury poisoning (column 2); and a dummy for having at least five health symptoms potentially linked to mercury poisoning (column 3). All specifications include district dummies and a constant term (not shown). Robust t-statistics in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

impacts of ASGM, with a particular focus on mercury use and other environmental issues. The timing of our survey shortly after the lifting of a nationwide ban on all ASGM activities also gave us the unique opportunity to explore the views on such a radical policy intervention to control the negative effects of the sector.

We find that local communities see both opportunities and risks in ASGM. They generally have a favorable view overall of the impact of ASGM on local communities, but there are also critical views – even among ASGM workers – on the negative effects, including illegal land appropriation, migration and related social problems, and pollution of the natural environment. Indeed, our survey shows that environmental problems are prevalent in ASGM communities, and that ASGM is seen as the main cause of environmental degradation by the local communities — even by the miners themselves. Views instead diverged strongly when it came to support for the ASGM ban: mining-site respondents on average did not support the ban, while respondents from nearby settlements clearly supported it, despite acknowledging the detrimental economic effects it had had on their communities. Finally, knowledge about mercury use and its dangers was mixed, yet exposure to mercury through direct contact or fumes was worryingly widespread in ASGM communities, as were potential symptoms of mercury poisoning.

Our survey was not designed to be representative of all ASGM communities in Ghana, but the widespread critical views on environmental pressures and the support for the ASGM ban among communities close to mining sites implies that there is a need for strong policy intervention to address the negative local impacts. To increase popular support, government policy to control the ASGM sector should be accompanied by clear communication on the environmental and health benefits to local communities, while actively developing alternative sources of livelihood to help cushion the loss of household income from ASGM activities. Our worrying findings on exposure to mercury and indications of potential mercury poisoning symptoms also call for more research on these long-term health impacts of mercury use in ASGM. An intensified information campaign against mercury use and investment in policing of mercury use in ASGM on the one hand and development of alternative amalgamation methods suited to the Ghanaian geological context on the other hand are also desirable.

Ghanaian researchers have recently announced a promising nature-based solution to restoring land polluted by mercury.[24] However, this addresses only one of the multiple issues surrounding ASGM, the persistent use of mercury, and other environmental problems. Any policy – in Ghana and elsewhere – will have to address not only the negative externalities of ASGM on local communities, but balance their minimization against the positive local development contributions of the sector.

CRediT authorship contribution statement

Christa N. Brunnschweiler: Writing – review & editing, Writing – original draft, Visualization, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Deanna Karapetyan:** Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Päivi Lujala:** Writing – review & editing, Writing – original draft, Investigation, Funding acquisition.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.exis.2024.101403.

Appendix A. Additional information on sample

Sample by district and region

[24] "Restoring galamsey lands: UMaT clears mercury from soil", see https://www.graphic.com.gh/news/general-news/restoring-galamsey-lands-umat-clears-mercury-fromsoil.html (retrieved 16 July 2023).

District	Region	Mining communities	Respondents
Adansi North	Ashanti	Abadwum, Ahenbronoso, Akyease, Ampenkro, New House-Adomamu, Tanoso-Adumanu	90
Aowin	Western North	Suhum	16
Atiwa East	Eastern	Assamang Tamfoe, Bunso, Enyirensi, Mmoseaso	96
Builsa North	Upper East	Sandema Balansa, Sinaisi	10
Mamprugu-Moagduri	North East	Nangruma	14
Talensi	Upper East	Dakortyire, Tengzuk, Yiranyire	70
Wassa Amenfi East	Western	Wassa-Akropong	20
Wassa Amenfi West	Western	Amoaman, Apetiso, Wasa Dunkwa	71
Total			387

Notes: Total sample of 387 responses listed by district and region, with communities visited in each district.

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